19 Modeling K

19.1 Characteristics of modeling

PENTA6_D

One nets only half the thickness of the wall by reason of symmetry; modeling is made under a height and a thickness H = 1.0 with only one layer of elements. Each cube is cut out in 2 pentahedrons.

One uses modeling "3D_DIAG" applied to PENTA6, which corresponds to the lumpage of stamp of thermal mass.

L = 0.05
Limiting conditions

D
C
on [BC], [AB] and [cd.]: = 0

H
on [AD]: Tp is imposed
With
M1
M2

B H
Tp
100 °C
20 elements PENTA6_D
0
T
103 S
points
nodes

Initial conditions
M1
N21
with
N24
T = 0°C
M2
N69
with
N72
One fixes here the duration of the shock at 103 S.

19.2 Characteristics of the grid

A number of nodes: 84
A number of meshs and types: 40 PENTA6

19.3 Functionalities tested

Orders

THER_LINEAIRE
LIST_INST

RECU_CHAMP
INST

---

20 Results of modeling K

20.1 Values tested

Identification Reference
Aster %
difference
M1 (X = 0.2)

T = 0.1
65.48
65.28
-0.30
T = 0.2
75.58
75.81
+0.31
T = 0.7
93.01
92.87

-0.15
T = 2.0
99.72
99.70
-0.02

M2 (X = 0.8)

T = 0.1
8.09
8.087
-0.03
T = 0.2
26.37
25.81
-2.14
T = 0.7
78.47
78.04
-0.55
T = 2.0
99.13
99.08
-0.05

---

21 Modeling
L

21.1 Characteristics of modeling

HEXA8_D

One nets only half the thickness of the wall by reason of symmetry; modeling is made under a height and a thickness H = 1.0 with only one layer of elements.

One uses modeling "3D_DIAG" applied to HEXA8, which corresponds to the lumpage of stamp of thermal mass.

L = 0.05
Limiting conditions

D
C
on [BC], [AB] and [cd.]: = 0

H
on [AD]: Tp is imposed
With
M1
M2
B H
Tp
100 °C
20 elements HEXA8_D
0
T
103 S
points
nodes

Initial conditions
M1
N21
with
N24
T = 0°C
M2
N69
with
N72
One fixes here the duration of the shock at 103 S.

21.2 Characteristics of the grid

A number of nodes: 84
A number of meshs and types: 20 HEXA8

21.3 Functionalities tested

Orders

THER_LINEAIRE
LIST_INST

RECU_CHAMP
INST

22 Results of modeling L

22.1 Values tested

Identification Reference
Aster %
difference
M1 (X = 0.2)

T = 0.1
65.48
65.28
-0.30
T = 0.2
75.58
75.81
+0.31
T = 0.7
93.01
92.87
-0.15
T = 2.0
99.72
99.70
-0.02

M2 (X = 0.8)

T = 0.1
8.09
8.087
-0.03
T = 0.2
26.37
25.81
-2.10
T = 0.7
78.47
78.04
-0.55
T = 2.0
99.13
99.08
-0.05

23 Summary of the results

At the end of 0.7 S the error is definitely lower than 1% for the various thermal elements 2D (QUAD8) and 3D (HEXA8 - HEXA20 - PENTA6 - PENTA15 - TETRA4) used.

It does not seem that the lumpage improves the numerical result.

It would be advisable to test the elements lumpés with a true jump as in modeling B.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
Document: V4.21.100

TTLL100 - Thermal shock on a plane wall with
condition of exchange

Summary:
This test of transitory linear thermics consists in imposing a cold thermal shock on an infinite plane wall on the assistance
of a condition limits of exchange. The shock is modelled by a linear slope T = 100 °C into 102 S.
The problem is dealt with in plan.
The reference solution is analytical.
The test is carried out on 2 modelings: (TRIA3, QUAD4) and (TRIA6, QUAD9).
One tests the algorithm of linear thermics transitory when the matrix of mass is diagonalisée (modeling
PLAN_DIAG with `'mass lumping '').

1
Problem of reference

1.1 Geometry

y
With
B
C
- L
0
M1
2
M
L
X

AB = BC = L = 0.1 m
X (M1) = 0.02 m
X (m2) = 0.08 m

1.2
Material properties

= 1 W/m °C
C
p = 1000 J/m3 °C

1.3
Boundary conditions and loadings

T
Exchange

= (
-

H T
T (X, T
ext.
))

N x=±L
with
H =
.
100 W/m2 ° C
T

=
ext. (C)
.
100
t=

0
T
- =

ext. (C)
.
0
t=10 2
1.4 Conditions
initial
T (X, 0) = 100°C for any X
Discretization in time (T):
10
not for
[0.
,
1.D2]
that is to say
T = 103 S
9
not for
[1 D2
,
1.D1]
that is to say
T = 102 S
9
not for
[1.D1
,
1.]

that is to say
T = 101 S
5
not for
[1.
,
2.]
that is to say
T = 2.101 S
8
not for
[2.
,
10.]
that is to say
T = 1 S

2
Reference solution
2.1
Method of calculation used for the reference solution
T (X, T) - T
+
X
ext. =
With exp (

-

T

N
N
) cos (N)
T

0 - T
C L
L
ext.
n=1
p
X
= X-coordinate
T
= time
T0 =
initial temperature
T
=
ext.
outside temperature
N
=
,
1
,
2
,
3 ...
with
positive roots of tan = hL =
N
N
N
/
.
10
4 sin
and
WITH = A
N

=
N
N
2 +

N
sin (2 N)
2.2
Results of reference
Temperatures at the points M1 (X = 0.02) and m2 (X = 0.08),
and at various moments (T = 0.1, 0.5, 2.0 and 10.0).
The values of reference are obtained by calculating the first 30 terms of the series (Mathematica).
2.3
Uncertainty on the solution
Analytical solution.
2.4 References
bibliographical
[1]
INCROPERA F.P., OF WITT D.P., Fundamentals of heat and mass transfer. Third Edition.
1990.

---

3 Modeling
With
3.1
Characteristics of modeling
TRIA3, QUAD4
By reason of symmetry, one nets only one half the thickness of the wall. Modeling is made on
a height H = 0.1 m with 2 layers of elements.

M'1
M'2
D
C
Limiting conditions

on [AB], [AD] and [CD]: null flow

H
on [BC]: exchange H, Text
Text
With
B
M1
M2
100 °C
0°C
T
0
102 S
Initial conditions
points
nodes
X
y
T = 100 °C

M1 N16
0.02
0.0
M2 N6
0.08
0.0
M'1
N14
0.02
0.1
M'2
N4
0.08
0.1
3.2
Characteristics of the grid
A number of nodes: 18

A number of meshs and types: 5 QUAD4, 10 TRIA3
3.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
MODELING
PLAN_DIAG
[U4.22.01]
AFFE_CHAR_THER_F
EXCHANGE
[U4.25.02]
THER_LINEAIRE
[U4.62.01]

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
M1 (X = 0.02) N16
T = 0.1
100.00
99.998
+0.00

T = 0.5
99.408
99.042
0.37
T = 2.0
79.859
79.794
0.08
T = 10.0
15.717
16.138
+2.68
M2 (X = 0.08) N6
T = 0.1
93.666
93.380
0.31
T = 0.5
63.500
63.813
+0.49
T = 2.0
35.717
35.667
0.14
T = 10.0
6.7948
6.9326
+2.03
M'1 (X = 0.02) N14
T = 0.1
100.00
99.998
+0.00
T = 0.5
99.408
99.077
0.33
T = 2.0
79.859
80.002
+0.18
T = 10.0

15.717
16.211
+3.14
M'2 (X = 0.08) N4
T = 0.1
93.666
92.895
0.82
T = 0.5
63.500
61.882
2.55
T = 2.0
35.717
35.331
1.08
T = 10.0
6.7948
6.8885
+1.38
4.2 Parameters
of execution
Version: 4.01.12
Machine: CRAY C98
System: UNICOS
Obstruction memory:
8 megawords
Time CPU To use: 9.2 seconds
Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
HI-75/98/040 - Ind A

---

5 Modeling
B
5.1
Characteristics of modeling
TRIA6, QUAD9

By reason of symmetry, one nets only one half the thickness of the wall. Modeling is made on a height H = 0.1 m with 2 layers of elements.

M'1
M'2
D
C
Limiting conditions

on [AB], [AD] and [CD]: null flow

H
on [BC]: exchange H, Text
Text
With
B
M1
M2
100 °C
0°C
T
0
102 S
Initial conditions
points
nodes
X

y
T = 100 °C

M1 N16
0.02
0.0
M2 N6
0.08
0.0
M'1
N14
0.02
0.1
M'2
N4
0.08
0.1

5.2
Characteristics of the grid

A number of nodes: 55
A number of meshs and types: 5 QUAD9, 10 TRIA6

5.3 Functionalities
tested

Orders
Keys
CREA_MAILLAGE
MODI_MAILLE
OPTION:
“QUAD8_9”
[U4.12.06]
AFFE_MODELE
MODELING
PLAN_DIAG
[U4.22.01]
AFFE_CHAR_THER_F
EXCHANGE
[U4.25.02]
THER_LINEAIRE
[U4.62.01]

---

6 Results of modeling B

6.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
M1 (X = 0.02) N18			
T = 0.1	100.00	100.00	+0.00
T = 0.5	99.408	99.278	0.13
T = 2.0	79.859	79.898	+0.05
T = 10.0	15.717	16.043	+2.07
M2 (X = 0.08) N49			
T = 0.1	93.666	94.077	+0.44
T = 0.5			

63.500
63.979
+0.75
T = 2.0
35.717
35.825
+0.30
T = 10.0
6.7948
6.9321
+2.02
M'1 (X = 0.02) N12
T = 0.1
100.00
100.00
+0.00
T = 0.5
99.408
99.311
0.10
T = 2.0
79.859
80.101
+0.30
T = 10.0
15.717
16.093
+2.39
M'2 (X = 0.08) N30
T = 0.1
93.666
93.469
0.21
T = 0.5
63.500
62.860
1.01
T = 2.0
35.717
35.641
0.21
T = 10.0
6.7948

6.9068
+1.65

6.2 Parameters
of execution

Version: 4.01.12
Machine: CRAY C98
System: UNICOS
Obstruction memory:
8 megawords
Time CPU To use: 10.0 seconds

7
Summary of the results

Modeling "PLAN_DIAG" gives rather satisfactory results. Although the grid comprises
few elements in the thickness, the variation on the temperatures remain lower than 3.2%.
Although the thermal shock is brutal, the diagonalisation of the matrix of mass makes it possible to obtain one
solution in temperature which does not oscillate during the transient.

Date:
20/09/02
Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER*
Clé
:
V4.21.301-A Page:
1/8

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
V4.21.301 document

TTLL301 - Thermal transfer in a bar with imposed temperature (sinusoid)

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a linear problem 1D represented by two modelings, one planes, the other voluminal one.

The functionalities tested are as follows:
plane thermal element,
voluminal thermal element,

transitory algorithm of thermics,
limiting conditions: sinusoidal variation of the temperature imposed in the course of time.

· The interest of the test resides in the taking into account of the variation in the temperature imposed during
time and of the geometrical discretization.

The results are compared with those provided by NAFEMS.

1
Problem of reference

1.1 Geometry

TB = 100 sin (t/40) °C
With
B
X
0.08
0.1

Dimensions in meters

1.2
Properties of material

= 35 W/m °C
thermal conductivity
CP = 440.5 J/kg °C specific heat
= 7200 kg/m3 mass
voluminal

1.3
Boundary conditions and loadings

· temperature imposed on point a: MT = 0 °C,
· temperature imposed on point b: TB = 100 sin (t/40) °C.

1.4 Conditions
initial

T = 0: T (X) = 0 °C

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is that given in the card "TEST n° T3" of the tests of reference published by NAFEMS.

2.2
Results of reference

Temperature as in point X = 0.08 at the moment T = 32 S

2.3
Uncertainty on the solution

Nonavailable on card NAFEMS.

2.4 References
bibliographical

[1]
NAFEMS (the National Agency for Finite Element Methods Standard and (the U.K.)) :
"Standard The NAFEMS Benchmarcks", TNSB rév 3, October 1990.

---

3 Modeling

With

3.1
Characteristics of modeling

PLAN (TRIA3)

y
D
C
N18
.01 m
X
With
.08
N17
B
.1
Limiting conditions:
- dimensioned AB CD = 0
- dimensioned AD
= 0 °C
- dimensioned BC
T = 100 sin (t/40) °C

3.2
Characteristics of the grid

A number of nodes:
22
A number of meshs and types: 10 TRIA3

3.3 Functionalities
tested

Orders

! FORMULATE

CALC_FONC_INTERP

Interpol
"INT"

AFFE_MODELE
THERMICS
PLAN
ALL

AFFE_CHAR_THER_F
TEMP_IMPO

THER_LINEAIRE
TEMP_INIT
VALE

LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The discretization in step of time is as follows:

5 steps for [0. , 1.0D+0] is T = 2.D-1
18 steps for [1.D+0, 1.0D+1] are T = 5.D-1
20 steps for [1.D+1, 2.0D+1] are T = 5.D-1
20 steps for [2.D+1, 3.0D+1] are T = 5.D-1
10 steps for [3.D+1, 3.5D+1] are T = 5.D-1

4
Results of modeling A

4.1 Values tested

Identification	*Reference*	*Aster*	*% difference*	*Tolerance*
Temperature at the point: T (°C)				
X = 0.08 m with T = 32 S				
N17	*36.60*	*37.87*	*3.480*	*2%*
N18	*36.60*	*36.98*	*1.036*	*2%*

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 4.57 seconds

---

5 Modeling B

5.1 Characteristics of modeling

Modeling: 3D (PENTA15)

Z
D H
With
E
y
0.01 m
N114
N115
N119
0.01 m
C
Limiting conditions:
G
N118
- face AEHD
X
= 0 °C
B

- face BFGC
T = 100 sin (t/40) °C
- others faces
F
= 0

5.2
Characteristics of the grid

A number of nodes:
148
A number of meshs and types: 20 PENTA15

5.3 Functionalities
tested

Orders

! FORMULATE

CALC_FONC_INTERP
Interpol
“INT”

AFFE_MODELE
THERMICS
3D
ALL

AFFE_CHAR_THER_F
TEMP_IMPO

THER_LINEAIRE
TEMP_INIT
VALE

LIST_INST

RECU_CHAMP
INST

5.4 Remarks

The discretization in step of time is as follows:

5 steps for [0. , 1.0D+0] is T = 2.D-1
18 steps for [1.D+0, 1.0D+1] are T = 5.D-1
20 steps for [1.D+1, 2.0D+1] are T = 5.D-1
20 steps for [2.D+1, 3.0D+1] are T = 5.D-1
10 steps for [3.D+1, 3.5D+1] are T = 5.D-1
Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
Thermal TTLL301 Transfer in a bar with imposed temperature
Date:
20/09/02
Author (S):
C. DURAND, *E. SCREW, F. LEBOUVIER Clé*
:
V4.21.301-A Page:
7/8

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster
% difference
Tolerance
Temperature at the point:

X = 0.08 m with T = 32 S

N114 36.60
36.60
0.006
2%
N115 36.60
36.47
-0.355
2%
N118 36.60
36.47
-0.355
2%
N119 36.60
36.60
0.006
2%

6.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 5.03 seconds
Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
HT-66/02/001/A

7
Summary of the results

This test is recommended by NAFEMS (but with another type of mesh).

Two modelings carried out give the following results:

· modeling A (PLANE with meshs TRIA3), the maximum change (3.48%) is higher than tolerance fixed initially (2%),
· modeling B (3D with meshs PENTA15), the maximum change (0.36%) is lower than tolerance fixed initially (2%).

The limiting condition is given by using the order "! FORMULATE". This choice allows good representation of the taking into account of the condition limits of sinusoidal form.

Quadratic modeling is adapted to simulate this test. A finer and balanced grid for linear modeling would allow to obtain better results.

The results of modeling A are thus regarded as acceptable.

The principal interest of this test is its origin: NAFEMS.

Code_Aster ®
Version
5.0

Titrate:
Thermal TTLL303 Transfer in a bar with generation of heat
Date:
20/09/02
Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER Clé*
:
V4.21.303-A Page:
1/6

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
V4.21.303 document

TTLL303 - Thermal transfer in a bar with internal generation of heat

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a problem plane 2D represented by only one modeling (plane).

The functionalities tested are as follows:

· plane thermal element,
· transitory algorithm of thermics,
· limiting conditions: heat source.

The interest of the test lies in the taking into account of a heat source.

The results are compared with an analytical solution.
Handbook of Validation
V4.21 booklet: Transitory thermics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
Thermal TTLL303 Transfer in a bar with generation of heat
Date:
20/09/02
Author (S):
C. DURAND, E. SCREW, F. LEBOUVIER Clé
:
V4.21.303-A Page:
2/6

1
Problem of reference

1.1 Geometry

y
D
C
Q
X
E
F
With
0.05 m
B
2L = 0.2 m

1.2
Properties of material

=
100 W/m °C
thermal conductivity
CP = 7000
j/m3 °C voluminal heat

1.3
Boundary conditions and loadings

· Heat source interns Q = 106 W/m3,
· [AB], [CD] = 0,
· [BC], [DA] T = 0 °C.

1.4 Conditions
initial

T (T = 0) = 0°C

2
Reference solution

2.1
Method of calculation used for the reference solution

QL2
X 2

I

32
(-1)
2i + 1

2i + 1 2
T =

1 -
cos
exp

3

T
2

L -
3
= (2 1)
2

2
0
+

-

I
I
L
C
L

The values of reference are obtained with I = 1000.

2.2 Results of reference

Temperature at the points E and F at the moment T = 0.25 and 0.5 S

2.3 Uncertainty on the solution

Analytical solution.

2.4 References bibliographical

[1]
B.M. Nicolaï, J. of Baerdemaeker, "Computation of heat conduction in materials with random variable thermophysical properties ", Int. J. num. Meth. Engng, flight 36, pp 523-536, 1993.

---

3 Modeling
With

3.1
Characteristics of modeling

PLAN (TRIA6, QUAD8)

Y
X
C
y
=15°
N151
0.03
N152
G
N154
X
N1
N156
N4
B
N158
N7
N161
N10
N163
N13
0.1
N16
0.05
N19
E
Limiting conditions:
- dimensioned EB, CG, GE = 0
- dimensioned BC
T = 0 °C

3.2
Characteristics of the grid

A number of nodes:
314
A number of meshs and types: 97 (20 TRIA6, 77QUAD8)

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN

AFFE_CHAR_THER_F
SOURCE

TEMP_IMPO
ALL

THER_LINEAIRE
TEMP_INIT
VALE

LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The discretization in step of time is as follows:

50 steps for [0. , 0.50] are T = 1.D-2

4
Results of modeling A

4.1 Values
tested

Relative variation %
Absolute deviation
Identification Reference
Aster difference tolerance difference tolerance
Temperatures (°C)

X = 0, T = 0.25 S

N1 28.62
28.58
-0.145
1%
-0.042
0.05
N4 28.62

28.58
-0.145
1%
-0.042
0.05
N7 28.62
28.58
-0.145
1%
-0.042
0.05
N10 28.62
28.58
-0.145
1%
-0.042
0.05
N13 28.62
28.58
-0.145
1%
-0.042
0.05
N16 28.62
28.58
-0.145
1%
-0.042
0.05
N19 28.62
28.58
-0.145
1%
-0.042
0.05
X = 0.05, T = 0.25 S

N151 22.38
22.35

-0.127
1%
-0.028
0.05
N152 22.38
22.35
-0.127
1%
-0.028
0.05
N154 22.38
22.35
-0.127
1%
-0.028
0.05
N156 22.38
22.35
-0.127
1%
-0.028
0.05
N158 22.38
22.35
-0.127
1%
-0.028
0.05
N161 22.38
22.35
-0.127
1%
-0.028
0.05
N163 22.38
22.35
-0.127
1%
-0.028
0.05
X = 0, T = 0.50 S

N1 41.14
41.11
-0.081
1%
-0.033
0.05
N4 41.14
41.11
-0.080
1%
-0.033
0.05
N7 41.14
41.11
-0.081
1%
-0.033
0.05
N10 41.14
41.11
-0.081
1%
-0.033
0.05
N13 41.14
41.11
-0.081
1%
-0.033
0.05
N16 41.14
41.11
-0.081
1%
-0.033
0.05
N19 41.14
41.11
-0.081
1%

-0.033
0.05
X = 0.05, T = 0.50s

N151 31.24
31.21
-0.091
1%
-0.029
0.05
N152 31.24
31.21
-0.091
1%
-0.029
0.05
N154 31.24
31.21
-0.091
1%
-0.029
0.05
N156 31.24
31.21
-0.091
1%
-0.029
0.05
N158 31.24
31.21
-0.091
1%
-0.029
0.05
N161 31.24
31.21
-0.091
1%
-0.029

0.05
N163 31.24
31.21
-0.091
1%
-0.029
0.05

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory: 8 megawords
Time CPU To use: 4.04 seconds

---

5 Summary of the results

The results obtained are satisfactory, the maximum change is 0.15%.

The points of observations, located at X = 0.05 and pertaining to meshs of the different types, have it

even result.

This test made it possible to test in linear transient (modeling PLAN), the order AFFE_CHAR_THER_F with the operand SOURCE.

TTNL02 - Thermal transient with change of phase

Summary:

This elementary test makes it possible to deal with one-way problem in non-linear transitory thermics and of
to check the taking into account of a liquid/solid phase shift by Code_Aster while introducing by the intermediary of the voluminal enthalpy latent heat of fusion. The solution is analytical and utilizes
functions of erf error and erfc. The problem is dealt with in the plane and voluminal cases.

For modelings presented here, the variations of the results obtained by Code_Aster range between 1 and
4% of the analytically calculated reference.

1
Problem of reference

1.1 Geometry

Ti = 740 °C
Tm = 660 °C
T0 = 580 °C

Solid phase
Liquid phase
0
L
L = 0.1m

1.2
Material properties

They are the subscripted characteristics of aluminium by S for the solid phase and L for the phase liquid. They are supposed to be constant within each phase.

3
3
voluminal

mass
= 2550 kg/m
= 2390 kg/m
S
1
6
3
6
3
voluminal heat

C =
10
3.00
J/m °C
C =
10
2.58
J/m °C
1
S
conductivi thermal

t-piece
K = 210 W/m°C
K = 95 W/m°C

S
1

3
heat
fusion

of

latent

L =
10
437.44
J/kg
températur
fusion

of

E
T = 660.0°C
m
9
3
of

variation
voluminal

enthalpy
H =
10
1.08048
J/m

1.3
Boundary conditions and loadings

Temperature imposed at the ends.

T = 580.0 C
°

in X = 0
0

T = 740.0 C
°

in X = L
I

1.4 Conditions
initial

Uniform initial temperature

init
T
= I
T = 740.0 C
°

2
Reference solution

2.1
Method of calculation used for the reference solution

One has an semi-analytical solution utilizing the functions of errors:

2
X
2
2
+
2
erf (X) =
and dt and erfc (X)

=
and dt
0
X

This solution is valid for a semi-infinite medium, it could thus be used only in one field of variation limited of the variable of time.
L
S
That is to say X
T
T the position of the solid interface/liquid. Are St =
and
=
where D and D
T
2D
S
L
total
S

K
K
the solid diffusivity of the mediums and liquid D indicate
S
=
, D
L
S

=. The solution of the equation of

C
L
C
S
L
heat is form:

T - T
X
T (X, T) = T
m
0
0 +
erf

if X
X
S
erf ()

2D T
T
S
T - T
X

T (X, T) = T
m
I
+
erfc
if X X
L
I

D
2D T
T
S
L

erfc

dl

The data of ttotal is enough to define the solution, one thus fixes ttotal = 420.0

2.2
Results of reference

TIME:
0.5 1.0 1.5 2.0 2.5 3.0
X-coordinate
.000
580.
580.
580.
580.
580.
580.
.005
682.43
661.33
647.50
638.74
632.69
628.20
.010
726.05
705.75
692.06
682.43
675.24
669.63
.015
738.11
728.70
718.44
709.60
702.23
696.06
.020
739.86
737.22

731.99
726.05
720.27
714.94
.025
740.
739.50
737.56
734.47
730.81
727.00
.030
740.
739.93
739.39
738.11
736.20
733.88
.035
740.
739.99
739.88
739.45
738.61
737.40
.040
740.
740.
739.98
739.86
739.55
739.00
.045
740.
740.
740.
739.97
739.87
739.65
.050
740.
740.
740.

740.
739.97
739.89
.055
740.
740.
740.
740.
740.
739.97
.060
740.
740.
740.
740.
740. 740.
.065
740.
740.
740.
740.
740.
740.
.070
740. 740. 740. 740. 740. 740.
.075
740. 740. 740. 740. 740. 740.
.080
740. 740. 740. 740. 740. 740.
.085
740. 740. 740. 740. 740. 740.
.090
740. 740. 740. 740. 740. 740.
.095
740. 740. 740. 740. 740. 740.
.100
740. 740. 740. 740. 740. 740.
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TIME:
3.5 4.0 4.5 5.0 5.5 6.0
X-coordinate
.000 580.
580. 580.
580. 580.
580.
.005 624.68 621.84 619.48 617.48 615.25 614.25
.010 665.09 661.33 657.43 653.65 650.37 647.49
.015 690.83 686.33 682.43 678.99 675.95 673.22
.020 710.11 705.75 701.81 698.25 709.92 692.06
.025 723.23 719.60 716.17 712.95 720.89 707.09
.030 731.34 728.70 726.05 723.43 728.48 718.44
.035 735.89 734.18 732.34 730.43 733.42 726.53
.040 738.21 737.22 736.07 734.79 736.44 731.99
.045 739.29 738.77 738.11 737.33 738.18 735.47
.050 739.74 739.50 739.15 738.71 739.12 737.56
.055 739.91 739.81 739.65 739.42 739.60 738.75
.060 739.97 739.93 739.86 739.75 739.83 739.39
.065 739.99 739.98 739.95 739.90 739.93 739.72
.070 740.
739.99 739.98 739.96 739.97 739.88
.075 740.
740. 740.
739.99 739.99 739.95
.080 740.
740. 740.
740. 740.
739.98

.085 740.
740. 740.
740. 740.
739.99
.090 740.
740. 740.
740. 740.
740.
.095 740.
740. 740.
740. 740.
740.
.100 740.
740. 740.
740. 740.
740.

(In °C, according to the X-coordinate in meter and of time in seconds).

Note:

One limits oneself to the variations during the 6 first second, beyond 10 seconds the condition with limit at the end X = L is not assured any more.

2.3
Uncertainty on the solution

Unknown factor, due to the evaluation of the functions of error.

2.4 References
bibliographical

[1]
Mr. Necati Özisik - Heat Conduction - Chapter 10: Phase-change problems example 10-3 -
John Wiley & Sounds.

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Code_Aster ®
Version
6.4

3 Modeling
With

3.1
Characteristics of modeling

Modeling 2D:

N6
N11
N16
N21

3.2
Characteristics of the grid

20 QUAD8

3.3
Functionalities tested

Order
Key word factor
Simple key word
Argument

DEFI_MATERIAU THER_NL
LAMBDA

BETA

THER_NON_LINE TEMP_INIT
CHAM_NO

INCREMENT

CONVERGENCE
RESI_GLOB_RELA
1.E-2

ITER_GLOB_MAXI
25

CRIT_LAGR_RELA
1.E-3

FILING

PARM_THETA
0.8

LAGRANGIAN
RHO
4

R 4

FILING

3.4 Notice

The latent heat of fusion is provided via the enthalpy on an interval of 0.01 °C.

H
9

=1.08 10
Voluminal enthalpy
T=0.01
Temperature

4
Results of modeling A

4.1 Values
tested

The nodes observed have as a co-ordinate y = 0.0

Identification
Reference
Aster %
difference
temperature
T = 0.5 S N6 (X = 0.005)
682.43
676.24
-0.908
T = 1.0 S N6 (X = 0.005)
661.33
640.58

-3.137
T = 3.0 S N6 (X = 0.005)
628.20
615.72
-1.987
T = 6.0 S N6 (X = 0.005)
614.25
605.37
-1.446

T = 0.5 S N11 (X = 0.010)
726.05
736.92
+1.497
T = 1.0 S N11 (X = 0.010)
705.75
710.18
+0.628
T = 3.0 S N11 (X = 0.010)
669.63
648.30
-3.185
T = 6.0 S N11 (X = 0.010)
647.49
629.97
-2.707

T = 0.5 S N16 (X = 0.015)
738.11
741.19
+0.418
T = 1.0 S N16 (X = 0.015)
728.70
737.23
+1.170
T = 3.0 S N16 (X = 0.015)
696.06
692.52

-0.508
T = 6.0 S N16 (X = 0.015)
673.22
652.62
-3.059

T = 0.5 S N21 (X = 0.020)
739.86
741.60
+0.235
T = 1.0 S N21 (X = 0.020)
737.22
741.16
+0.534
T = 3.0 S N21 (X = 0.020)
714.94
723.46
+1.192
T = 6.0 S N21 (X = 0.020)
692.06
685.31
-0.976

Calculation by finite elements requires a discretization in times of T

10
5
4
-
=
S at least for
first steps. The boundary condition imposed at the origin making pass the temperature abruptly of 740.°C with 580.°C. One observes on the level of the first steps of time some oscillations which stabilize then rather quickly, despite everything the maximum temperature is exceeded, it does not have there
respect of the discrete maximum. This phenomenon is observed at the time of the thermal shocks, only one
particular digital processing on the level of the matrix of mass can cure this last.

Handbook of Validation

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5 Modeling B

5.1 Characteristics of modeling

Modeling 3D:

No324
No312 No300 No277

5.2 Characteristics of the grid

20 HEXA20

5.3 Functionalities tested

Order
Key word factor

Simple key word
Argument

DEFI_MATERIAU THER_NL
LAMBDA

BETA

THER_NON_LINE
TEMP_INIT VALE
740.0
INCREMENT

CONVERGENCE
RESI_GLOB_RELA
1.E-2

ITER_GLOB_MAXI
25

CRIT_LAGR_RELA
1.E-3

PARM_THETA
0.8

LAGRANGIAN
RHO
4

R
4

6 Results of modeling B

6.1 Values tested

The nodes observed have as co-ordinates: X = y = 0.005

Identification	Reference	Aster	% difference
Temperature			
T = 0.5 S No324 (Z = 0.005)	682.43	671.47	-1.59
T = 1.0 S No324 (Z = 0.005)	661.33	698.97	-3.38
T = 3.0 S No324 (Z = 0.005)	628.20	615.54	-2.02
T = 6.0 S No324 (Z = 0.005)	614.25	612.41	

-0.30

T = 0.5 S No312 (Z = 0.010)
726.05
733.77
+1.06
T = 1.0 S No312 (Z = 0.010)
705.75
707.08
+0.19
T = 3.0 S No312 (Z = 0.010)
669.63
647.77
-3.26
T = 6.0 S No312 (Z = 0.010)
647.49
645.01
-0.38

T = 0.5 S No300 (Z = 0.015)
738.11
740.86
+0.373
T = 1.0 S No300 (Z = 0.015)
728.70
736.05
+1.01
T = 3.0 S No300 (Z = 0.015)
696.06
691.42
-0.67
T = 6.0 S No300 (Z = 0.015)
673.22
670.77
-0.36

T = 0.5 S No277 (Z = 0.020)
739.86
741.34
+0.20
T = 1.0 S No277 (Z = 0.020)
737.22
740.36
+0.48
T = 3.0 S No277 (Z = 0.020)
714.94
722.46
+1.05
T = 6.0 S No277 (Z = 0.020)
692.06
696.09
-0.58

7
Summaries of the results

The error obtained compared to the analytical solution remains reasonable for the points of observation
listed in the tables. Let us announce however that the thermal shock imposed on the beginning of the transient
cause oscillations (when one observes the variation in the temperature in a point during
times) which diminish quickly and which disappeared at time T = 0.5 S.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
Document: V4.22.003

TTNL03 - Thermohydration.
Simulation of an adiabatic test

Summary:

The purpose of this test is to validate the behavior thermo-hydrating THER_HYDR, by simulating a test adiabat:
a freshly-mixed concrete sample is plunged in a calorimeter, the catch being carried out with release of heat,
it is a question of finding the field of temperature and hydration in the course of time.

The temperature and the degree of hydration are uniform in the sample. The temperature measured in calorimeter will be thus the reference solution, the hydration being determined by analytical integration of the law of evolution.

2 modelings are proposed: three-dimensional and axisymmetric.

1
Problem of reference

1.1 Geometry
y
q.n = 0
4
3
1 m
Concrete
1
2
X
1 m

1.2
Material properties

The material has the following thermal characteristics:

Thermal conductivity: ks = 6 kJ/h/m/°K *voluminal variation of enthalpy: H = 2.4.105 kJ/m3,*

and characteristics relating to the behavior hydrating following:

Heat per degree of hydration: Q0 = 1.4904105 kJ/m3

Constant of Arrhenius: Ar = 4000/°K.

Note:

The constant of Arrhenius is always expressed in Kelvin degree. The temperatures are expressed in °C.

Affinity function of the hydration:

Degree of hydration H
Affinity A (H) (1/h)
0 6510
0.008 6360
0.016 2485
0.019 2460
0.038 9520
0.047 21800
0.08 37600
0.138 51600
0.232 51400
0.351 28200
0.44 16100
0.5 11700
0.63 5570
0.73 4240
0.81 1780
0.88 302
0.97 50
1.00 0

Titrate:

1.3 Boundary conditions and loadings

One imposes a heat flux no one on all the faces of the solid. The loading is only initiated by a heat source depending on the hydration Q = Q0 h.

1.4 Conditions initial

The initial temperature is of 20.9°C

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The reference solution in temperature is given by at every moment measured temperatures during the adiabatic test.

The reference solution for the degree of hydration is calculated analytically according to temperatures measured by integrating the law of evolution of the degree of hydration hy:

Ar
-
hy A H E T
=
+
( )
(
.
273 6) T T being expressed in °C

2.2
Results of Reference

The results relate to the first 60 hours of the test.

T (out of H)
T (in °C)
hy (en%)
0 20.9 0
1 21.4 0.8
2 21.9 1.6
3 22.1 1.9
4 22.3 2.2
5 22.5 2.58
10 35.3 23.2
15 57.8 59.4
20 68.3 76
30 75.8 88
45 77.9 92
60 79.1 94

2.3
Uncertainty on the solution

Measure temperatures during the test. Integration of the law of evolution of hy on steps of time

varying between 1h and 5h.

2.4 References
bibiographic

[1]
CESAR-LCPC 3.2. Handbook of examples. Modeling of the concrete at the youth. January 1996
[2]
Gilles DEBRUYNE: Analyze models of behavior of the concrete in CESAR:
transferability of model TEXO-MEXO in Code_Aster. CR MMN 97-193. 24/12/97
Handbook of Validation
V4.22 booklet: Nonlinear thermics of the linear structures
HT-66/03/008/A

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling AXIS

3.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4

3.3 Functionalities tested

Orders

DEFI_FONCTION HYDR

DEFI_MATERIAU THER_HYDR AFFINITY
QSR_K
CHALHYDR
THER_NON_LINE COMP_THER_NL
RELATION
THER_HYDR

4 Results of modeling A

4.1 Values tested

Identification Moments Reference
Aster %
difference
T node 1
5
22.5 22.47
-0.139
T node 1
15
57.8 56.82
-1.696
T node 1
60
79.1 76.67
-3.066
hy Pt of Gauss 1
5

2.58D-2 2.52D-2
-2.101
hy Pt of Gauss 1
15
5.94D-1 5.97D-1
0.53
hy Pt of Gauss 1
60
9.4D-1 9.32D-1
-0.871

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5 Modeling
B

5.1
Characteristics of modeling

Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X

5.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8 + 4 QUAD4 (faces)

5.3 Functionalities
tested

Orders

DEFI_FONCTION HYDR

DEFI_MATERIAU THER_HYDR AFFINITY QSR_K
CHALHYDR
THER_NON_LINE COMP_THER_NL
RELATION THER_HYDR

6
Results of modeling B

6.1 Values
tested

Identification Moments Reference
***Aster** %*
difference
T node 1
5
22.5 22.47
-0.139
T node 1
15
57.8 56.82
-1.696
T node 1
60
79.1 76.67
-3.066
hy Pt of Gauss 1
5
2.58D-2 2.52D-2
-2.101
hy Pt of Gauss 1
15
5.94D-1 5.97D-1
0.53
hy Pt of Gauss 1

60
9.4D-1 9.32D-1
-0.871

---

7 *Summary of the results*

The error obtained compared to the reference solution is about 1% with regard to
temperature and the hydration. Let us announce that the problem was dealt with with steps of time of the order
from 15 minutes what is relatively small for the phenomenon of hydration which lasts several
tens of hours.

Intentionally white left page.

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
V4.22.302 document

TTNL302 - Infinite wall subjected to a constant flow with variable properties

Summary:

This test results from the validation independent of version 3 in nonlinear transitory thermics.

It is about a linear problem 1D represented by five modelings, one planes, four the other voluminal ones.

The functionalities tested are as follows:
· element of plane thermics,
· voluminal element of thermics,
· algorithm of transitory thermics non-linear,
· variable properties,
· limiting condition: imposed flow.

The interest of the test lies in the taking into account of properties variable (thermal conductivity and

heat
voluminal).

The results are compared with an analytical solution.

1
Problem of reference

1.1 Geometry

y
D
C
Q
E
X
With
B
L

Q (W/m ²)
, C
L = 2 m
1,5

AE=EB= 1m
1
1
T (S)
T (°C)
1

1.2
Properties of material

= 1.0 + 0.5 T W/m.°C
Thermal conductivity
C = 1.0 + 0.5 T J/m3.°C Heat
voluminal

1.3
Boundary conditions and loadings

· with dimensions [AD]: flow imposed Q = 1 W/m ² for T > 0,
· with dimensions [AB], [BC], [CD] = O.

1.4 Conditions
initial

T (X, 0) = 0°C for any X

2
Reference solution

2.1
Method of calculation used for the reference solution

Semi-analytical solution utilizing functions of error:

x2

X

T (X, T) = 2 1+ 2 (T/) exp-
+ x.erfc -

1

-
4t

2 T

2
2
with er (
FC X)
and
=
dt
X

where X = X-coordinate
T = time

This formula is valid only for (T) = C (T) = 1. + 0.5T

2.2
Results of reference

Temperature at points A (X = 0) and E (X = 1) at the moment T following: T = 0.1, 0.3, 0.5, 0.7 and 1s

2.3
Uncertainty on the solution

Unknown factor, due to the evaluation of the functions of error.

2.4 References
bibliographical

[1]
Segal, NR. Praagman, "A fast implementation of explicit time stepping algorithms with the finite element method for has class of nonlinear evolution problems ", Int. J. num. Meth. Engng, flight 23, pp 155-168, 1986.

---

3 Modeling
With

3.1
Characteristics of modeling

PLAN (QUAD9)

y
D
C
F
0.1 m
m20
m11 m10
m1
X
With
E
B
1. m
2.m
Limiting conditions:
Not
X
y
Node
With
0.0
0.0
N1
- dimensioned AB, BC, CD = 0
D
0.0
0.1
N3
- dimensioned AD
Q = 1 W/m ² °C
E
1.0
0.0
N61
F

1.0
0.1
N63

3.2
Characteristics of the grid

A number of nodes:
123
A number of meshs and types: 20 QUAD9

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
FLUX_REP

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 5.D-2] is T = 5.D-3
19 step for [5.D-2, 1.D0] is T = 5.D-2
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HT-66/02/001/A

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C)

Node N1 T = 0.1s
0.330
0.329
-0.204%
1%
""T = 0.3s
0.544

0.544
-0.048%
1%
““T = 0.5s
0.682
0.681
-0.075%
1%
““T = 0.7s
0.789
0.789
-0.036%
1%
““T = 1.0s
0.918
0.920
0.254%
1%
Node N3 T = 0.1s
0.330
0.329
-0.204%
1%
““T = 0.3s
0.544
0.544
-0.048%
1%
““T = 0.5s
0.682
0.681
-0.075%
1%
““T = 0.7s
0.789
0.789
-0.036%
1%
““T = 1.0s
0.918
0.920
0.254%
1%

Node N61 T = 0.1s
0.004
0.004
1.161%
1%
““T = 0.3s
0.071
0.071
-0.377%
1%
““T = 0.5s
0.160
0.161
0.573%
1%
““T = 0.7s
0.247
0.251
1.616%
1%
““T = 1.0s
0.366
0.380
3.951%
1%
Node N63 T = 0.1s
0.004
0.004
1.161%
1%
““T = 0.3s
0.071
0.071
-0.377%
1%
““T = 0.5s
0.160
0.161
0.573%

1%
““T = 0.7s
0.247
0.251
1.616%
1%
““T = 1.0s
0.366
0.380
3.951%
1%

4.2 Remarks

The relative error is to the maximum of 3.9%.

4.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 19.44 seconds

---

5 Modeling B

5.1 Characteristics of modeling

3D (HEXA20)

Z
y
Nodes
H
Nodes
N121
0.1 m 0.1 m
N126
G
N1
D
C
N8
E
X
F
With
B
1 m
Limiting conditions:
Nodes
X
y
Z
- faces ABCD, ABFE = 0
N1
0.0
0.0
0.05
- faces EFGH, DCGH

N8
0.0
0.1
-0.05
= 0
- face BFGC
N121
1.0
0.0
-0.05
= 0
- face AEHD
Q
N126
1.0
0.1
0.05
= 1 W/m ²

5.2
Characteristics of the grid

A number of nodes:
248
A number of meshs and types: 20 HEXA20

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER

FLUX_REP

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

5.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 5.D-2] is T = 5.D-3
19 step for [5.D-2, 1.D0] is T = 5.D-2
Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
TTNL302 infinite Wall subjected to a constant flow with variable properties
Date:
20/09/02
Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER Clé*
:
V4.22.302-A Page:
7/14

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster *%*
difference
tolerance
Temperature (°C)

Node N1 T = 0.1s
0.330
0.330
-0.129
1%
““T = 0.3s
0.544
0.543
-0.149
1%
““T = 0.5s
0.682
0.681
-0.154
1%
““T = 0.7s
0.789
0.788
-0.092
1%
““T = 1.0s
0.918
0.920
0.222
1%
Node N8 T = 0.1s
0.330
0.330
-0.129
1%
““T = 0.3s
0.544
0.543
-0.149
1%

““T = 0.5s
0.682
0.681
-0.154
1%
““T = 0.7s
0.789
0.788
-0.092
1%
““T = 1.0s
0.918
0.920
0.222
1%

Node N121 T = 0.1s
0.004
0.004
10.931
1%
““T = 0.3s
0.071
0.071
-0.242
1%
““T = 0.5s
0.160
0.161
0.587
1%
““T = 0.7s
0.247
0.251
1.619
1%
““T = 1.0s
0.366
0.380
3.95

1%
Node N126 T = 0.1s
0.004
0.004
10.931
1%
““T = 0.3s
0.071
0.071
-0.242
1%
““T = 0.5s
0.160
0.161
0.587
1%
““T = 0.7s
0.247
0.251
1.619
1%
““T = 1.0s
0.366
0.380
3.95
1%

6.2 Remarks

The relative error is to the maximum of 3.95%, except for X = 1 at the moment T = 0.1s the error is 11%.
This error was obtained for the smallest value of the temperature (T = 0.004°C). This variation be explained by the fact that the function of error in this point is 0.025347 and that uncertainty on calculation of the function of error is unknown.

6.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 8.30 seconds

Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
HT-66/02/001/A

---

7 Modeling C

7.1 Characteristics of modeling

3D (TETRA4)

X
G
C
Longitudinal axis X following the trisecting one (X=Y=Z)
Limiting conditions:
B
- faces ABCD, ABFE
= 0
0.2 m
- faces EFGH, DCGH
= 0
- face BFGC
= 0
Z
- face AEHD
Q = 1 W/m ²
0.2 m
Z
Z
Y
X = 1.

N1
N6
N8
N103
N106
D
H
N105
N3
N4
N9
N108
N2
N5
N7
N104
N107
X
Y X
Y
H
D
With
E
X
Section X = 0.
Section X = 1.
E
With

7.2
Characteristics of the grid

A number of nodes:
224
A number of meshs and types: 692 TETRA4 (and 8 TRIA3)

7.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
THERMICS

3D

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
FLUX_REP

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

7.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 5.D-2] is T = 5.D-3
19 step for [5.D-2, 1.D0] is T = 5.D-2

:
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8
Results of modeling C

8.1 Values
tested

Identification Reference
Aster
Relative variation (%)
Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures in °C:

Face
X = 0.m

N7 node
T = 0.1s
0.330
0.3295
-0.162%
1.%
-0.000536
0.005
" "
T = 0.3s
0.544

0.5425
-0.273%
1.%
-0.00149
0.005
" "
T = 0.5s
0.682
0.6796
-0.351%
1.%
-0.00239
0.005
" "
T = 0.7s
0.789
0.7861
-0.362%
1.%
-0.00285
0.005
" "
T = 1.0s
0.918
0.9165
-0.159%
1.%
-0.00146
0.005
N5 node
T = 0.1s
0.330
0.3279
-0.627%
1.%
-0.00207
0.005
" "
T = 0.3s
0.544
0.5418
-0.406%
1.%

-0.00221
0.005
" "
T = 0.5s
0.682
0.6791
-0.422%
1.%
-0.00288
0.005
" "
T = 0.7s
0.789
0.7858
-0.409%
1.%
-0.00323
0.005
" "
T = 1.0s
0.918
0.9162
-0.192%
1.%
-0.00176
0.005

Section
X = 1.m

Node N107 T = 0.1s
0.00394
0.004140

5.085%
1.% 0.000200 0.005
" "
T = 0.3s
0.0706
0.07013
-0.665%
1.%
-0.000470
0.005
" "
T = 0.5s
0.160
0.1596
-0.228%
1.%
-0.000364
0.005
" "
T = 0.7s
0.247
0.2488
0.730%
1.%
0.00180
0.005
" "
T = 1.0s
0.366
0.3766
2.889%
1.%
0.0106
0.005
Node N108 T = 0.1s
0.00394
0.004002
1.577%
1.%
-0.0000621
0.005
" "
T = 0.3s

0.0706
0.06937
-1.742%
1.%
-0.00123
0.005
" "
T = 0.5s
0.160
0.1586
-0.895%
1.%
-0.00143
0.005
" "
T = 0.7s
0.247
0.2476
0.238%
1.%
0.000587
0.005
" "
T = 1.0s
0.366
0.3753
2.534%
1.%
0.00928
0.005

8.2 Remarks

The selected nodes correspond to the extreme results on the same section.

8.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 13.08 seconds

---

9 Modeling
D

9.1
Characteristics of modeling

3D (TETRA10)

Z
Longitudinal axis X following the trisecting one (X=Y=Z)
N4
N7
N12 N16 N25
Limiting conditions:
X
D
H
G
C
N1

N9
N15 N17 N23
- faces ABCD, ABFE
= 0
N2
N10 N13 N20 N22
- faces EFGH, DCGH
= 0
- face BFGC
B
= 0
N3
N6
N14 N18 N21
- face AEHD
Q = 1 W/m ²
X
N5
N8
N11 N19 N24
Y
With
E
Z
0.2 m
Section X = 0.
Z
N601
N605
N611
Y
0.2 m
N602
X = 1.
N603
N599
N606
N610
N607
N608
H
D
X

X
Y
N600
N604
N609
Section X = 1
E
With

9.2
Characteristics of the grid

A number of nodes:
1310
A number of meshs and types: 697 TETRA10 (and 8 TRIA6)

9.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
THERMICS

3D

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
FLUX_REP

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

9.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 5.D-2] is T = 5.D-3
19 step for [5.D-2, 1.D0] is T = 5.D-2

---

10 Results of modeling D

10.1 Values
tested

Identification Reference
Aster
Relative variation (%)
Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures in °C:

Face
X = 0.m

N4 node
T = 0.1s
0.330
0.3291
-0.281%
1.%
-0.000926
0.005
" "
T = 0.3s
0.544
0.5423
-0.318%
1.%
-0.00173
0.005
" "
T = 0.5s
0.682
0.6794
-0.383%
1.%
-0.00261
0.005
" "
T = 0.7s
0.789
0.7860
-0.384%
1.%
-0.00303
0.005
" "
T = 1.0s

0.918
0.9164
-0.180%
1.%
-0.00165
0.005
N25 node
T = 0.1s
0.330
0.3292
-0.255%
1.%
-0.000843
0.005
" "
T = 0.3s
0.544
0.5423
-0.314%
1.%
-0.00171
0.005
" "
T = 0.5s
0.682
0.6794
-0.382%
1.%
-0.00261
0.005
" "
T = 0.7s
0.789
0.7860
-0.383%
1.%
-0.00303
0.005
" "
T = 1.0s
0.918
0.9163
-0.180%

1.%
-0.00165
0.005

Section
X = 1.m

Node N606 T = 0.1s
0.00394
0.004331
9.913%
1.% 0.000391 0.005
" "
T = 0.3s
0.0706
0.07021
-0.551%
1.%
-0.000389
0.005
" "
T = 0.5s
0.160
0.1596
-0.251%
1.%
-0.000402
0.005
" "
T = 0.7s
0.247
0.2488
0.710%

1.%
0.00175
0.005
" "
T = 1.0s
0.366
0.3764
2.855%
1.%
0.0104
0.005
Node N611 T = 0.1s
0.00394
0.004332
9.944%
1.% 0.000392 0.005
" "
T = 0.3s
0.0706
0.07021
-0.550%
1.%
-0.000388
0.005
" "
T = 0.5s
0.160
0.1596
-0.251%
1.%
-0.000402
0.005
" "
T = 0.7s
0.247
0.2488
0.710%
1.%
0.00175
0.005
" "
T = 1.0s
0.366

0.3764
2.855%
1.%
0.0104
0.005

10.2 Remarks

The calculated results are almost identical on the nodes of the same section.

10.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory: 8 megawords
Time CPU To use: 25.88 seconds

---

11 Modeling

E

11.1 Characteristics of modeling

3D (HEXA27)

Longitudinal axis X following the trisecting one (X=Y=Z)
X
G C
Limiting conditions:
B
- faces ABCD, ABFE
= 0
- faces EFGH, DCGH
= 0
0.1 m
- face BFGC
= 0
- face AEHD
Q = 1 W/m ²
Z
0.1 m
Z
Z
X = 1.
Y
N3
N85
N2
N43 N165 N42
D
H
N86 N249 N88
N166 N308 N168
N4
N87
N1
N44 N167 N41
X
Y X
Y
With
E
H

D
X
Section X = 0.
Section X = 1.
E
With

11.2 Characteristics of the grid

A number of nodes:
369
A number of meshs and types: 20 HEXA27 (and 1 QUAD9)

11.3 Functionalities tested

Orders

AFFE_MODELE
AFFE
THERMICS

3D

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
FLUX_REP

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

11.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 5.D-2] is T = 5.D-3
19 step for [5.D-2, 1.D0] is T = 5.D-2

---

12 Results of modeling E

12.1 Values tested

Identification Reference
Aster
Relative variation (%)
Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures in °C:

Face
X = 0.m

Node N249 T = 0.1s
0.330
0.3291
-0.283%
1.%
-0.000933
0.005
" "
T = 0.3s
0.544
0.5423
-0.317%
1.%
-0.00173
0.005
" "
T = 0.5s
0.682
0.6794
-0.376%
1.%
-0.00256
0.005
" "
T = 0.7s
0.789
0.7860
-0.378%
1.%
-0.00298
0.005
" "
T = 1.0s
0.918
0.9165
-0.168%
1.%

-0.00154
0.005

Section
X = 1.m

Node N308 T = 0.1s
0.00394
0.004331
9.926%
1.% 0.000391
0.005
" "
T = 0.3s
0.0706
0.07021
-0.554%
1.%
-0.000391
0.005
" "
T = 0.5s
0.160
0.1596
-0.227%
1.%
-0.000363
0.005
" "
T = 0.7s
0.247
0.2488
0.726%

1.%
0.00179
0.005
" "
T = 1.0s
0.366
0.3766
2.886%
1.%
0.0106
0.005

12.2 Remarks

The calculated results are identical (with a margin of 107) on the nodes of the same section.

12.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 9.68 seconds
Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
TTNL302 infinite Wall subjected to a constant flow with variable properties
Date:
20/09/02
Author (S):
C. DURAND, E. SCREW, F. LEBOUVIER Clé

13 Summary of the results

Five modelings carried out, have same cutting in the direction of propagation of temperature, they are different only by their type of meshs.

Five modelings give results whose certain values exceed the fixed tolerance initially (1%). The maximum change is 9.9%. It appears for the smallest value of reference located in the middle of the wall and at the beginning of the transient.

A grid finer associate with a finer temporal discretization should improve quality of results.

Moreover, the reference solution utilizes a function of error whose precision is unknown.

The results are regarded as acceptable taking into account the points evoked above.

This test made it possible to test hexahedral and tetrahedral meshs in non-linear thermics transient as well as the principal following thermal orders:

· DEFI_MATERIAU associated with key word THER_NL, allowing to define the characteristics of one material whose characteristics vary according to the temperature (conductivity and enthalpy),
· THER_NON_LINE orders allowing the resolution of a thermal nonlinear problem stationary or not.

***C. DURAND**, E. SCREW, F. LEBOUVIER* *Clé*
:
V4.22.303-A Page:
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Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
V4.22.303 document

TTNL303 - Infinite wall subjected to a jump of temperature with variable properties

Summary:

This test results from the validation independent of version 3 in nonlinear transitory thermics.

It is about a linear problem 1D represented by four modelings, two plane and two voluminal.

The functionalities tested are as follows:
· plane thermal element,
· voluminal thermal element,
· variable thermal conductivity,
· non-linear transitory thermal algorithm,
· limiting conditions: temperature imposed with jump.

The interest of the test lies in the taking into account of variable properties in transitory analysis and the variation
temperatures imposed according to time.

1
Problem of reference

1.1 Geometry

y
D
C
X
With
B
L = 0.2m

TAD (°C)
TBC (°C)
(W/m/°C)
200°

200°
400
100°
100°
200
T (S)
T (S)
T (°C)
10
10
100°
200°

1.2
Properties of material

= 200 + T (thermal W/m °C) conductivity
C = 8 X 106 (J/m3 °C)
voluminal heat

1.3
Boundary conditions and loadings

X = 0 | T = 200°C 0 < T 10 S

| T = 100°C T > 10 S
X = L

T = 100°C T 0 S

1.4 Conditions
initial

T (X, 0) = 100°C for any X

Version
5.0

Titrate:
TTNL303 infinite Wall subjected to a jump of temperature

Date:
20/09/02
Author (S):
C. DURAND, E. SCREW, F. LEBOUVIER Clé
:
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2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution was obtained with the computation software by finite elements “IVOHEAT” [bib2]
quoted in the reference [bib1]. This solution is based on network made up of 20 elements isoparametric with 4 nodes of identical size, by using a method of Crank-Nicolson modified with an accuracy of 10-6.

2.2
Results of reference

Temperature with:

· T = 10 S for x= 0.01, 0.02, 0.04, 0.06, 0.08 and 0.1,
· T = 13 S for x= 0.01, 0.02, 0.04, 0.06, 0.08 and 0.1.

2.3 References bibliographical

[1]
S. Orivuori, “Efficient method for solution of nonlinear heat conduction problems”, Int. J. num. Meth. Engng, flight 14, n°10, pp 1461-1476, 1979

[2]
S. Orivuori, "A finite element method applied to the solution of the transient heat conduction problem', Licentiate Thesis, Tech. Univ., Helsinki (1977), in Finnish.
Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
HT-66/02/001/A

---

3 Modeling With

3.1 Characteristics of modeling

PLAN (TRIA6)

y
D
C
0.02m
X
With
B
0.2 m
Nodes
X
y
Limiting conditions:
N11
0.01
0.00
- dimensioned AB, CD
N21
0.02
0.00

= 0
N41
0.04
0.00
- dimensioned AD
| T = 200°C 0 < T 10 S
N61
0.06
0.00
| T = 100°C T > 10 S
N81
0.08
0.00
- dimensioned BC
T = 100°C
T 0 S
N101
0.10
0.00

3.2
Characteristics of the grid

A number of nodes:
205
A number of meshs and types: 80 TRIA6

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F

TEMP_IMPO

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 1.D-3] is T = 1.D-4
9 steps for [1.D-3, 1.D-2] are T = 1.D-3
9 steps for [1.D-2, 1.D-1] are T = 1.D-2
9 steps for [1.D-1, 1.D0] are T = 1.D-1
9 steps for [1.D0, 10.D0] are T = 1.D0
3 steps for [10.D0, 13.D0] are T = 1.D0

4

Results of modeling A

4.1 Values tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C) with t=10 S

N11 176.165
174.954
-0.687
2%
N21 153.213
151.049
-1.412
2%
N41 118.600
116.576
-1.707
2%
N61 103.715
103.195
-0.502
2%
N81 100.368
100.417
0.049
2%
N101 100.014
100.088
0.074
2%

Temperature (°C) with t=13 S

N11 128.125
128.377
0.197
2%
N21 139.970
139.846
-0.089
2%
N41 124.719
122.209
-2.013
2%
N61 107.182
106.279
-0.842
2%
N81 101.290
101.186
-0.103
2%
N101 100.134
100.203
0.067
2%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 10.26 seconds

5 Modeling
B

5.1
Characteristics of modeling

3D (PENTA6)

0.02m
X
0.02m
N98
N81
Z
N63
N45
N26
N91
0.2 m
N17
N73
Limiting conditions:
N55
y
N37
- face X = 0.0
| T = 200°C 0 < T 10 S

N19
| T = 100°C T > 10 S
N10
- face X = 0.2
T = 100°C
T 0 S
- others faces
= 0

5.2
Characteristics of the grid

A number of nodes:
189
A number of meshs and types: 160 PENTA6

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
TEMP_IMPO

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

5.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 1.D-3] is T = 1.D-4
9 steps for [1.D-3, 1.D-2] are T = 1.D-3
9 steps for [1.D-2, 1.D-1] are T = 1.D-2
9 steps for [1.D-1, 1.D0] are T = 1.D-1
9 steps for [1.D0, 10.D0] are T = 1.D0
3 steps for [10.D0, 13.D0] are T = 1.D0

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C) with t=10 S

N10 176.165
175.087
-0.612
2%
N17 176.165
174.910
-0.713
2%
N19 153.213
151.182
-1.326
2%
N26 153.213
151.020
-1.431
2%
N37 118.600
116.314
-1.928
2%
N45 118.600
116.379
-1.872
2%
N55 103.715
102.759
-0.921
2%
N63 103.715
102.892
-0.793
2%
N73 100.368
100.239
-0.129
2%
N81 100.368
100.285
-0.083
2%
N91 100.014

100.060
0.046
2%
N98 100.014
100.066
0.052
2%
Temperature (°C) with t=13 S

N10 128.125
129.395
0.991
2%
N17 128.125
128.291
0.130
2%
N19 139.970
139.819
-0.108
2%
N26 139.970
140.209
0.171
2%
N37 124.719
122.986
-1.390
2%
N45 124.719
122.569
-1.724
2%
N55 107.182
105.967
-1.134
2%
N63 107.182
106.050
-1.056
2%

N73 101.290
100.945
-0.341
2%
N81 101.290
101.005
-0.282
2%
N91 100.134
100.126
-0.008
2%
N98 100.134
100.142
0.008
2%

6.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory: 8 megawords
Time CPU To use: 11.30 seconds

Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
TTNL303 infinite Wall subjected to a jump of temperature

Date:

7 Modeling
C

7.1
Characteristics of modeling

3D (HEXA8)

Limiting conditions:
- face x=0 | T = 200°C 0 < T
0.02
10 S
| T = 100°C T > 10 S
0.02
- face x=0.2 T = 100°C T 0 S
- others faces = 0
N321
Z
N257
X
N193
Y
X
N122
N36
N17
Sight plan X0Y
O
N352
0.03
Y
N288
N224
N160
N112
X

N80
origin of axis X
Nodes
X
Sight plan YOZ
N80, N17
0.01
N112, N36
0.02
Z
N160, N122 0.04
N224, N193 0.06
0.05
N288, N257 0.08
=40°
Y
N352, N321 0.10
O

7.2
Characteristics of the grid

A number of nodes:
588
A number of meshs and types: 360 HEXA8

7.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
TEMP_IMPO

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

7.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 1.D-3] is T = 1.D-4
9 steps for [1.D-3, 1.D-2] are T = 1.D-3
9 steps for [1.D-2, 1.D-1] are T = 1.D-2
9 steps for [1.D-1, 1.D0] are T = 1.D-1
9 steps for [1.D0, 10.D0] are T = 1.D0
3 steps for [10.D0, 13.D0] are T = 1.D0

8
Results of modeling C

8.1 Values tested

Relative variation %
Absolute deviation
Identification Reference Aster difference
tolerance difference tolerance

Temperature (°C)

T = 10 S

N80 176.165
174.992
-0.666
2%
-1.17
3.0
N17 176.165
174.992
-0.666
2%
-1.17
3.0
N112 153.213
151.092
-1.384
2%

-2.12
3.0
N36 153.213
151.092
-1.384
2%
-2.12
3.0
N160 118.600
116.331
-1.913
2%
-2.27
3.0
N122 118.600
116.331
-1.913
2%
-2.27
3.0
N224 103.715
102.817
-0.866
2%
-0.898
3.0
N193 103.715
102.817
-0.866
2%
-0.898
3.0
N288 100.368
100.265
-0.102
2%
-0.103
3.0
N257 100.368
100.265
-0.102
2%
-0.103

3.0
N352 100.014
100.066
0.052
2%
0.052
3.0
N321 100.014
100.066
0.052
2%
0.052
3.0
T = 13 S

N80 128.125
128.829
0.550
2%
0.704
3.0
N17 128.125
128.829
0.550
2%
0.704
3.0
N112 139.970
139.893
-0.055
2%
-0.077
3.0
N36 139.970
139.893
-0.055
2%
-0.077
3.0

N160 124.719
122.718
-1.605
2%
-2.00
3.0
N122 124.719
122.718
-1.605
2%
-2.00
3.0
N224 107.182
105.988
-1.114
2%
-1.19
3.0
N193 107.182
105.988
-1.114
2%
-1.19
3.0
N288 101.290
100.974
-0.312
2%
-0.316
3.0
N257 101.290
100.974
-0.312
2%
-0.316
3.0
N352 100.134
100.136
0.002
2%
0.002
3.0
N321 100.134

100.136
0.002
2%
0.002
3.0

8.2 Parameters
of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 16.56 seconds

---

9 Modeling
D

9.1
Characteristics of modeling

PLAN (TRIA3, QUAD4)

C
Y
0.06
y
X
N75
N61
D
N47
N33
B
N12 N19
N71
=50°
N57
N43
X
N29
With
N8 N15
0.1
Nodes
X
y
N8
0.01
0.00
Limiting conditions:
N15
0.02
0.00
- dimensioned AB, CD
= 0
N29
0.04
0.00
- dimensioned AD | T = 200°C 0 < T 10 S
N43
0.06
0.00

| T = 100°C T > 10 S
N57
0.08
0.00
- dimensioned BC T = 100°C T 0 S
N71
0.10
0.00

9.2
Characteristics of the grid

A number of nodes:
147
A number of meshs and types: 200 (40 QUAD4, 160 TRIA3)

9.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
TEMP_IMPO

THER_NON_LINE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

9.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 1.D-3] is T = 1.D-4
9 steps for [1.D-3, 1.D-2] are T = 1.D-3
9 steps for [1.D-2, 1.D-1] are T = 1.D-2
9 steps for [1.D-1, 1.D0] are T = 1.D-1
9 steps for [1.D0, 10.D0] are T = 1.D0
3 steps for [10.D0, 13.D0] are T = 1.D0

---

10 Results of modeling D

10.1 Values
tested

Relative variation %
Absolute deviation
Identification Reference Aster difference
tolerance difference tolerance

Temperature (°C)

T = 10 S

N8 176.165
174.997
-0.663
2%
-1.17
3.0
N12 176.165
175.154
-0.574
2%
-1.01
3.0
N15 153.213
151.117
-1.368
2%
-2.10
3.0
N19 153.213
151.246
-1.284
2%
-1.97
3.0
N29 118.600
116.416
-1.842

2%
-2.18
3.0
N33 118.600
116.246
-1.985
2%
-2.35
3.0
N43 103.715
102.884
-0.801
2%
-0.831
3.0
N47 103.715
102.664
-1.014
2%
-1.05
3.0
N57 100.368
100.283
-0.084
2%
-0.085
3.0
N61 100.368
100.208
-0.159
2%
-0.160
3.0
N71 100.014
100.067
0.053
2%
0.053
3.0
N75 100.014
100.057
0.043
2%

0.044
3.0
T = 13 S

N8 128.125
128.512
0.302
2%
0.387
3.0
N12 128.125
129.103
0.764
2%
0.978
3.0
N15 139.970
139.689
-0.201
2%
-0.281
3.0
N19 139.970
140.233
0.188
2%
0.263
3.0
N29 124.719
122.723
-1.601
2%
-2.00
3.0
N33 124.719
123.198
-1.220
2%
-1.52

3.0
N43 107.182
106.051
-1.055
2%
-1.13
3.0
N47 107.182
105.887
-1.209
2%
-1.30
3.0
N57 101.290
101.004
-0.282
2%
-0.286
3.0
N61 101.290
100.902
-0.383
2%
-0.388
3.0
N71 100.134
100.143
0.009
2%
0.009
3.0
N75 100.134
100.116
-0.018
2% 0.018 3.0

10.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

*Obstruction memory:
8 megawords
Time CPU To use: 11.06 seconds
Handbook of Validation
V4.22 booklet: Non-linear transitory thermics of the linear structures
HT-66/02/001/A*

---

11 Summary of the results

*A modeling among four modelings carried out give results of which a value
exceed little the tolerance fixed initially (2%). The maximum change is of:*

*· 2.013% for modeling PLAN (TRIA6),
· 1.928% for modeling 3D (PENTA6),
· 1.913% for modeling 3D (HEXA8),
· 1.985% for modeling PLAN (TRIA3, QUAD4).*

*It is noted that this variation is whatever the modeling close to 2%, all modelings
carried out, have same cutting in the direction of propagation of the temperature.*

The results obtained are regarded as acceptable for the whole of modelings

*This test made it possible to test the taking into account of a variable thermal conductivity with a condition
limit varying in the course of time.*

Code_Aster ®
Version
4.0
Titrate:
TTLP100 Exchange-wall in transitory thermics
Date:
28/01/98
Author (S):
I. VAUTIER
Key:
V4.23.100-A Page:
1/6
Organization (S): EDF/IMA/MMN
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
Document: V4.23.100
TTLP100 - Exchange-wall in transitory thermics
Summary
One calculates the linear transitory response thermal or not linear of two plates separated by a play in *which is carried out a transfer of heat. The problem is 2D but the boundary conditions make that temperature depends only on the X-coordinate and time. The stationary state is quickly reached, which is calculable analytically.*
The test makes it possible to check the good taking into account of the terms related to the heat transfer between 2 walls.

1
Problem of reference

1.1 Geometry

y
1
0
X
l1 = l2 = 0.495 m
0
0.495 0.505
1
L = 1 m
L
L
1
2

1.2
Material properties

= 40 *W/m°C*
0 with
°
0 *C*
CP =
-
7 3
. 10 4
3
J/m ° C

or
=

-
220 10 3
3
J/*m*
with
°
300 *C*
To deal with the same problem in nonlinear thermics, one defines a enthalpy refines of which slope is equal to the specific heat *CP*.

1.3
Boundary conditions and loadings

T (X = 0) = 100°C = To
T (X = L) = 300°C = TL
Heat transfer enters the walls located in X = 0.495 and X = 0.505, with a coefficient of exchange from 80 W/m2 °C.

1.4 Conditions
initial

T (T = 0) =
To in the plate of left
TL in the plate of right-hand side

2
Reference solution

2.1
Method of calculation used for the reference solution

The stationary analytical solution is obtained by solving a null Laplacian on each of both plates of the form T (X) = ax + B, the 4 coefficients (2 per plate) are obtained by clarifying them boundary conditions:

(*hTL* - *To*)
From where:
0. *X* 0 495
.
: *T* = *To* +
X
+ (
H L +
1
2
L)
(*hTL* - *To*)
0 505
.
X 1. : *T* = *TL* -
L - *X*
+ (
H L +
1
2
L) (
)

2.2 Results of reference

Temperatures on the line y = 0

2.3 Uncertainty on the solution

Analytical solution.

---

3 Modeling
With
3.1
Characteristics of modeling

N24
N4
N46
N124
N104 N146
N2
N6
N102
N106
N12
N34
N56
N112
N34
N156
N1
N5
N101
N105
N13
N3
N35
N113 N103 N135

The grid is carried out with elements of the type QUAD8.
Calculation is made in linear thermics, with = 0.57.
One takes 50 steps of times from 0 to 5 102 S. the results are examined in T = 5 102 S.

3.2
Characteristics of the grid

4 QUAD8, 4 SEG3, 26 nodes

3.3 Functionalities
tested

Order
Keys

AFFE_CHAR_THER
ECHANGE_PAROI
[U4.25.02]
THER_LINEAIRE
PARM_THETA

[U4.33.01]

4

Results of modeling A

4.1 Values

tested

Identification

Reference

Aster

% difference

TEMP N3 node

133.557026

133.557047

+1.6 105

TEMP N5 node

166.442953

166.442907

2.8 105

TEMP N101 node

233.557047

233.557093

+2. 105

TEMP N103 node

266.442953

266.442973

+7.5 106

4.2 Remarks

The Aster solution reached the stationary state starting from T = 4.7 102 S.

4.3 Parameters

of execution

Version: 3.6.0

Machine: CRAY C90

Obstruction memory: 8MW

Time CPU To use: 14 seconds

Handbook of Validation

V4.23 booklet: Transitory thermics of the plane systems

HI-75/96/029 - Ind A

Code_Aster ®

Version

4.0

Titrate:

TTLP100 Exchange-wall in transitory thermics

Date:

5 Modeling
B
5.1
Characteristics of modeling

Calculation is made in nonlinear thermics, with = 0.57.
One makes 1 step of times from 0 to 109 S and 300 steps of times of 109 S with 1.5 105 S.
The results are examined in T = 1.5 105 S.

5.2
Characteristics of the grid

4 QUAD8, 4 SEG3, 26 nodes

5.3 Functionalities
tested

Order
Keys
AFFE_CHAR_THER
ECHANGE_PAROI
[U4.25.02]
THER_NON_LINE
PARM_THETA
[U4.33.02]

6
Results of modeling B
6.1 Values
tested

Identification
Reference
Aster
% difference
TEMP N3 node
133.557026
133.500054
0.043
TEMP N5 node
166.442953
166.399598
0.026
TEMP N101 node

233.557047
233.619046
0.027
TEMP N103 node
266.442953
266.513231
0.026

6.2 Remarks

The precision required on the results is only 103 (instead of 106 into linear) because one does not have still, with T = 1.5 105 S, rigorously reached the stationary state.

6.3 Parameters
of execution

Version: 3.6.0
Machine: CRAY C90
Obstruction memory: 50 MW
Time CPU To use: 1700 seconds

7
Summaries of the results

The enormous difference in computing time between THER_LINEAIRE and THER_NON_LINE is explained in
part by the fact that one had to much more finely discretize the steps of time into nonlinear (3000 between 0 and 1.5 105 S instead of 50 between 0 and 5. 102 S) to ensure the convergence of THER_NON_LINE.

In addition, the algorithm of Lagrangian increased used in THER_NON_LINE is much more expensive that the simple one - method used in THER_LINEAIRE.

A request for improvement of the performances was deposited.

Code_Aster ®
Version
5.0

Titrate:
Thermal TTLP300 Transfer in an orthotropic metal bar
Date:
20/09/02
Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER Clé*
:
V4.23.300-A Page:
1/6

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
V4.23.300 document

TTLP300 - Thermal transfer in a bar
metal orthotropic

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a problem plane 2D represented by only one modeling (plane).

The functionalities tested are as follows:
· plane thermal element,
· orthotropic material,
· transitory algorithm of thermics,
· limiting condition: convection.

The interest of the test lies in the taking into account of an orthotropic material.

The results are compared with a solution based on a graphic estimate.

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

y
has
has
= 50.8 X 10-3m have
B = 25.4 X 10-3m

D
C
B
X
With
B
(0) =
B
X, y, C
H Tf

1.2
Properties of material

X = 34.614 W/m °C thermal conductivity along axis X
y = 6.237 W/m °C
thermal conductivity along the axis y
CP = 37.719 J/kg. °C
specific heat

= 6407.38
kg/m3 mass
voluminal

1.3
Boundary conditions and loadings

Convection:

· H = 1362.71 W/m2 °C,
· Tf = 37.78 °C.

1.4 Conditions
initial

T (X, y, T = 0) = 260° C

2
Reference solution

2.1
Method of calculation used for the reference solution

The original reference solution given in the book [bib1] is based on a graphic estimate.
This reference is quoted in the handbook of checking of ANSYS [bib2]

2.2
Results of reference

Temperature at points A B C D at the moment T = 3s

2.3
Uncertainty on the solution

Unknown factor, it was not possible to get the original reference (delivers old, more published).

2.4 References
bibliographical

[1]
Schneider, P.J., "Conduction Heat Transfer", Addison-Wesley Publishing Co., Inc. Reading, Mass., 2nd Printing, 1957.
[2]
ANSYS: "Checking manual", 1st edition, June 1, 1976

---

3 Modeling
With

3.1
Characteristics of modeling

PLAN (QUAD8)

Y
N82
C
Limiting conditions:
- dimensioned AB and DA: = 0
- dimensioned BC and CD: Text = 37.78 °C
H = 1362.71 w/m ² °C
N113
D
B
y
N1
X
= 30°
X
AN26

3.2
Characteristics of the grid

A number of nodes:
113
A number of meshs and types: 30 QUAD8

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_ORTH

AFFE_CARA_ELEM
SOLID MASS

AFFE_CHAR_THER_F
EXCHANGE

THER_LINEAIRE
TEMP_INIT
VALE

EXCIT
CARA_ELEM

RECU_CHAMP
INST

3.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 1.D-4] is T = 1.D-5
9 steps for [1.D-4, 1.D-3] are T = 1.D-4
9 steps for [1.D-3, 1.D-2] are T = 1.D-3
9 steps for [1.D-2, 1.D-1] are T = 1.D-2
9 steps for [1.D-1, 1.D0] are T = 1.D-1
20 steps for [1.D+0, 3.D0] are T = 1.D-1

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster
% difference
Tolerance
moment T = 3 S

Points T (°C)

With (N26)
237.50
238.95
0.611
5%
B (N113)
137.22
140.71
2.541
5%
C (N82)
65.98
66.19
0.318
5%
D (N1)
94.44
93.30
-1.206
5%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 4.70 seconds
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

5
Summary of the results

The results obtained are satisfactory, the maximum change is of 2.5% lower than the fixed tolerance initially (5%) (the reference solution is obtained graphically).

This test made it possible to test in linear transient, modeling PLAN, the orders:

· DEFI_MATERIAU associated with key word THER_ORTH, allowing to define the characteristics of an orthotropic material,
· AFFE_CARA_ELEM associated with the MASSIVE key word, allowing to define the axes of orthotropism.

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
V4.23.301 document

TTLP301 - Transfer of heat in a plate perforated

Summary:

This test, industrialist, result from the validation independent of version 3 in linear transitory thermics.

It is about a problem plane 2D represented by two modelings, one planes, the other voluminal one.

The functionalities tested are as follows:
· plane thermal element,
· voluminal thermal element,
· transitory algorithm of thermics,
· boundary conditions of exchange and flow.

1
Problem of reference

1.1 Geometry

Ø 12.7
Coolant
D
E
Ø 15.87
C
Ø 18.79
Graphite
With
B
Fuel

1.2
Properties of material

=
0.1 W/cm °C

Thermal conductivity
CP = 1.0 J/cm3 °C
Voluminal heat

1.3
Boundary conditions and loadings

· [ED] Convection coefficient H = 1 W/cm2 °C Text = 0°C,
· [AC] Density flux Q = 1 W/cm2,
· [AB], [BE], [CD.] = 0.

1.4 Conditions
initial

T (T = 0) = 0

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is a numerical solution obtained by the finite element method. This *solution is based on a linear triangular network presented below. Calculations were carried out by considering an increment of time T = 0.01 S.*

2.2 Results of reference

Temperature at the point C for t=0.1, 0.2,…, 0.9, 1.0, 1.1, 1.2 S

2.3 References bibliographical

[1]
J. Donea, “One the accuracy of finite element solutions to the transient heat-conduction equation ", Int. J. num. Meth. Engng, flight 8, n°1, pp 103-110, 1974

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

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3 Modeling With

3.1 Characteristics of modeling

PLAN (TRIA6)

Limiting conditions:

- dimensioned AC
Q
= 1 W/cm ²
- dimensioned ED
H
= 1 W/cm ² °C
Text = 0°C
- dimensioned AB, BE, cd.
= 0
y
D
E
N1
C
With
B
X

3.2
Characteristics of the grid

A number of nodes:
718
A number of meshs and types: TRIA6: 335 (SEG3: 22)

3.3
Functionalities tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

AFFE_CHAR_THER
FLUX_REP

EXCHANGE

THER_LINEAIRE

TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

3.4 Remarks

Limiting condition, Flow = 0. , not modelled (implicit).

The discretization in step of time is as follows:

10 steps for [0. , 0.2D+0] is T = 2.D-2
10 steps for [0.2D+0, 1.2D+1] are T = 1.D-1

4
Results of modeling A

4.1 Values
tested

Identification Reference

Aster
% difference
Tolerance
Node Time (S)
T (°C)
T (°C)

n1 0.1
1.045
1.0664
2.05%
2%
" 0.2
1.447
1.4515
0.31%
2%
" 0.3
1.742
1.7480
0.35%
2%
" 0.4
1.982
1.9847
0.14%
2%
" 0.5
2.189
2.1929
0.18%
2%
" 0.6
2.373
2.3757
0.11%
2%
" 0.7
2.541
2.5451
0.16%
2%

" 0.8
2.698
2.7010
0.11%
2%
" 0.9
2.846
2.8491
0.11%
2%
" 1.0
2.986
2.9889
0.10%
2%
" 1.1
3.120
3.1232
0.10%
2%
" 1.2
3.248
3.2517
0.11%
2%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 3.89 seconds

5.0

Titrate:
TTLP301 Transfer of heat in a perforated plate

Date:
20/09/02
Author (S):
C. DURAND, E. SCREW, F. LEBOUVIER Clé
:
V4.23.301-A Page:
6/8

5 Modeling
B

5.1
Characteristics of modeling

3D (PENTA15)

Limiting conditions:
- dimensioned AC
Q
= 1 W/cm ²
- dimensioned ED
H
= 1 W/cm ² °C
Text = 0°C
- dimensioned AB, BE, cd. = 0
y
D
n1
E
C
n1
n719
n911
n1629
n1821
With
B
X

5.2
Characteristics of the grid

A number of nodes:
2538
A number of meshs and types: PENTA15: 670 (QUAD8: 44)

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

AFFE_CHAR_THER
FLUX_REP

EXCHANGE

THER_LINEAIRE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

5.4 Remarks

Condition limits = 0. implicit: not modelled.

The discretization in step of time is as follows:

10 steps for [0. , 0.2D+0] is T = 2.D-2

10 steps for [0.2D+0, 1.2D+1] are T = 1.D-1
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster
% difference
Tolerance
Node Time (S)
T (°C)
T (°C)

n1 0.1
1.045
1.0665
2.05%
2%
" 0.2
1.447
1.4514
0.30%

2%
" 0.3
1.742
1.7480
0.35%
2%
" 0.4
1.982
1.9847
0.14%
2%
" 0.5
2.189
2.1929
0.18%
2%
" 0.6
2.373
2.3757
0.11%
2%
" 0.7
2.541
2.5451
0.16%
2%
" 0.8
2.698
2.7010
0.11%
2%
" 0.9
2.846
2.8491
0.11%
2%
" 1.0
2.986
2.9889
0.10%
2%
" 1.1
3.120

3.1232
0.10%
2%
" 1.2
3.248
3.2517
0.11%
2%

6.2 Remarks

Difference between the values with the nodes n1, n719, n911, n1629, n1821 about 1.e-8.

6.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 7.74 seconds
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

7
Summary of the results

Two modelings give results whose only one value exceeds the fixed tolerance
initially. The maximum change is equal to 2.05%, and is thus not very higher than the fixed tolerance (2%). it
is located on the smallest value of temperature and for the weakest moment the T (starting of problem).

Two modelings, PLAN (TRIA6) and 3D (PENTA15) gives the same results, which is
normal since the grid and the degree of interpolation are identical.

A finer grid in the zone of the N1 node should improve quality of the results which are
regarded as acceptable taking into account modelings carried out.

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
V4.23.302 document

TTLP302 - Thermal transfer in a field Plan with geometrical singularity

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a problem plane 2D represented by two modelings, one planes, the other voluminal one.

The functionalities tested are as follows:
· plane thermal element,
· voluminal thermal element,
· transitory algorithm of thermics,
· geometrical singularity,
· limiting conditions: imposed temperature.

The interest of the test, in addition to the fact that it is an industrial case, lies in the taking into account of a singularity
geometrical in transitory thermal analysis.

1 *Problem of reference*

1.1 Geometry

Y
T= 0°
J
I
H
G
T=1000°
C
D
0.5
0.2
X
With
B
E
F
0.3
0.4
0.3

1.2 *Properties of material*

=
1. W/m°C
Thermal conductivity
CP = 1. J/m3 °C
Voluminal heat

1.3
Boundary conditions and loadings

· [AJ] imposed temperature T = 1000°C,
· [FG] imposed temperature T = 0°C,
· others with dimensions = 0.

1.4 Conditions
initial

X
T (X, y,)
0 = erfc (
) for T = 0.0005 S
2 T

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The reference solution is a numerical solution obtained by the finite element method [bib2] quoted in the reference [bib1]. This solution is based on a network of 168 square elements of 0.05m of dimensioned, with 200 steps of time (T = 0.0005 S).

2.2 Results of reference

Temperature at the points B C D E H and I at the moment T = 0.1s

2.3 Uncertainty on the solution

Unknown factor.

2.4 References bibliographical

[1]
J.C. Bruch Jr., G. Zyroloski, `Transient two-dimensional heat conduction problems solved by the finite element method', Int. J. num. Meth. Engng, flight 8, n°3, pp 481-494, 1974.
[2]
G.E. Bell, "A method for treating boundary singularities in time-dependent problems" TR/8, Dept. of Math., Brunel Univ. Uxbridge, Middlesex, 19 pp., 1972.

Author (S):
C. DURAND, E. SCREW, F. LEBOUVIER Clé
:
V4.23.302-A Page:
4/6

3 Modeling
With

3.1
Characteristics of modeling

PLAN (QUAD4)

y
J
I
H
G
Limiting conditions:
N42
N64
- dimensioned AJ: T = 1000°C
- dimensioned FG: T = 0°C
- dimensioned AB, BC, CD,
OF, EF, GJ = 0
N39
N61
C
D
N37
N59
X
With
B
E
F

3.2
Characteristics of the grid

A number of nodes:

82
A number of meshs and types: 60 QUAD4

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

AFFE_CHAR_THER_F
TEMP_IMPO

AFFE_CHAM_NO
SIZE
"TEMP_R"

THER_LINEAIRE
AFFE
NODE

TEMP_INIT
CHAM_NO

RECU_CHAMP
LIST_INST

INST

3.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 1.D-4] is T = 1.D-5
9 steps for [1.D-4, 1.D-3] are T = 1.D-4
9 steps for [1.D-3, 1.D-2] are T = 1.D-3
9 steps for [1.D-2, 1.D-1] are T = 1.D-2
Handbook of Validation

4
Results of modeling A

4.1 Values tested

Identification Reference
Aster
% difference
Tolerance
Temperature (°C)

T = 0.1 S

Points

B (N37)
787.
785.35
-0.210
2%
C (N39)
634.
631.74
-0.357
2%
D (N61)
86.
85.40
-0.696
2%
E (N59)
28.
27.80
-0.730
2%
H (N64)
119.
118.84
-0.136
2%
I (N42) 538.
536.97
-0.192
2%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 3.28 seconds
Handbook of Validation

5
Summary of the results

Modeling carried out (PLANE with meshs QUAD4) gives satisfactory results. The variation maximum is -0.73%, and it is located on the smallest value of reference.

The taking into account of the initial condition of type erfc (X (2t) was carried out correctly. It has need the use of order AFFE_CHAM_NO allowing to define a field of temperature initial of each node of the model.

Organization (S): EDF/IMA/MMN, Delta CAD

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
Document: V4.23.303

TTLP303 - Transfer of heat in a plate orthotropic: imposed temperatures

Summary:

This test results from the validation independent of version 3 in thermics.
Analyze:
Linear transitory thermics
Problem:
plane 2D
Functionalities tested:
· thermal element hull
· plane thermal element
· orthotropic material
· transitory algorithm of thermics
· limiting conditions: imposed temperatures
Interest of the test:
· orthotropic material
· analytical solution
A number of modelings:
· 1 modeling hull
· 1 plane modeling

---

1 Problem of reference

1.1 Geometry

y
D
C
To (X, y, 0) = -1.111°C
Ly = 6 m
X
With
B
Lx = 3 m

1.2
Properties of material

=
1.319 W/m °C
thermal conductivity along axis X
X

=
0.659 W/m °C
thermal conductivity along the axis y
y
C
1899.1 J/m3 °C
voluminal heat

1.3
Boundary conditions and loadings

Contour ABCD: T = -17.778°C

1.4 Conditions
initial

To (T = 0) = -1.111°C

V4.23.303-A Page:
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2
Reference solution
2.1
Method of calculation used for the reference solution

2
2
nx
jy
N2 2

J

y
T (X, y, T) =
With
X
sin
sin
exp

-

2
+
T/C
N

2

=1
=1
L
L
N
J
y
L
L

X

X
y

(
4 T

I)
5
5
where A
N
J
=
- 1 - 1 - 1 - 1 - 3 .
2
32
2

=
+
N
([ )] ([ )]
T
T
nj
I
O

9
9
Temperature in °C with T = 4320s
3.0
-17.7778 -17.5742 -17.3905
-17.2448
-17.1515
-17.1189
2.7
-17.7778 -17.5764 -17.3948
-17.2507
-17.1581

-17.1262
2.4
-17.7778 -17.5832 -17.4077
-17.2684
-17.1790
-17.1482
2.1
-17.7778 -17.5945 -17.4291
-17.2979
-17.2137
-17.1847
1.8
-17.7778 -17.6102 -17.4590
-17.3391
-17.2620
-17.2355
1.5
-17.7778 -17.6302 -17.4970
-17.3914
-17.3235
-17.3002
1.2
-17.7778 -17.6542 -17.5426
-17.4541
-17.3973
-17.3777
0.9
-17.7778 -17.6816 -17.5949
-17.5261
-17.4819
-17.4667
0.6
-17.7778 -17.7120 -17.6526
-17.6056
-17.5753
-17.5649
0.3
-17.7778 -17.7444 -17.7142
-17.6903
-17.6749
-17.6696
0.0
-17.7778 -17.7778 -17.7778

-17.7778
-17.7778
-17.7778
YÇ
XÆ
0.0
0.3
0.6
0.9
1.2
1.5
The values of reference are obtained with N = J = 1000

2.2
Results of reference

T = 4.320s (1.2hr): temperature at the following points:
· in X = 0.6: for y = 0.6, 1.5, 2.4, 3.0
· in X = 1.5: for y = 0.6, 1.5, 2.4, 3.0

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
J.C. Bruch Jr., G. Zyroloski, `Transient two-dimensional heat conduction problems solved by the finite element method', Int. J. num. Meth. Engng, flight 8, n°3, pp 481-494, 1974.

---

3 Modeling
With

3.1
Characteristics of modeling
HULL (TRIA6)
y
1.5 m
G
F
Limiting conditions
- dimensioned EF, FG: = 0
- dimensioned AE, AG: T =-17.778°C
Cutting:
- 5 elements in X
y
- 10 elements in y
3.0 m
X
With
E
3.2
Characteristics of the grid
A number of nodes:
231
A number of meshs and types: 100 TRIA6
3.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
THERMICS
HULL
ALL
[U4.22.01]
DEFI_MATERIAU
THER_ORTH
[U4.23.01]
AFFE_CARA_ELEM
HULL
[U4.24.01]
AFFE_CHAR_THER_F
TEMP_IMPO
[U4.25.02]
THER_LINEAIRE
TEMP_INIT

VALE
[U4.33.01]
CARA_ELEM
LIST_INST
RECU_CHAMP
INST
[U4.62.01]
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HI-75/98/040 - Ind A

4
Results of modeling A
4.1 Values
tested
Relative variation %
Absolute deviation
Identification
Reference
Aster
difference
tolerance
difference
tolerance
Temperature in °C
X = 0.6
T (y = 0.6)
-17.6526
1%
0.05
T (y = 1.5)

-17.4970
1%
0.05
T (y = 2.4)
-17.4077
1%
0.05
T (y = 3.0)
-17.3905
1%
0.05
X = 1.5
T (y = 0.6)
-17.5649
1%
0.05
T (y = 1.5)
-17.3002
1%
0.05
T (y = 2.4)
-17.1482
1%
0.06
T (y = 3.0)
-17.1189
1%
0.05

4.2 Parameters of execution

Version: 3.06
Machine: CRAY C90
System: 8.04 UNICOS
Obstruction memory: megawords
Time CPU To use: seconds

5 Modeling
B
5.1
Characteristics of modeling
HULL (TRIA3)

y
1.5 m
G
F
Limiting conditions
- dimensioned EF, FG: = 0
- dimensioned AE, AG: T = -17.778°C
Cutting:
- 5 elements in X
y
- 10 elements in y
3.0 m
X
With
E

5.2
Characteristics of the grid
A number of nodes:
66
A number of meshs and types: 100 TRIA3

5.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
THERMICS

HULL
ALL
[U4.22.01]
DEFI_MATERIAU
THER_ORTH
[U4.23.01]
AFFE_CARA_ELEM
HULL
[U4.24.01]
AFFE_CHAR_THER_F
TEMP_IMPO
[U4.25.02]
THER_LINEAIRE
TEMP_INIT
VALE
[U4.33.01]
CARA_ELEM
LIST_INST
RECU_CHAMP
INST
[U4.62.01]

6
Results of modeling B
6.1 Values
tested
Relative variation %
Absolute deviation

Identification
Reference
Aster
difference
tolerance
difference
tolerance
Temperature in °C
X = 0.6
T (y = 0.6)
-17.6526
1%
0.05
T (y = 1.5)
-17.4970
1%
0.05
T (y = 2.4)
-17.4077
1%
0.05
T (y = 3.0)
-17.3905
1%
0.05
X = 1.5
T (y = 0.6)
-17.5649
1%
0.05
T (y = 1.5)
-17.3002
1%
0.05
T (y = 2.4)
-17.1482
1%
0.06
T (y = 3.0)
-17.1189
1%
0.05

6.2 Parameters

of execution
Version: 3.06
Machine: CRAY C90
System: 8.04 UNICOS
Obstruction memory:
megawords
Time CPU To use: seconds
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HI-75/98/040 - Ind A

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7 Modeling
C
7.1
Characteristics of modeling
PLAN (QUAD9)
y
G
Limiting conditions
1.5 m
- dimensioned EF, FG: = 0
- dimensioned AE, AG: T = -17.778°C
F
N225
N231
N181
N187
Y
3. m
N115
N121

N49
X
N55
With
=15°
0.5
X
E

7.2

Characteristics of the grid

A number of nodes:
231
A number of meshs and types: 50 QUAD9

7.3 Functionalities
tested

Orders
Keys

AFFE_MODELE
THERMICS
PLAN
ALL
[U4.22.01]
DEFI_MATERIAU
THER_ORTH
[U4.23.01]
AFFE_CHAR_THER_F
TEMP_IMPO
[U4.25.02]
AFFE_CARA_ELEM
SOLID MASS
ANGL_REP
[U4.24.01]
THER_LINEAIRE
TEMP_INIT
VALE
[U4.33.01]
CARA_ELEM
LIST_INST
RECU_CHAMP
INST
[U4.62.01]

7.4 Remarks

The discretization in step of time is as follows:

240 steps for [0. , 4320.D0] is T = 18.D0

8
Results of modeling C
8.1 Values
tested
Relative variation %
Absolute deviation
Identification
Reference
Aster
difference
tolerance
difference
tolerance
Temperature in °C
X = 0.6
N49 (y = 0.6)
-17.6526
-17.6515
-0.006
1%
0.001
0.05
N115 (y = 1.5)
-17.4970
-17.4942
-0.016

1%
0.003
0.05
N181 (y = 2.4)
-17.4077
-17.4040
-0.021
1%
0.004
0.05
N225 (y = 3.0)
-17.3905
-17.3867
-0.022
1%
0.004
0.05
X = 1.5
T (y = 0.6)
-17.5649
-17.5627
-0.012
1%
0.002
0.05
T (y = 1.5)
-17.3002
-17.2952
-0.029
1%
0.005
0.05
T (y = 2.4)
-17.1482
-17.1418
-0.037
1%
0.006
0.06
T (y = 3.0)
-17.1189
-17.1123
-0.039

1%
0.007
0.05

8.2 Parameters of execution

Version: 4.02
Machine: CRAY C90
System: 8.04 UNICOS
Obstruction memory:
8 megawords
Time CPU To use: 20.6 seconds

9
Summary of the results

Two modelings HULL give results very far away from the reference solution, two anomalies software were emitted under numbers Al 96-144 et al. 96-178.
Modeling PLAN, carried out with meshs QUAD9, gives satisfactory results, the variation maximum obtained is 0.039%.

Date:
20/09/02
Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER Clé*
:
V4.23.304-A Page:
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Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
V4.23.304 document

TTLP304 - Transfer of heat in a plate orthotropic: imposed flows

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a problem plane 2D represented by a modeling (plane).

The functionalities tested are as follows:
· plane thermal element,
· orthotropic material,

· ***transitory algorithm of thermics,***
· ***limiting conditions: imposed flow.***

The interest of the test lies in the taking into account of an orthotropic material.

The results are compared with an analytical solution.

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
TTLP304 Transfer of heat in an orthotropic plate: imposed flows
Date:
20/09/02
Author (S):
C. DURAND, *E. SCREW, F. LEBOUVIER Clé*
:
V4.23.304-A Page:
2/6

1
Problem of reference

1.1 Geometry

y
Lx = 2.7 m
D
C
L
T
y = 5.4 m
O (X, y, 0) = -1.111°C
X
With
B

1.2
Properties of material

X = 2.638 W/m °C thermal conductivity along axis X
y = 0.633 W/m °C thermal conductivity along the axis y
C 1899.1
Voluminal J/m3 °C heat

1.3
Boundary conditions and loadings

Contour [AB], [BC], [CD]: T = -17.778°C
Side [AD]: = 0

1.4 Conditions
initial

T (T = 0) = -1.111°C

2
Reference solution

2.1

Method of calculation used for the reference solution

(2n 1) X
jy
(2n 1) 2 2

j2 2

T (X, y, T) =
-
B
X
y
cos
sin
exp -
-

+
T
N

2
2

2
4
N =1
J 1
L
Ly
=

L
L
X
X
y

8 (T)
5
2
5
where B
I
N +
J
=
(- 1)
(- 1) - 1 - 3 2
=
+ 32

N
2
[
]

T
T
J (2 N - 1)
9
I
O
9

Temperature in °F with T =1.2 hr (4320s)

2.7	15,6151	15,6480	15,7455	15,9049	16,1211	16,3876	16,6964	17,0381	17,4022	17,7778
2.4	15,6462	15,6786	15,7748	15,9318	16,1449	16,4076	16,7120	17,0487	17,4076	17,7778
2.1	15,7391	15,7700	15,8620	16,0122	16,2160	16,4673	16,7584	17,0805	17,4238	17,7778
1.8	15,8921	15,9208	16,0058	16,1447	16,3333	16,5657	16,8349	17,1328	17,4503	17,7778
1.5	16,1025	16,1279	16,2035	16,3269	16,4944	16,7009	16,9401	17,2048	17,4869	17,7778
1.2	16,3655	16,3869	16,4506	16,5547	16,6959	16,8700	17,0716	17,2947	17,5325	17,7778
0.9	16,6744	16,6911	16,7409	16,8222	16,9325	17,0685	17,2261	17,4004	17,5862	17,7778
0.6	17,0203	17,0318	17,0660	17,1218	17,1975	17,2909	17,3991	17,5187	17,6462	17,7778
0.3	17,3923	17,3982	17,4156	17,4440	17,4825	17,5300	17,5851	17,6459	17,7108	17,7778
0.0	17,7778	17,7778	17,7778	17,7778	17,7778	17,7778	17,7778	17,7778	17,7778	17,7778

Y

X
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7

The values of reference are obtained with n=j=1000

2.2 Results of reference

T = 1.2hr (4320s): temperature at the following points:

· in X = 0.0: for y = 0.6, 1.5, 2.7,
· in X = 0.9: for y = 0.6, 1.5, 2.7,
· in X = 1.8: for y = 0.6, 1.5, 2.7.

2.3 Uncertainty on the solution

Analytical solution.

2.4 References bibliographical

[1]
J.C. Bruch Jr., G. Zyroloski, `Transient two-dimensional heat conduction problems solved by the finite element method', Int. J. num. Meth. Engng, flight 8, n°3, pp 481-494, 1974.

Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

---

3 Modeling With

3.1 Characteristics of modeling

PLAN (QUAD4, TRIA3)

y
2.7 m
F
E
Limiting conditions
- dimensioned AB, BH, HE: T=-1.111°C
TRIA3
- dimensioned EF, FG, GA: = 0
G
H
Cutting:
2.7 m
- AB, GH, FE 9 elements
- AG, BH 5 elements
QUAD4
- GF, HE 4 elements
1.5m

X
With
B

3.2
Characteristics of the grid

A number of nodes:
100
A number of meshs and types: 117 (45 QUAD4, 72 TRIA3)

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_ORTH

AFFE_CHAR_THER_F
TEMP_IMPO

AFFE_CARA_ELEM
SOLID MASS

THER_LINEAIRE
TEMP_INIT
VALE

CARA_ELEM

LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The discretization in step of time is as follows:

10 steps for [0. , 5.00D0] is T = 0.5
9 steps for [5.00D0, 5.00D1] are T = 5.
9 steps for [5.00D1, 5.00D2] are T = 50.
38 steps for [5.00D2, 4.30D3] are T = 100.
1 step for [4.30D3, 4.32D3] is T = 20.

4
Results of modeling A

4.1 Values
tested

Relative variation %
Absolute deviation
Identification Reference Aster difference tolerance difference
tolerance
Temperature
in
°F

X
=
0.0

N3 (y = 0.6)
-17.0203
-17.0146 -0.033
1% 0.006 0.05
N6 (y = 1.5)
-16.1025
-16.0957 -0.042
1% 0.007 0.05
N10 (y = 2.7)
-15.6151
-15.5784 -0.235
1% 0.037 0.05

X = 0.9

N33 (y = 0.6)
-17.1218
-17.1167 0.029 1%
0.005
0.05
N36 (y = 1.5)
-16.3269
-16.3127 -0.087 1%
0.014
0.05

N40 (y = 2.7)
-15.9049
-15.8905 -0.091
1% 0.014 0.05

X = 1.8

N63 (y = 0.6)
-17.3991
-17.3961 -0.017
1% 0.003 0.05
N66 (y = 1.5)
-16.9401
-16.9297 -0.061
1% 0.010 0.05
N70 (y = 2.7)
-16.6964
-16.6930 -0.020
1% 0.003 0.05

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 4.11 seconds
Handbook of Validation
V4.23 booklet: Transitory thermics of the plane systems
HT-66/02/001/A

---

5 Summary of the results

The results obtained are satisfactory, the maximum change obtained is 0.235%.

For the points of observation selected, the variations are more important with the nodes belonging to meshs TRIA3.

Titrate:
TTLV01 Sphere: heat transfer by convection

Date:
20/09/02

Author (S):
C. DURAND, *E. SCREW, F. LEBOUVIER Clé*

:
V4.25.001-A Page:
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Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
V4.25.001 document

TTLV01 - Sphere: heat transfer by convection

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a three-dimensional problem represented by four modelings, one voluminal, the three others axisymmetric.

The functionalities tested are as follows:
· voluminal thermal elements,
· axisymmetric thermal elements,
· transitory algorithm of thermics,
· limiting conditions: convection.

The results are compared with those provided by VPCS.

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V4.25 booklet: Transitory thermics of the voluminal structures
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1
Problem of reference

1.1 Geometry

D
D = 0.2m
R
O
He, Te

1.2
Properties of material

=
48.822 Thermal W/m °C conductivity
CP
=
669.0 J/kg °C specific heat

7200 kg/m3 mass
voluminal

1.3
Boundary conditions and loadings

Convection on external surface with air:

· He = 232.5 W/m2 °C,
· Te = 1000 °C.

1.4 Conditions
initial

Initial temperature: T (T = 0) = 20 °C

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is that given in card TTLV01/89 of guide VPCS.

· calculation of the coefficients,
· reading on abacus of Gurney-Lurie.

2.2
Results of reference

Temperature on the surface and in the center of the sphere for T ranging between 400 S and 2400 S

2.3
Uncertainty on the solution

< 2%
In 600 second old lower part, uncertainty increases (difficult reading of the abacuses).

2.4 References
bibliographical

[1]
Guide validation of the software packages of structural analysis. French company of Mechanics, AFNOR 1990 ISBN 2-12-486611-7
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

3D (PENTA6 and TETRA4)

Limiting conditions:
C
- faces OAB, OAD,
ODC, OBC
= 0
30°
- face ABCD
H = 232.5 W/m ² °C
H
Text =1000°C
D
y
Z
F
G
Not
Node
O
O
N291
B
E
With
N292
15°
B
N345
C
N234
22,5°
D
N179
X
E
N254
30°
F
N133
G
N5

With
H
N198

3.2
Characteristics of the grid

A number of nodes:
361
A number of meshs and types: 450 PENTA6, 50 TETRA4 (and 50 TRIA3)

3.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
THERMICS

3D

AFFE_CHAR_THER_F
EXCHANGE

THER_LINEAIRE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

3.4 Remarks

One takes, for voluminal heat, CP = CP = 4816800.0 J/m3 °C.

The condition limits = 0. is implicit on the free edges.

Discretization of time: (36 intervals)

of
0 to 100 seconds: 8 intervals of 12.5 S.
of
100 to 300 seconds: 8 intervals of 25.0 S.
of
300 to 700 seconds: 8 intervals of 50.0 S.
of
700 to 1400 seconds: 7 intervals of 100.0 S.
of
1400 to 2400 seconds: 5 intervals of 200.0 S.

---

4 Results of modeling A

4.1 Values tested

Identification Reference
Aster
Relative variation (%)
Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures:

In the center (O: N291)
T (°C)

T = 400 S
334
340.56
1.965%
5.%
6.56
20.
T = 600 S
500
493.15
-1.371%
5.%
-6.85
20.
T = 800 S
618
610.27
-1.252%
5.%
-7.73
20.
T = 1000 S
706
700.18
-0.824%
5.%
-5.82

20.
T = 1200 S
774
769.35
-0.600%
5.%
-4.65
20.
T = 1400 S
828
822.57
-0.656%
5.%
-5.43
20.
T = 1600 S
872
863.33
-0.994%
5.%
-8.67
20.
T = 1800 S
902
894.73
-0.806%
5.%
-7.27
20.
T = 2000 S
923
918.91
-0.443%
5.%
-4.09
20.
T = 2200 S
942
937.54
-0.474%
5.%
-4.46
20.

T = 2400 S
956
951.89
-0.430%
5.%
-4.11
20.

On the surface (a: N292)
T (°C)

T = 400 S
461
474.82
2.998%
5.%
13.8
20.
T = 600 S
608
596.37
-1.913%
5.%
-11.6
20.
T = 800 S
696
689.64
-0.914%
5.%
-6.36
20.
T = 1000 S
774
761.24

-1.648%
5.%
-12.8
20.
T = 1200 S
828
816.33
-1.410%
5.%
-11.7
20.
T = 1400 S
868
858.70
-1.071%
5.%
-9.30
20.
T = 1600 S
902
891.16
-1.202%
5.%
-10.8
20.
T = 1800 S
923
916.17
-0.741%
5.%
-6.83
20.
T = 2000 S
942
935.42
-0.698%
5.%
-6.58
20.
T = 2200 S
956
950.26
-0.601%

5.%
-5.74
20.
T = 2400 S
962
961.69
-0.033%
5.%
-0.314
20.

4.2 Remarks

The relative variations are higher than 2% for T = 400. S, inferiors for T 600. S

On the surface, the results calculated by Code_Aster are symmetrical compared to the diagonal AC. The maximum variation observed, into relative as in absolute, is 0.29% is 1,4°C, between point A (N291) and the point D (N179) at the moment T = 400. S. These variations decrease in absolute value when time increase.

4.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 5.76 seconds
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

---

5 Modeling B

5.1 Characteristics of modeling

AXIS (TRIA3, QUAD4)

Limiting conditions:
- dimensioned AB, AC = 0
- dimensioned BC
H = 232.5 W/m ² °C
N61
C
30°
Text =1000°C
N60
N59
(Z)
y
Not
Node
N58
With
N1
N57
B
N56
N56
C
N61
B
15°

X
N1
With
(R)

5.2
Characteristics of the grid

A number of nodes:
61
A number of meshs and types: 45 QUAD4, 5 TRIA3 (and 5 SEG2)

5.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
THERMICS

AXIS

AFFE_CHAR_THER
EXCHANGE

THER_LINEAIRE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

5.4 Remarks

One takes, for voluminal heat, CP = CP = 4816800.0 J/m3 °C.

The condition limits = 0. is implicit on the free edges.

Discretization of time: (36 intervals)

of
0 to 100 seconds: 8 intervals of 12.5 S.
of
100 to 300 seconds: 8 intervals of 25.0 S.
of
300 to 700 seconds: 8 intervals of 50.0 S.
of
700 to 1400 seconds: 7 intervals of 100.0 S.
of
1400 to 2400 seconds: 5 intervals of 200.0 S.

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster
Relative variation (%)
Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures:

In center (a: N1)
T (°C)

T = 400 S
334
339.95
1.780%
5.%
5.95
20.
T = 600 S
500
492.47
-1.506%
5.%
-7.53
20.
T = 800 S
618
609.59
-1.361%
5.%
-8.41
20.
T = 1000 S
706
699.55
-0.914%
5.%
-6.45

20.
T = 1200 S
774
768.78
-0.675%
5.%
-5.22
20.
T = 1400 S
828
822.05
-0.718%
5.%
-5.95
20.
T = 1600 S
872
862.88
-1.046%
5.%
-9.12
20.
T = 1800 S
902
894.34
-0.849%
5.%
-7.66
20.
T = 2000 S
923
918.58
-0.479%
5.%
-4.42
20.
T = 2200 S
942
937.26
-0.503%
5.%
-4.74
20.

T = 2400 S
956
951.65
-0.455%
5.%
-4.35
20.

On the surface (NR: N56)
T (°C)

T = 400 S
461
475.14
3.068%
5.%
14.1
20.
T = 600 S
608
596.46
-1.899%
5.%
-11.5
20.
T = 800 S
696
689.58
-0.922%
5.%
-6.42
20.
T = 1000 S
774
761.11

-1.666%
5.%
-12.9
20.
T = 1200 S
828
816.15
-1.431%
5.%
-11.8
20.
T = 1400 S
868
858.51
-1.093%
5.%
-9.49
20.
T = 1600 S
902
890.97
-1.223%
5.%
-11.0
20.
T = 1800 S
923
915.99
-0.760%
5.%
-7.01
20.
T = 2000 S
942
935.26
-0.715%
5.%
-6.74
20.
T = 2200 S
956
950.11
-0.616%

5.%
-5.89
20.
T = 2400 S
962
961.56
-0.046%
5.% -0.441
20.

6.2 Remarks

The relative variations are higher than 2% for T = 400. S, inferiors for T 600. S

The maximum variation observed between two nodes on surface, into relative as in absolute, is 0.012%
that is to say 0,055°C, between the point B (N56) and the point C (N61) at the moment T = 400. S. These variations decrease in
absolute value when time increases.

6.3 Parameters
of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 4.03 seconds
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
TTLV01 Sphere: heat transfer by convection

7 Modeling
C

7.1
Characteristics of modeling

AXIS (TRIA6, QUAD8)

Limiting conditions:
- dimensioned AB, AC = 0
- dimensioned BC
H = 232.5 W/m ² °C
Text =1000°C
C
N171
N170
30°
N169
Not
Node
N168
With
N1
(Z)
y
N167
N166
B
N163
N165
C
N171
N158
N164
N156

N163
B
N1
15°
X
With
(R)

7.2
Characteristics of the grid

A number of nodes:
171
A number of meshs and types: 45 QUAD8, 5 TRIA6 (and 5 SEG3)

7.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
THERMICS

AXIS

AFFE_CHAR_THER
EXCHANGE

THER_LINEAIRE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

7.4 Remarks

One takes, for voluminal heat, CP = CP = 4816800.0 J/m3 °C.

The condition limits = 0. is implicit on the free edges.

Discretization of time: (36 intervals)

of
0 to 100 seconds: 8 intervals of 12.5 S.
of
100 to 300 seconds: 8 intervals of 25.0 S.
of
300 to 700 seconds: 8 intervals of 50.0 S.
of
700 to 1400 seconds: 7 intervals of 100.0 S.
of
1400 to 2400 seconds: 5 intervals of 200.0 S.

8
Results of modeling C

8.1 Values
tested

Identification Reference
Aster
Relative variation (%)

Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures:

In center (a: N1)
T (°C)

T = 400 S
334
341.10
2.126%
5.%
7.10
20.
T = 600 S
500
493.15
-1.370%
5.%
-6.85
20.
T = 800 S
618
609.65
-1.303%
5.%
-8.05
20.
T = 1000 S
706
699.70

-0.893%
5.%
-6.30
20.
T = 1200 S
774
768.80
-0.672%
5.%
-5.20
20.
T = 1400 S
828
822.00
-0.725%
5.%
-6.00
20.
T = 1600 S
872
862.78
-1.058%
5.%
-9.22
20.
T = 1800 S
902
894.22
-0.863%
5.%
-7.78
20.
T = 2000 S
923
918.45
-0.493%
5.%
-4.55
20.
T = 2200 S
942
937.14
-0.516%

5.%
-4.86
20.
T = 2400 S
956
951.54
-0.467%
5.%
-4.46
20.

On the surface (NR: N163)
T (°C)

T = 400 S
461
474.78
2.989%
5.%
13.8
20.
T = 600 S
608
596.02
-1.971%
5.%
-12.0
20.
T = 800 S
696
689.12
-0.989%
5.% -6.88
20.
T = 1000 S

774
760.65
-1.725%
5.%
-13.3
20.
T = 1200 S
828
815.72
-1.483%
5.%
-12.3
20.
T = 1400 S
868
858.12
-1.138%
5.% -9.88
20.
T = 1600 S
902
890.63
-1.261%
5.%
-11.4
20.
T = 1800 S
923
915.69
-0.792%
5.%
-7.31
20.
T = 2000 S
942
935.00
-0.743%
5.%
-7.00
20.
T = 2200 S
956
949.90

-0.639%
5.%
-6.10
20.
T = 2400 S
962
961.37
-0.065%
5.%
-0.625
20.

8.2 Remarks

The relative variations are higher than 2% for T = 400. S, inferiors for T 600. S

Variations observed between the results calculated by Code_Aster on two nodes of surface external, are lower than 0,011°C (either 0.002%).

8.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 4.50 seconds
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

---

9 Modeling D

9.1 Characteristics of modeling

AXIS (TRIA6, QUAD9)

Limiting conditions:
- dimensioned AB, AC = 0
- dimensioned BC
H = 232.5 W/m ² °C
Text =1000°C
C
N216
N215
30°
N214
Not
Node
N213
With
N1
(Z)
y
N212
N211

B
N207
N210
C
N216
N209
N208
N65
N207
B
N1
15°
X
With
(R)

9.2 Characteristics of the grid

A number of nodes:
216
A number of meshs and types: 45 QUAD9, 5 TRIA6 (and 5 SEG3)

9.3 Functionalities tested

Orders

AFFE_MODELE
AFFE
THERMICS

AXIS

AFFE_CHAR_THER
EXCHANGE

THER_LINEAIRE
TEMP_INIT
VALE

INCREMENT
LIST_INST

RECU_CHAMP
INST

9.4 Remarks

One takes, for voluminal heat, CP = CP = 4816800.0 J/m3 °C.

The condition limits = 0. is implicit on the free edges.

Discretization of time: (36 intervals)

of
0 to 100 seconds: 8 intervals of 12.5 S.
of
100 to 300 seconds: 8 intervals of 25.0 S.
of
300 to 700 seconds: 8 intervals of 50.0 S.
of
700 to 1400 seconds: 7 intervals of 100.0 S.
of
1400 to 2400 seconds: 5 intervals of 200.0 S.

---

10 Results of modeling D

10.1 Values tested

Identification Reference
Aster
Relative variation (%)
Absolute deviation (°C)

difference
tolerance
difference
tolerance
Temperatures:

In center (a: N1)
T (°C)

T = 400 S
334
341.10
2.125%
5.%
7.10
20.
T = 600 S
500
493.14
-1.371%
5.%
-6.86
20.
T = 800 S
618

609.95
-1.303%
5.%
-8.05
20.
T = 1000 S
706
699.70
-0.893%
5.%
-6.30
20.
T = 1200 S
774
768.79
-0.673%
5.%
-5.21
20.
T = 1400 S
828
821.99
-0.726%
5.%
-6.01
20.
T = 1600 S
872
862.78
-1.058%
5.%
-9.22
20.
T = 1800 S
902
894.22
-0.863%
5.%
-7.78
20.
T = 2000 S
923
918.45

-0.493%
5.%
-4.55
20.
T = 2200 S
942
937.13
-0.516%
5.%
-4.87
20.
T = 2400 S
956
951.54
-0.467%
5.%
-4.46
20.

On the surface (NR: N207)
T (°C)

T = 400 S
461
474.78
2.989%
5.%
13.8
20.
T = 600 S
608
596.01
-1.971%
5.%
-12.0

20.
T = 800 S
696
689.12
-0.989%
5.% -6.88
20.
T = 1000 S
774
760.65
-1.725%
5.%
-13.4
20.
T = 1200 S
828
815.72
-1.483%
5.%
-12.3
20.
T = 1400 S
868
858.12
-1.138%
5.%
-9.88
20.
T = 1600 S
902
890.63
-1.261%
5.%
-11.4
20.
T = 1800 S
923
915.69
-0.792%
5.%
-7.31
20.
T = 2000 S

942
935.00
-0.743%
5.%
-7.00
20.
T = 2200 S
956
949.89
-0.639%
5.%
-6.11
20.
T = 2400 S
962
961.37
-0.065%
5.%
-0.626
20.

10.2 Remarks

The relative variations are higher than 2% for T = 400. S, inferiors for T 600. S

The results calculated by Code_Aster on the nodes of external surface are almost identical (maximum: 5.105 °C is 107 into relative).

10.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 4.34 seconds
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

---

11 Summary of the results

The results obtained are satisfactory. The maximum change obtained (3%) is on surface external of the sphere for the weakest moment the T. This variation decreases when the moment T increases.

Whatever the modeling, the results are increasingly more precise in the center than on the surface external of the sphere.

With identical cutting the results between the linear and quadratic elements are appreciably them same.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
Document: V4.25.100
TTLV100 - Thermal shock in a pipe with
condition of exchange

Summary:
This test of transitory linear thermics consists in imposing a cold thermal shock on a hollow roll presumedly infinite using a limiting condition of exchange.
The shock is modelled by a linear slope T = 269°C into 12 S.
The problem is dealt with into axisymmetric.
The reference solution is obtained on a fine network.
The test is carried out on 2 modelings: (TRIA3, QUAD4) and (TRIA6, QUAD9).
One tests the algorithm of linear thermics transitory when the matrix of mass is diagonalisée (modeling
AXIS_DIAG with `'mass lumping '').

1
Problem of reference
1.1 Geometry

Z
IH
With
B
R
Re
M1 m2
Z

IH = 417 mm
Re = 496 mm
R (A) = 417 mm
R (B) = 496 mm
R (M1) = 443.43 mm
R (m2) = 469.67 mm
1.2
Material properties
= 19.97 W/m °C
CP = 4.89488 106 J/m3 °C
1.3
Boundary conditions and loadings
T
Exchange

= (
-

H T
T (R, T))
N
ext.
R =ri
2
with
H =
.
40000 W/m ° C
T

( )
With
0 =
.
289 ° C
ext.
T =
T () A 12 =.
20 ° C
ext.
T =
S
1.4 Conditions
initial

T (R, 0) = 289°C for any R
Discretization in time (T):
12
not for
[0.
,
12.]
that is to say
T = 1. S
2
not for
[12.
,
20.]
that is to say
T = 4. S
4
not for
[20.
,
100.]
that is to say
T = 20. S
2
not for
[100.
,
200.]
that is to say
T = 50. S
2
not for
[200.
,
400.]
that is to say
T = 100. S
8
not for
[400.
,
2000.]
that is to say

T = 200. S

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The reference solution is obtained on a fine network comprising 99 quadratic elements QUAD8 in the thickness without option of matrix of diagonal thermal mass.

2.2 Results of reference

Temperatures at the points M1 (R = 443.33) and m2 (R = 469.67),
and at various moments (T = 12. , 100. , 600. and 2000.).

---

3 Modeling
With
3.1
Characteristics of modeling
TRIA3, QUAD4
The infinite cylinder being supposed, one nets only one section height H = 40 mm with 2 layers elements.
M'1
M'2
D
C
Limiting conditions

on [AB], [BC] and [CD]: null flow

H
on [AD]: exchange H, Text
Text
With
B
M1
M2
289 °C
20°C
T
0
12 S
Initial conditions
points
nodes
R
Z
T = 289 °C

M1 N10
443.33 0.0
M2 N5
469.67
0.0
M'1
N11
443.33 40.
M'2
N7

469.67
40.
3.2
Characteristics of the grid
A number of nodes: 12
A number of meshs and types: 3 QUAD4, 6 TRIA6
3.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
MODELING
AXIS_DIAG
[U4.22.01]
AFFE_CHAR_THER_F
EXCHANGE
[U4.25.02]
THER_LINEAIRE
[U4.62.01]

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference

M1 (R = 443.33)
T = 12.
288.64
282.63
2.08
T = 20.
202.76
199.84
1.44
T = 600.
93.027
92.821
0.22
T = 2000.
29.419
29.865
+1.51
M2 (R = 469.67)
T = 12.
289.00
288.84
0.06
T = 20.
275.04
268.63
2.32
T = 600.
143.00
142.74
0.18
T = 2000.
35.858
36.629
+2.15
M'1 (R = 443.33)
T = 12.
288.64
283.09
1.92
T = 20.
202.76
206.66
+1.92

T = 600.
93.027
93.731
+0.76
T = 2000.
29.419
29.988
+1.93
M'2 (R = 469.67)
T = 12.
289.00
288.82
0.06
T = 20.
275.04
267.66
2.68
T = 600.
143.00
141.57
1.00
T = 2000.
35.858
36.470
+1.71

4.2 Parameters of execution

Version: 4.01.12
Machine: CRAY C98
System: UNICOS
Obstruction memory: 8 megawords
Time CPU To use: 7.6 seconds

---

5 Modeling

B

5.1

Characteristics of modeling

TRIA6, QUAD9

The infinite cylinder being supposed, one nets only one section height H = 40 mm with 2 layers elements.

M'1
M'2
D
C

Limiting conditions

on [AB], [BC] and [CD]: null flow

H
on [AD]: exchange H, Text
Text
With
B
M1
M
289 °C
2
20°C
T
0
12 S

Initial conditions

points
nodes
R
Z
T = 289 °C

M1 N25
443.33 0.0
M2 N9

469.67
0.0
M'1
N28
443.33 40.
M'2
N1
469.67
40.
5.2
Characteristics of the grid
A number of nodes: 35
A number of meshs and types: 3 QUAD9, 6 TRIA6
5.3 Functionalities
tested
Orders
Keys
CREA_MAILLAGE
MODI_MAILLE
OPTION:
"QUAD8_9"
[U4.12.06]
AFFE_MODELE
MODELING
AXIS_DIAG
[U4.22.01]
AFFE_CHAR_THER_F
EXCHANGE
[U4.25.02]
THER_LINEAIRE
[U4.62.01]
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HI-75/98/040 - Ind A

Code_Aster ®
Version
4.0
Titrate:
Thermal TTLV100 Shock in a pipe with condition of exchange
Date: 01/12/98
Author (S)
:

6
Results of modeling B

6.1 Values
tested

Identification	*Reference*	*Aster*	*% difference*
M1 (R = 443.33)			
T = 12.	*288.64*	*286.80*	*0.63*
T = 20.	*202.76*	*202.25*	*0.25*
T = 600.	*93.027*	*92.955*	*0.08*
T = 2000.	*29.419*	*29.524*	*+0.36*
M2 (R = 469.67)			
T = 12.	*289.00*	*288.99*	*+0.00*
T = 20.	*275.04*	*273.35*	*0.61*
T = 600.	*143.00*	*142.99*	*0.00*
T = 2000.			

35.858
36.050
+0.54
M'1 (R = 443.33)
T = 12.
288.64
287.13
0.52
T = 20.
202.76
205.35
+1.28
T = 600.
93.027
93.378
+0.38
T = 2000.
29.419
29.580
+0.55
M'2 (R = 469.67)
T = 12.
289.00
288.99
+0.00
T = 20.
275.04
272.65
0.87
T = 600.
143.00
142.39
0.43
T = 2000.
35.858
35.972
+0.32

6.2 Parameters of execution

Version: 4.01.12
Machine: CRAY C98
System: UNICOS
Obstruction memory:

8 megawords
Time CPU To use: 8.0 seconds
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HI-75/98/040 - Ind A

---

7 Summary of the results

Modeling "AXIS_DIAG" gives rather satisfactory results. Although grid
comprise that 3 elements in the thickness, the variation on the temperatures remains lower than 2.7%.
In spite of the violence of the thermal shock, the diagonalisation of the matrix of mass makes it possible to obtain one
solution in temperature which does not oscillate during the transient.

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
V4.25.300 document

TTLV300 - Parallelepiped subjected to a density of flow on its faces

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a voluminal problem represented by a modeling 3D.

The functionalities tested are as follows:
· voluminal thermal element,
· transitory algorithm of thermics,
· limiting conditions: imposed flow.

The results are compared with a three-dimensional analytical solution.

Titrate:
TTLV300 Parallelepiped subjected to a density flux on its faces
Date:

1
Problem of reference

1.1 Geometry

Z
Dimensions of the parallelepiped: 2m X 3.2m X 4m

- L1 = 1.0 m
- L2 = 1.6 m
- L3 = 2.0 m
L2

Not O (0. , 0. , 0.)
X
C O
Not H (0.5, 0.8, 1.0)
Not C (1.0, 1.6, 2.0)
H
L3
Y
L1

1.2
Properties of material

=
1. W/m °C
thermal conductivity
CP
=
1. J/kg °C
specific heat

1.
kg/m3 mass
voluminal

1.3
Boundary conditions and loadings

Flow imposed on the 6 faces Q = 0.5 W/m2 = qw

1.4 Conditions
initial

T (T = 0) = 1°C = T0

2
Reference solution

2.1
Method of calculation used for the reference solution

.t
T (X, y, Z, T) = T0 + 2qw
(A + B + C)

with:

(2m -)
1 L1 + X
(2m -)
1 L1 - X
With = i.erfc
+ i.erfc

=0
2 .t

2 .t

m

(2m -)
1 L2 + y
(2m -)
1 L2 - y
B = i.erfc
+ i.erfc

=0
2 .t

2 .t

m

(2m -)
1 L
Z
(2m -)

3 +

1 L - Z
C = i.erfc
+ i.erfc
3

=
2
.t

2
.t

m 0

= .cp

The values of reference are obtained with m = 1000.

2.2
Results of reference

Temperature at the points: O (0,0,0), H (0.5, 0.8, 1.) and C (1. , 1.6, 2.)

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
M.J Chang, L.C Chow, W.S Chang, “Improved alternating direction implicit for solving transient three dimensional heat diffusion problems ", Numerical Heat Transfer, flight 19, pp 69-84, 1991.
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures

HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

3D (HEXA8, PENTA6)

Z
Modeling 1/8 of the parallelepiped
G
F
Grid:
- 6 elements according to X
L2
- 8 elements following y
- 10 elements according to Z
Limiting conditions:
D
C
- faces [ABCD], [BEFC], [DCFG]: qw = 0.5
H
- faces [ABEO], [AOGD], [OEFG]:
E X
= 0.
L3
O

3
L 2
Points
X
y
Z
Node
O
0.00
0.00
0.00
N2
H
0.50
0.8
1.00
N409
C
1.00
1.6
2.00
N814
With
B
L
y
1

3.2
Characteristics of the grid

A number of nodes:
819
A number of meshs and types: 288 HEXA8, 576 PENTA6 (168 QUAD4, 96 TRIA3)

3.3 Functionalities
tested

Orders

AFFE_MODELE

THERMICS

3D

AFFE_CHAR_THER
FLUX_REP

THER_LINEAIRE
TEMP_INIT
VALE

LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The condition limits = 0. is implicit on the free edges.

Discretization of time: 36 intervals, between 0 and 10 seconds (of 0.005 S with 1.s by interval).

4
Results of modeling A

4.1 Values

tested

Identification
Reference
Aster %
difference
Tolerance
Not O

(N2) T = 0.05 S
1.0001
1.00000443
-0.010
1%
T = 0.1 S
1.00398
1.003172
-0.080
1%
T = 0.2 S
1.03331
1.03127
-0.198
1%
T = 0.3 S
1.08533
1.08227
-0.282
1%
T = 0.5 S
1.23086
1.2266
-0.345
1%
T = 1. S
1.69979
1.6945
-0.311
1%
T = 5. S
5.9292

5.9234
-0.098
1%
T = 10. S
11.242
11.236
-0.054
1%

Not H

(N409) T = 0.05 S
1.0083
1.006472
-0.181
1%
T = 0.1 S
1.03819
1.03573
-0.237
1%
T = 0.2 S
1.12556
1.1229
-0.235
1%
T = 0.3 S
1.22594
1.2233
-0.217
1%
T = 0.5 S
1.43580
1.4331
-0.188
1%
T = 1. S
1.96667

1.9639
-0.140
1%
T = 5. S
6.2167
6.2139
-0.045
1%
T = 10. S
11.529
11.526
-0.023
1%

Not C

(N814) T = 0.05 S
1.3785
1.3726
-0.429
1%
T = 0.1 S
1.5352
1.5308
-0.290
1%
T = 0.2 S
1.7572
1.7536
-0.206
1%
T = 0.3 S
1.9295
1.9261
-0.176
1%
T = 0.5 S
2.2142

2.2110
-0.146
1%
T = 1. S
2.8085
2.8054
-0.112
1%
T = 5. S
7.0792
7.0762
-0.043
1%
T = 10. S
12.392
12.389
-0.027
1%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 7.07 seconds

5
Summary of the results

The results obtained are satisfactory. The maximum change (0.43%), is located on external surface parallelepiped (Point C) at the moment T weakest. At the end of 10 S, this variation decreases, the maximum
is then of 0.054% (not O: center parallelepiped).

This test made it possible to test in linear transient modeling 3D with meshs HEXA8 and PENTA6.

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
V4.25.301 document

TTLV301 - Parallelepiped subjected to one temperature imposed on its faces

Summary:

This test results from the validation independent of version 3 in linear transitory thermics.

It is about a voluminal problem represented by only one modeling (3D).

The functionalities tested are as follows:
· voluminal thermal element,
· transitory algorithm of thermics,
· limiting conditions: imposed temperature.

The results are compared with an analytical solution.

2/6

1
Problem of reference

1.1 Geometry

Z
Dimensions of the parallelepiped: 2m X 3.2m X 4m
- L1 = 1.0 m
- L
L2
2 = 1.6 m
- L3 = 2.0 m
O
X
Not O (0. , 0. , 0.)
H
Not H (0.5, 0.8, 1.0)
L3
Y
L1

1.2
Properties of material

=
1. W/m °C
thermal conductivity
CP
=
1. J/kg °C
specific heat

1.
kg/m3 mass
voluminal

1.3
Boundary conditions and loadings

Temperature imposed on the 6 faces T = 2 °C = Tw

1.4 Conditions
initial

T (T = 0) = 1°C = To

2
Reference solution

2.1
Method of calculation used for the reference solution

(2m
2
-)
1 X

(2n -) 1 y

(2l -)
1 Z

T (X, y, Z, T) = T + has
exp (-
.t

W
nml
mnl
) .cos
cos
cos

2L1

m=1 n=1 l=1

2L2

2L3
(
64 T0 - Tw)
(2m -)
1
(2n -)
1
(2l -)
1
amnl = 3
(
sin
sin
sin
2m -)
1 (2n -)
1 (2l -)
1

2

2

2

2
2
2
m

N

L

2
(2 -) 1
(2 -) 1
(2 -) 1
mnl =
+
+

2L
2L
2

1

2

3
L

= .cp

The values of reference are obtained with m = N = L = 100.

2.2
Results of reference

Temperature at the points: O (0,0,0) and H (0.5, 0.8, 1.)

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
M.J Chang, L.C Chow, W.S Chang, “Improved alternating direction implicit for solving transient three dimensional heat diffusion problems ", Numerical Heat Transfer, flight 19, pp 69-84, 1991.
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

3D (HEXA27)

Z
Modeling 1/8 of the parallelepiped
G
F
Grid:
- 5 elements according to X
L2
- 8 elements following y
- 10 elements according to Z
Limiting conditions:
D
C
- faces [ABCD], [BEFC], [DCFG]: T = 2°C
- faces [ABEO], [AOGD], [OEFG]: = 0.
H
E X
L3
O
Points
X
y
Z

Node
O
0.00
0.00
0.00
N5
H
0.50
0.80
1.00
N1075
With
B
L
y
1

3.2
Characteristics of the grid

A number of nodes:
3927
A number of meshs and types: 400 HEXA27

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS

3D

AFFE_CHAR_THER
TEMP_IMPO

THER_LINEAIRE
TEMP_INIT
VALE

LIST_INST

RECU_CHAMP
INST

3.4 Remarks

The condition limits = 0. is implicit on the free edges.

Discretization of time: 24 intervals between 0. and 1.2 seconds:

T = 0.00
with T = 0.02
: 4 0.005 seconds intervals.
T = 0.02
with T = 0.05
: 3 intervals of 0.01
seconds.
T = 0.05
with T = 0.15
: 4 0.025 seconds intervals.
T = 0.15
with T = 0.4
: 5 intervals of 0.05
seconds.
T = 0.4
with T = 1.2
: 8 intervals of 0.1
seconds.

V4.25.301-A Page:
5/6

4
Results of modeling A

4.1 Values tested

Identification	*Reference*	*Aster %*	*difference*	*Tolerance*	*Not O*
N5 (0. , 0. , 0.)					
T = 0.1 S	*1.05137*	*1.04934*	*-0.193*	*1%*	
T = 0.2 S	*1.24768*	*1.24181*	*-0.471*	*1%*	
T = 0.3 S	*1.45136*	*1.44378*	*-0.522*	*1%*	
T = 0.5 S	*1.73684*	*1.72955*	*-0.420*	*1%*	

T = 0.7 S
1.88010
1.87516
-0.263
1%
T = 1.0 S
1.96406
1.96191
-0.110
1%
T = 1.2 S
1.98398
1.98282
-0.059
1%

Not H

N1075 (0.5, 0.8, 1.0)

T = 0.1 S
1.33579
1.32490
-0.816
1%
T = 0.2 S
1.61081
1.60337
-0.462
1%
T = 0.3 S
1.75959
1.75424
-0.304
1%

T = 0.5 S
1.90017
1.89718
-0.157
1%
T = 0.7 S
1.95657
1.95478
-0.091
1%
T = 1.0 S
1.98723
1.98646
-0.039
1%
T = 1.2 S
1.99433
1.99391
-0.021
1%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 16.36 seconds
Handbook of Validation
V4.25 booklet: Transitory thermics of the voluminal structures
HT-66/02/001/A

5
Summary of the results

The results obtained are satisfactory. The maximum change obtained (0.816%), is located at the point H placed
halfway enters surface external and the center of the parallelepiped. At the end of 1.2s, this variation decrease, the maximum obtained is then of 0.059% (not O: center parallelepiped).

This test made it possible to test in linear transient modeling 3D with meshs HEXA27.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V4.41 booklet: Stationary thermics with radiation
Document: V4.41.001

TPNA01 - Stationary axisymmetric problem with radiation

Summary:

This elementary test makes it possible to deal with axisymmetric problem in stationary thermics with a condition
with the limits of the radiation type. The solution is analytical. The problem is dealt with into axisymmetric and in
voluminal.

For modelings presented here, the variations of the results obtained by Code_Aster range between 1 and
2% of the analytically calculated reference.

1
Problem of reference

1.1 Geometry

Z
Re = 0.391 m
Re = 0.300 m
R

The hollow roll is supposed infinitely long.

1.2
Material properties

Only the coefficient of conductivity intervenes. Code_Aster makes compulsory the supply of a function
representing the given voluminal enthalpy starting from the voluminal coefficient of heat.

voluminal heat
C
1.00 J/m3 ° C
p =

thermal conductivity
K = 40 W/m° C

1.3
Boundary conditions and loadings

Condition of the radiation type on surface interns cylinder, condition of the convection type (exchange with the external medium) on external surface.

No the boundary condition on the ends of the cylinder (what amounts imposing a null flow).

T
4

I

intern

surface
K
= (T+ 273.15) 4

- (T + 273.15
ext.
)
N

with = 0.6, =
10
5.73
-8 W/2 4
m K
and iext
T
= 500.0°
C, T

in

expressed

Centigrade
°
T

external

surface
K
= He [eext
T - T]
N
with H E = 142.0
2
W/m C
°
and eext
T
= 20.0 C
°
Handbook of Validation

2
Reference solution

2.1
Method of calculation used for the reference solution

One in the case of lays out of an analytical solution a cylinder infinite length:

T - T
T Log (Re) - T Log (IH)
T (R)
E
I
=
Log (R
I
E
) +

Re
Log (Re) - Log (IH)
Log

IH

2.2
Results of reference

R (m)	T (°C)
.30000	105.55
.32275	99.21
.34550	93.30
.36825	87.76
.39100	82.56

Value of the temperature according to R

R (m)	(W/m2)
.300	11577.49
.391	8822.98

Value of flow according to R

2.3
Uncertainty on the solution

Exact solution.

2.4 References
bibliographical

[1]
Guide validation of the software packages of structural analysis. French company of the Mechanics AFNOR 1990 ISBN 2-12-486611-7

Handbook of Validation
V4.41 booklet: Stationary thermics with radiation
HT-66/03/008/A

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 2D:

N1
N3
N6
N11
N9

3.2
Characteristics of the grid

2 QUAD8

3.3
Functionalities tested

Order Mot-clé Key word
Argument
factor
simple

DEFI_MATERIAU THER_NL
LAMBDA

BETA

THER_NON_LINE TEMP_INIT
STATIONARY “YES”

CONVERGENCE
RESI_GLOB_RELA
1.E-2

ITER_GLOB_MAXI
9

CRIT_LAGR_RELA
1.E-3

OPTION
“FLUX_ELNO_TEMP”

4
Results of modeling A

4.1 Values
tested

The nodes observed have as a co-ordinate Z = 0.0

Identification	Reference	Aster %	difference
temperature			
N1 (r=.30000)	105.55	105.52	-0.03
N3 (r=.32275)	99.21	99.17	-0.04
N6 (r=.34550)	93.30	93.26	-0.04
N11 (r=.36825)	87.76	87.73	-0.04
N9 (r=.39100)	82.56	82.53	-0.04

Identification	Reference	Aster %	difference
flow			
net M1 N1 node	11577.49	11533.37	-0.38
net m2 N9 node			

8822.98
8855.97
-0.37

4.2 Remarks

The boundary condition of the radiation type is provided in the form of a function of temperature interpolated linearly between each point (one discretized the curve using 101 here points).

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling 3D:

5.2
Characteristics of the grid

32 HEXA20

5.3
Functionalities tested

Order Mot-clé
Key word
Argument
factor
simple
DEFI_MATERIAU THER_NL
LAMBDA

BETA

THER_NON_LINE TEMP_INIT
STATIONARY
"YES"

CONVERGENCE
RESI_GLOB_RELA
1.E-2

ITER_GLOB_MAXI
10

CRIT_LAGR_RELA
1.E-3

OPTION
"FLUX_ELNO_TEMP"

6
Results of modeling B

6.1 Values
tested

The nodes observed have as co-ordinates: y = Z = 0.0

Identification
Reference
Aster
% difference
temperature
NO106 (x=.30000)
105.55
105.51
-0.03
NO105 (x=.32275)
99.21
99.17
-0.04
NO115 (x=.34550)
93.30
93.26
-0.04
NO125 (x=.36825)
87.76
87.73
-0.04
NO123 (x=.39100)

82.56
82.52
-0.04

Identification
Reference
Aster
% difference
flow
net MA17 node NO106
11577.49
11680.50
+0.89
net MA16 node NO123
8822.98
8968.85
+1.65

6.2 Remarks

The function of flow used in modeling A is also used here.

Handbook of Validation
V4.41 booklet: Stationary thermics with radiation
HT-66/03/008/A

7
Summaries of the results

The taking into account of the conditions of radiation is completely correct in this stationary case.
Let us note that this test utilized a coefficient of thermal conductivity constant, only
non-linearity thus relates to the boundary conditions.

The errors are higher on the calculation of flow, which one can explain by the use of
smoothings with the nodes, carried out starting from the computed values at the points of integration
(points of
GAUSS).

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.41 booklet: Nonlinear stationary thermics of the axisymmetric structures
V4.41.300 document

TPNA300 - Tube generating heat with variable conductivity

Summary:

This test results from the validation independent of version 3 in nonlinear stationary thermics.

It is about an axisymmetric problem 2D represented by four modelings, two axisymmetric, plane and the voluminal last.

The functionalities tested are as follows:
· axisymmetric thermal element,
· plane thermal element,
· voluminal thermal element,
· variable properties,
· limiting conditions (imposed temperature, heat source).

The interest of the test lies in the taking into account of variable properties and the nonlinear

behavior.

1
Problem of reference

1.1 Geometry

Y
Te
Ti
laughed
X
With
B
(W/m/°C)
ro
...
40
Q
(T)
20
T (°C)

0
50
100

laughed = 6.35 X 10-3 m
Re = 25.4 X 10-3 m

1.2
Properties of material

= Co+C1T W/m°C
Thermal conductivity
with Co = 21.461 W/m °C

C1 = 0.234 W/m °C ²

1.3
Boundary conditions and loadings

· surface interior:
Ti = -17.78 °C,
· surface outside: Te = -17.78 °C,
· heat source: Q = 1.035 x107 W/m3.

1.4 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

The original reference solution given in the book [bib1] is based on a graphic estimate. This reference is quoted in the handbook of checking of ANSYS [bib2].

2.2
Results of reference

Temperature along AB with R = 2.167 mm

2.3
Uncertainty on the solution

Unknown factor, it was not possible to get the original reference (delivers old, more published).

2.4 References bibliographical

[1]
Schneider, P.J., "Conduction Heat Transfer", Addison-Wesley Publishing Co., Inc. Reading, Mass., 2nd Printing, 1957.
[2]
ANSYS, "checking manual", 1st edition, June 1, 1976

---

3 Modeling
With

3.1
Characteristics of modeling

AXIS (QUAD4, TRIA3)

y (Z)
D C
0.003
X (R)
WITH E F G H I J K L B
Boundary conditions:
Node
R
Z
Points
Node
R
Z
(10-3m)
(10-3m)
(10-3m) (10-3m)
- dimensioned AB, CD: = 0
N4
8.47
0.0
E
N6
8.47
3.0
- dimensioned AD, BC: T=-17.78°C
N7

10.58
0.0
F
N9
10.58
3.0
N10
12.70
0.0
G
N12
12.70
3.0
N13
14.82
0.0
H
N15
14.82
3.0
N16
16.92
0.0
I
N18
16.92
3.0
N19
19.05
0.0
J
N21
19.05
3.0
N22
21.17
0.0
K
N24
21.17
3.0
N25
23.28

0.0
L
N27
23.28
3.0

3.2
Characteristics of the grid

A number of nodes:
30
A number of meshs and types: 27: (9 QUAD4, 18 TRIA3)

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
AXIS
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
TEMP_IMPO

SOURCE

THER_NON_LINE
TEMP_INIT
STATIONARY
"YES"

EXCIT
CHARGE

RECU_CHAMP

INST
0.

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C)

N4
-5.00
-4.92
-1.70
5%
N7 2.22
2.06
-7.35

5%
N10 5.56
5.57
0.10
5%
N13 6.67
6.60
-1.07
5%
N16 5.56
5.60
0.76
5%
N19 2.78
2.76
-0.71
5%
N22
-1.67
-1.93
15.30
5%
N25
-8.89
-8.63
-2.90
5%

N6
-5.00
-4.96
-0.87
5%
N9 2.22
2.04
-8.18
5%
N12 5.56
5.56
0.04

5%
N15 6.67
6.60
-1.02
5%
N18 5.56
5.61
0.91
5%
N21 2.78
2.77
-0.26
5%
N24
-1.67
-1.91
14.24
5%
N27
-8.89
-8.61
-3.17
5%

4.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 2.24 seconds

5 Modeling

B

5.1
Characteristics of modeling

PLAN (QUAD8, TRIA6)

Boundary conditions:
C
N294
N285
- dimensioned AB, CD: = 0
N268
- dimensioned AD, BC: T=-17.78°C
N245
N214
y
N184
N160
N211 N204
N134
N181
N168
D
N149 N121
N117
N103
30°
X
In N60 N46 N33 N21 N13 N7 N2 N5 B

5.2
Characteristics of the grid

A number of nodes:
300
A number of meshs and types: 95 (73 QUAD8, 22 TRIA6)

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
TEMP_IMPO

SOURCE

THER_NON_LINE
TEMP_INIT
STATIONARY
“YES”

EXCIT
CHARGE

RECU_CHAMP
INST
0.

6
Results of modeling B

6.1 Values tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C)

N60
-5.00
-4.84
-3.194
5%
N46 2.22
2.14
-3.491
5%
N33 5.56
5.65
1.544
5%
N21 6.67

6.66
-0.082
5%
N13 5.56
5.65
1.694
5%
N7 2.78
2.80
0.665
5%
N2
-1.67
-1.90
13.788
5%
N5
-8.89
-8.62
-3.089
5%

N134
-5.00
-4.84
-3.194
5%
N160 2.22
2.14
-3.491
5%
N184 5.56
5.65
1.543
5%
N214 6.67
6.66
-0.082
5%
N245 5.56

5.65
1.694
5%
N268 2.78
2.80
0.665
5%
N285
-1.67
-1.90
13.737
5%
N294
-8.89
-8.62
-3.089
5%

N103
-5.00
-4.84
-3.141
5%
N117 2.22
2.15
-3.365
5%
N149 5.56
5.65
1.557
5%
N121 6.67
6.66
-0.078
5%
N168 5.56
5.65
1.694
5%
N181 2.78

2.80
0.650
5%
N211
-1.67
-1.90
13.777
5%
N204
-8.89
-8.62
-3.075
5%

6.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 2.83 seconds

---

7 Modeling
C

7.1
Characteristics of modeling

3D (HEXA8, PENTA6)

Z
y
N134
N14
N51
N90
N171
.001
N151
N30
N68
N114
N3
30°
N19
N7
N37
N85
N61
N124
N220
N11
N43
N266
N22
N177
N102
N255
N67
N208
N150
Boundary conditions:
N291
N251

- internal and external face
T=-17.78°C
- others
X
= 0
N307

7.2
Characteristics of the grid

A number of nodes:
309
A number of meshs and types: 190 (144 HEXA8, 46 PENTA6)

7.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
TEMP_IMPO

SOURCE

THER_NON_LINE
TEMP_INIT
STATIONARY
"YES"

EXCIT
CHARGE

RECU_CHAMP
INST
0.

8
Results of modeling C

8.1 Values
tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C)

N22
-5.00
-4.90
-1.909
5%
N43 2.22
2.09

-5.933
5%
N67 5.56
5.58
0.408
5%
N102 6.67
6.63
-0.561
5%
N150 5.56
5.62
0.993
5%
N208 2.78
2.77
-0.217
5%
N251
-1.67
-1.92
15.047
5%
N291
-8.89
-8.63
-2.960
5%

N14
-5.00
-4.90
-1.908
5%
N30 2.22
2.09
-5.933
5%
N51 5.56
5.58

0.408
5%
N68 6.67
6.63
-0.561
5%
N90 5.56
5.62
0.993
5%
N114 2.78
2.77
-0.217
5%
N134
-1.67
-1.92
15.047
5%
N151
-8.89
-8.63
-2.960
5%

N19
-5.00
-4.93
-1.440
5%
N37 2.22
2.16
-2.596
5%
N61 5.56
5.54
-0.274
5%
N85 6.67
6.65

-0.260
5%
N124 5.56
5.60
0.705
5%
N177 2.78
2.82
1.536
5%
N220
-1.67
-1.90
13.946
5%
N255
-8.89
-8.58
-3.474
2%

8.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory: 8 megawords
Time CPU To use: 2.81 seconds

9 Modeling
D

9.1
Characteristics of modeling

AXIS (QUAD9)

y (Z)
D C
0.003
WITH E F G H I J K L B
0.0025
X (R)
Boundary conditions:
Node
R
Z
Points
Node
R
Z
(10-3m)
(10-3m)
(10-3m) (10-3m)
- dimensioned AB, CD: = 0
N11
8.47
2.5

E
N15
8.47
5.5
- dimensioned AD, BC: T=-17.78°C
N21
10.58
2.5
F
N25
10.58
5.5
N31
12.70
2.5
G
N35
12.70
5.5
N41
14.82
2.5
H
N45
14.82
5.5
N51
16.92
2.5
I
N55
16.92
5.5
N61
19.05
2.5
J
N65
19.05
5.5
N71
21.17
2.5

K
N75
21.17
5.5
N81
23.28
2.5
L
N85
23.28
5.5

9.2
Characteristics of the grid

A number of nodes:
95
A number of meshs and types: 18 QUAD9

9.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER
TEMP_IMPO

SOURCE

THER_NON_LINE
TEMP_INIT
STATIONARY

"YES"

EXCIT
CHARGE

RECU_CHAMP
INST
0.

---

10 Results of modeling D

10.1 Values tested

Relative variation %
Absolute deviation
Identification Reference Aster difference
tolerance difference tolerance
Temperature (°C)

N11
-5.00
-4.83
-3.333
5% 0.167 0.3
N21 2.22
2.15
-3.347
5%
-0.074
0.3
N31 5.56
5.65
1.551
5%
0.086
0.3
N41 6.67
6.66
-0.078
5%
-0.005
0.3
N51 5.56
5.65
1.694
5%
0.094
0.3
N61 2.78
2.80
0.663
5%
0.018
0.3
N71

-1.67
-1.90
13.741
5%
-0.229
0.3
N81
-8.89
-8.62
-3.088
5% 0.275 0.3

N15
-5.00
-4.83
-3.333
5% 0.167 0.3
N25 2.22
2.15
-3.347
5%
-0.074
0.3
N35 5.56
5.65
1.551
5%
0.082
0.3
N45 6.67
6.66
-0.078
5%
-0.005
0.3
N55 5.56
5.65
1.694

5%
0.094
0.3
N65 2.78
2.80
0.663
5%
0.018
0.3
N75
-1.67
-1.90
13.741
5%
-0.229
0.3
N85
-8.89
-8.62
-3.088
5% 0.275 0.3

10.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory: 8 megawords
Time CPU To use: 2.44 seconds
Handbook of Validation
V4.41 booklet: Nonlinear stationary thermics of axisymmetric structures HT-66/02/001/A

Code_Aster ®
Version 5.0

Titrate:
TPNA300 Tubes generating heat with variable conductivity
Date:

11 Summary of the results

Four modelings give results whose certain values exceed the fixed tolerance initially (5%):

· for modeling A (AXIS: QUAD4, TRIA3), the maximum change is 15,3% and 4 values on 16 exceed the tolerance,
· for modeling B (PLANE: QUAD8, TRIA6), the maximum change is 13,8% and 3 values on 24 exceed the tolerance,
· for modeling C (3D: HEXA8, PENTA6), the maximum change is 15% and 5 values on 24 exceed the tolerance,
· for modeling D (AXIS: QUAD9), the maximum change is 13,7% and 4 values out of 16 exceed the tolerance.

These goings beyond of tolerance are observed for values close to 0.

Calculations were carried out in °C. Determination of the variation, by considering the temperatures in ° F (as in the reference solution), a maximum change very different from that obtained in °C gives (3% instead of 15%).

Moreover, it was not possible to get the original reference (delivers of Kreith), quoted in handbook of checking of ANSYS. Method of acquisition the reference solution (estimate graph) and its uncertainty are thus not known.

The results are regarded as acceptable taking into account the points evoked above.

This test made it possible to test the taking into account a variable thermal conductivity within several modelings. The principal orders tested are as follows:

· DEFI_MATERIAU associated with key word THER_NL, allowing to define the characteristics of one material whose characteristics vary according to the temperature,
· THER_NON_LINE orders allowing the resolution of a thermal nonlinear problem stationary or not.

Code_Aster ®
Version
5.0

Titrate:
TPNL300 unidimensional Transfer of heat with radiation
Date:
20/09/02
Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER Clé*
:
V4.42.300-A Page:
1/8

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.42 booklet: Nonlinear stationary thermics of the linear structures
V4.42.300 document

TPNL300 - Unidimensional transfer of heat with radiation

Summary:

This test results from the validation independent of version 3 in nonlinear stationary thermics.

It is about a linear problem 1D represented by two modelings, one planes, the other voluminal one.

The functionalities tested are as follows:
· plane thermal element,
· voluminal thermal element,
· limiting conditions: (imposed temperatures, radiation).

The interest of the test lies in the taking into account of the radiation.

The results are compared with those provided by NAFEMS.

Handbook of Validation
V4.42 booklet: Nonlinear stationary thermics of the linear structures
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

With
B
X
0.1 m

1.2
Properties of material

= 55.6 W/m.°C
Thermal conductivity
C
= 460 J/kg.°C
Specific heat
= 7850 kg/m3 Mass
voluminal

1.3
Boundary conditions and loadings

· temperature imposed on point a: MT = 726.85°C,
· exchange by radiation at point b:
- outside temperature = 26.85°C,
- = 0.98 emissivity,
- = 5.67x10-8 W/m ² K4 (constant of Stefan-Boltzman).

1.4 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is that given in the card "TEST n°2" of the tests of reference published by NAFEMS.

2.2
Results of reference

Temperature at point b: T = 653.85°C

2.3
Uncertainty on the solution

Nonavailable on card NAFEMS.

2.4 References
bibliographical

[1]
NAFEMS (the National Agency for Finite Element Methods Standard and (the U.K.)): "The standard NAFEMS Benchmarcks ", TNSB rév 3, October 1990.

---

3 Modeling With

3.1 Characteristics of modeling

PLAN (TRIA3, QUAD4)

y
C
D
N55
0.02m
N53
N51
With
B
X
Boundary conditions:
- Dimensioned AD:
T = 726.85°C
- Dimensioned AB, CD: = 0
- Dimensioned BC:
Text=26.85°C
= 0.98

3.2 Characteristics of the grid

A number of nodes:
55
A number of meshs and types: 60: (20 QUAD4, 40 TRIA3)

3.3 Functionalities tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
FLUX_NL
TEMP_IMPO

THER_NON_LINE
TEMP_INIT
STATIONARY
“YES”

EXCIT
CHARGE

RECU_CHAMP
INST
0.

:
V4.42.300-A Page:
5/8

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster *%*
difference
tolerance
Temperature at the point B

in °C

N51 653.85
653.87
0.003
2%
N53 653.85
653.87
0.003
2%
N55 653.85
653.87
0.003
2%

4.2 Parameters
of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 2.64 seconds
Handbook of Validation
V4.42 booklet: Nonlinear stationary thermics of the linear structures
HT-66/02/001/A

---

5 Modeling
B

5.1
Characteristics of modeling

3D (HEXA8)

Z
0.02m
y
N91
0.02m
N97
Boundary conditions:
X
N92
- face X = 0
T=726.85°C
N98

- face X = 0.1
Text=26.85°C
= 0.98
- others faces
= 0

5.2
Characteristics of the grid

A number of nodes:
99
A number of meshs and types: 40 HEXA8

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
FLUX_NL
TEMP_IMPO

THER_NON_LINE
TEMP_INIT
STATIONARY
"YES"

EXCIT
CHARGE

RECU_CHAMP
INST

0.

6 *Results of modeling B*

6.1 Values tested

Identification Reference
Aster *%*
difference
tolerance
Temperature at the point B

in °C

N91 653.85

653.87

0.003
2%
N92 653.85

653.87
0.003
2%
N97 653.85

653.87
0.003
2%
N98 653.85

653.87
0.003
2%

6.2 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 2.66 seconds

Handbook of Validation
V4.42 booklet: Nonlinear stationary thermics of the linear structures
HT-66/02/001/A

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7 *Summary of the results*

This test is recommended by NAFEMS (but with another type of grid).
Two modelings give very satisfactory results, the maximum change obtained is of 0.003%.

For modeling PLAN, in spite of the not-symmetry of the grid, one notes that the temperature with nodes (points of observation) pertaining to the TRIA3 and the QUAD4 is identical.

The limiting condition of radiation was imposed via a nonlinear loading of flow (flow function temperature). In this test the taking into account of the radiation is completely correct.

This test with licence to test order AFFE_CHAR_THER_F (associate with the operand FLUX_NL which allows to affect a flow non_linéaire in the case of) modelings PLAN and 3D.

Author (S):
***C. DURAND**, E. SCREW, F. LEBOUVIER Clé*
:
V4.43.001-A Page:
1/8

Organization (S): EDF/AMA, EDF/UTO/SIS, Delta CAD

Handbook of Validation
V4.43 booklet: Nonlinear stationary thermics of the voluminal structures
V4.43.001 document

TPNV01 - Hollow sphere: convection, radiation

Summary:

This test results from the validation independent of version 3 in nonlinear stationary thermics.

It is about a voluminal problem represented by two modelings, one 3D, the other axisymmetric one.

The functionalities tested are as follows:
· thermal element 3D,
· axisymmetric thermal element,
· conditions limit convection and of radiation.

The interest of the test lies in the taking into account of the radiation.

The results are compared with an analytical solution on a test VPCS.

1
Problem of reference

1.1 Geometry

Interior ray IH = 0.300 m
External ray Re = 0.392 m
IH
With
B
O
R
Re

1.2
Properties of material

= 40 W/m °C
Thermal conductivity
C = 1 J/m3 °C
Voluminal heat

1.3
Boundary conditions and loadings

· Internal Surface: radiation, = 0.6 (coefficient of gray body), T E
I = 500.0°C,
· External Surface: convection, H
E
E = 133.5 W/m2 °C, Te = 20.0°C.

1.4 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

T
T
I
E
-
T - T1
R
R
T (R
E
I
E
I
) =
+
1
1 R
1
1
-
-
R
R
R
R
E
I
E
I

E
E
E = E
H (E
T - E
T)
=
4
2

E
R E
H (E
T - E
T)
éq
2.1-1

E
4
4
I =. (I
T +
.
273 15) - (iT +
.
273
)
15

éq
2.1-2
= 4 2

E
4
4
R I. (iT +
.
273 1)
5
- (iT + 2.
73 15)

2
Te -

T
= 4 R = Co N sta N you
= 4
I
1

éq
2.1-3
- 1
R
R
E
I

=
-
5 7 3 x1 0 8
4
.
W/m ² K (constant of Stefan) with T in °C

The temperatures of reference are obtained while solving numerically by the method of Newton an equation of the 4th degree out of Ti obtained starting from the equations [éq 2.1-1] [éq 2.1-2] and [éq 2.1-3].

2.2 Results of reference

in a:
in b:
Temperatures
Ti = 91.77°C
Te = 71.22°C
Densities flux
I = 11675. W/m2
E = 6838. W/m2

2.3 Uncertainty on the solution

Analytical solution.

2.4 References bibliographical

[1]
Guide validation of the software packages of structural analysis. French company of Mechanics, AFNOR 1990 ISBN 2-12-486611-7
Handbook of Validation

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3 Modeling With

3.1 Characteristics of modeling

3D (HEXA20, PENTA15, QUAD8)

Z
y
N38
N463
30°
N46
N453
30°
N93
N440
Limiting conditions:
N145
N184
N443
- external face
H = 133.5 W/m ² °C
R

T
I = 0.3
ext. = 20°C
N460
- internal face
= 0.6
T
m8
ext. = 500°C
Re = 0.392
m2
- other faces
= 0
X

3.2
Characteristics of the grid

A number of nodes:
465
A number of meshs and types: 96 (32 HEXA20, 64 PENTA15)

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
3D
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
EXCHANGE
FLUX_NL

THER_NON_LINE
TEMP_INIT
STATIONARY
"YES"

EXCIT
CHARGE

RECU_CHAMP
INST
0.

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C)

N184 91.77
91.75
-0.026
1%
N145 91.77
91.75
-0.026
1%
N93 91.77
91.75
-0.018
1%
N46 91.77
91.76
-0.016
1%
N38 91.77
91.76
-0.016
1%

N460 71.22
71.21
-0.011
1%
N443 71.22
71.21
-0.011
1%
N440 71.22
71.21
-0.017

1%
N453 71.22
71.21
-0.021
1%
N463 71.22
71.20
-0.022
1%

Density flux (W/m ²)

Net m8, N184
11675.
11677.
0.016
2%
Net m2, N460
6838.
6843.
0.076
2%

4.2 Remarks

The boundary condition of the radiation type is provided in the form of a function of temperature interpolated linearly between each point (one discretized the curve in 101 points).

4.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
8 megawords
Time CPU To use: 6.33 seconds

Handbook of Validation
V4.43 booklet: Nonlinear stationary thermics of the voluminal structures
HT-66/02/001/A

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5 Modeling
B

5.1
Characteristics of modeling

AXIS (TRIA6, QUAD8, SEG3)

C
Limiting conditions:
N72
- dimensioned AB, CD
= 0
D
- dimensioned BC

H
=
133.5 W/m ² °C
N55
Text
= 20°C
N57
- dimensioned AD

=
0.6
Text
= 500°C
N47
N35
N30
y
N25
N12
30°
m8
m2
N1
N16
With
B
X

5.2
Characteristics of the grid

A number of nodes:
73
A number of meshs and types: 24: (16 TRIA6, 8 QUAD8)

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
AXIS
ALL

DEFI_MATERIAU
THER_NL

AFFE_CHAR_THER_F
EXCHANGE
FLUX_NL

THER_NON_LINE
TEMP_INIT
STATIONARY
“YES”

EXCIT
CHARGE

RECU_CHAMP
INST
0.

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster %
difference
tolerance
Temperature (°C)

N1 91.77
91.75
-0.019
1%
N12 91.77
91.75
-0.018
1%
N30 91.77
91.75
-0.021
1%
N47 91.77
91.75
-0.022
1%
N57 91.77
91.75
-0.020
1%

N16 71.22
71.21
-0.017
1%
N25 71.22
71.21
-0.017
1%
N35 71.22
71.21
-0.016
1%
N55 71.22
71.21
-0.014
1%
N72 71.22
71.21
-0.012
1%

Density flux (W/m ^{2})

Net m8, N1
11675.
11656.
-0.163
2%
Net m2, N16
6838.
6834.
-0.062
2%

6.2 Remarks

The boundary condition of the radiation type is provided in the form of a function of temperature interpolated linearly between each point (one discretized the curve in 101 points).

6.3 Parameters of execution

Version: 5.03

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory: 8 megawords
Time CPU To use: 2.63 seconds

7
Summary of the results

The results of reference provided by VPCS are incorrect. New results of reference have summer determined starting from an analytical approach.

The results obtained are satisfactory. The maximum change is of:

· modeling A (3D: HEXA20, PENTA15): 0.026% for the temperature and of 0.076% for flow,
· modeling B (AXIS: QUAD4, TRIA3): 0.022% for the temperature and of 0.16% for flow.

The limiting condition of radiation was imposed via a nonlinear loading of flow (flow function temperature). In this test the taking into account of the radiation is completely correct.

This test with licence to test order AFFE_CHAR_THER_F (associate with the operand FLUX_NL which allows to affect a flow non_linéaire) in the cases of modeling AXIS and 3D.

Organization (S): EDF/IMA/MMN

Handbook of Validation
V4.61 booklet: Metallurgy
Document: V4.61.100

MTLP100 - Heating and hardening of an infinite bar with square section

Summary:

The purpose of this test is to provide a metallurgy calculation of reference, in postprocessing of an evolutionary calculation of thermics planes linear which one knows the analytical solution. More concretely, this test validates calculations two-dimensional of linear thermics with conditions of exchange and provides values of reference for the austenitic model of transformation to the heating, like for the model of decomposition of austenite with cooling.

1
Problem of reference

1.1 Geometry

y
C
B
With
2L
O
X
2L

Infinite bar with square section:

side 2L = 0,10 m

Co-ordinates of the points (in m):

With
B
C
O
X 0.026
0.350
0.041 0.0
y 0.026

0.350
0.041 0.0

1.2
Properties of material

(Steel 16MND5)

CP = 5260000 J.m-3.°C1
= 33.5 W.m-1.°C-1

Coefficients for the metallurgy:

“Standard” TRC
AR3 = 830°C, alpha = -0.0306
MS0 = 400°C, AC1 = 724°C, AC3 = 846°C
1 = 0.034, 3 = 0.034

Microhardness of the différenres metallurgical phases:

for ferrite D = 200. HV
for the pearlite D = 200. HV
for the bainite D = 300. HV
for martensite D = 400. HV
for austenite D = 100. HV

1.3
Boundary conditions and loadings

T = 15 °C

H = 1675 W.m-2.°C1

1.4 Conditions
initial

T (X, y, 0) = 700°C.

Zf (X, y, 0) = 0.7
Zb (X, y, 0) = 0.3

2
Reference solution

2.1
Method of calculation used for the reference solution

.
On the heating, one imposes a rise in uniform temperature of 700 on 900°C into 200 S.

.
Analytical solution for thermal calculation (with cooling since 900°C).

T (X, y, T) = (X, y, T) (T (X, y,)
0 - T) + T

where:

- 2
T

- 2
T
I
I
(
)
CP
=

X y T
With E
X × A E
CP
, ,
cos
cos y
I
I
I
I

i=1
i=1

with I checking:

hL
I L
(

tg I L) =
=

.
5 00

and:

4 sin (L
I
)
Have =

2 L
I
sin (L
I
)

.
The values of reference for the metallurgical evolutions depend on the model and on integration in time of the relations of behaviors. One does not have values of reference.
.
The hardness of a material point depend on the metallurgical proportions of each phase, one do not have values of reference.

2.2
Results of reference

(Thermal Calculation):

.
temperature at the points A, B, C at the moment T = 300 S,
.
proportion of bainite at the items A, B, C at the moment T = 410, 300 and 300 S, respectively,
.
proportion of martensite at the points A, B, C at the moment T = 410 S,
.
proportion of austenite at point A at the moment T = 30 S and 140 S.
.
hardness at the point O at the moment T = 30 S, 140 S, 300 S and 410 S.

2.3
Uncertainty on the solution

Lower than 1% with 30 modes for each nap.

2.4 References
bibliographical

[1]
F.P. INCROPERA, D.P. OF WITT, J. WILEY. Fundamentals of heat and mass transfer. Third Edition. 1990.

---

3 Modeling
With

3.1
Characteristics of modeling

Elements "PLANE" 2D

By reason of symmetry, one nets only one quarter of square section and one refines in X = L and y = L.

y
L
C

B
With
O
L
X

Cutting:
5 meshs QUAD8 according to the x axis

5 meshs QUAD8 according to the y axis

Boundary conditions:
on X = 0 and y = 0
= 0

on X = L and y = L
- T N = (
H T (X, y, T) -
T)

Points of Gauss:

A:
net m13 point 1
B:
net m19 point 1
C:
net m19 point 3

Node:

O:
N1 node

3.2
Characteristics of the grid

A number of nodes:
96
A number of meshs and types:
25 QUAD8, 20 SEG3

3.3 Functionalities
tested

Orders

Keys
DEFI_TRC HIST_EXT
VALE

[U4.23.05]
TEMP_MS
P

THRESHOLD

AKM

BKM

TPLM

DEFI_MATERIAU META_THER TRC

[U4.23.01]

AR3

ALPHA AC1 AC3

MS0 TAUX_1 TAUX_3

DURT_META
F_DURT

P_DURT

B_DURT

M_DURT

A_DURT

THER_LINEAIRE OPTION
“META_ELGA_TEMP”
[U4.23.05]
TEMP_INIT
META_INIT

CALC_ELEM OPTION “DURT_ELGA_META”

[U4.61.02]

"DURT_ELNO_META"

3.4 Remarks

165 steps of calculation from 0 to 410 S (40 steps of 5 S, then 40 steps of 1 S, then 85 steps of 2 S).

4
Results of modeling A

4.1 Values
tested

Identification Sizes
Reference
Aster %
difference
T = 30 S M13 (PG1) P
0.0489
0.0489
1.64 106 absolute
T = 140 S M13 (PG1) P
0.9505
0.9505
4.10 105 absolute
T = 300 S M13 (PG1) TPG
464.1
464.37
0.058
T = 300 S M19 (PG1) TPG
338.5
338.79
0.086
T = 300 S M19 (PG3) TPG
245.4
245.68
0.116
T = 410 S M13 (PG1) ZB

0.7828

T = 300 S M19 (PG1) ZB

0.5873

T = 300 S M19 (PG3) ZB

0.3113

T = 410 S M13 (PG1) ZM

0.2156

T = 410 S M19 (PG1) ZM

0.4103

T = 410 S M19 (PG3) ZM

0.6846

T = 30 S N1
HV

223.643

T = 140 S N1
HV

106.430

T = 300 S N1
HV

100.000

T = 410 S N1
HV

308.248

TPG:
temperature at the point of GAUSS,
ZB:
proportion of bainite,

ZM:
proportion of martensite,
P:
proportion of austenite.
HV
hardness of Vickers

4.2 Parameters of execution

Version: 5.00.15

Machine: SGI - Origin 2000

Obstruction memory:
64 Mo
Time CPU To use:
31.54 seconds

5 Summary of the results

The temperatures calculated at points A, B and C are obtained with a margin of 0.1%. Proportions of austenite are perfectly given.

The proportions of bainites, martensite and the calculation of hardness are results allowing of to check nonthe regression of the Code (not of reference solution).
Handbook of Validation
V4.61 booklet: Hi-75/01/010/A metallurgy

Code_Aster ®
Version
5.0

Titrate:
SDND100 To release of a shoe rubbing with friction of the Coulomb type
Date:
14/09/01
Author (S):

***Fe WAECKEL**, G. DEVESA Key*
:
V5.01.100-C Page:
1/10

Organization (S): EDF/RNE/AMV

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.100 document

SDND100 - To release of a rubbing shoe
with friction of the Coulomb type

Summary

One considers the one-way system with a degree of freedom made up of a mass in rubbing contact of type
Coulomb on a rigid level, and of a spring attaching it to a fixed point. The mass is released in a position
initial except balance. It oscillates until the complete stop at the end of a finished time.
The first two modelings correspond to the transitory response by modal recombination of the shoe
rubbing, the third corresponds to its direct transitory answer. Three calculations are compared with the solution
analytical.

1
Problem of reference

1.1 Geometry

K
m
Uo
Z
Y
G
m
N
K
=45°
X

Direction of displacement: = 45° in plan XY

1.2
Material properties

Stiffness of the spring:
K = 10.000 N/m

Specific mass:
m = 1 kg
Gravity:
G = 10 m/s2
Coefficient of Coulomb:
μ = 0,1

1.3
Boundary conditions and loadings

The system rests on the plan Z = 0 on which it can slip with a coefficient of friction of Coulomb of μ = 0 1
, .

1.4 Conditions
initial

Initial displacement of the mass: r0 = 0,85 mm according to the direction.

Null initial speed.

2
Reference solution

2.1
Method of calculation used for the reference solution

For a system without damping, the differential equation to solve is written:

m
r& + K R = µ F with F = - mgsign (R
N
N
&)
R
(T =)
0 = R 0
0

R

& (T =)
0 = 0

It is shown [bib1] that the solution of the differential equation is written:

µ F
µ F
R T
N
=
+ R
N
( )
(-
) cos T
K
0
K
0

N
The amplitude of the extrema, which all come the tn+ =
1
, obeys the law of following recurrence:
0

μ F
R
(T
N
) = (-)
1
1 R
N
-
0
cos T
n+

K
0

R (T
)
μ F
with N =,
1 2,…, NR
n+1
N
such as
<

R
K R

0
0

R (T
)
μ F
+
The movement stops when
N 1
N

<
with the position R (T
)
R
K R
n+1.
0
0

2.2
Results of reference

Values of displacements in the direction for the moments of change of sign speed
(R (T), R (T),…, R (T
1
2
5) established above).

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
F. AXISA - Methods of analysis in nonlinear dynamics of the structures: non-linearities of contact - Course IPSI of the 28 at May 30, 1991

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

Code_Aster ®
Version
5.0

Titrate:
SDND100 To release of a shoe rubbing with friction of the Coulomb type
Date:
14/09/01
Author (S):

3 Modeling
With

3.1
Characteristics of modeling

An element of the type DIS_T on a mesh POI1 is used to model the system.
Conditions of relations between degrees of freedom are employed to force the movement to be one-way in the direction:

LIAISON_DDL: (NODE: NO1

DDL
:
("DX"
"DY")

COEF_MULT
:
(0.707
-0.707)

COEF_IMPO
:
0.)

An obstacle of the type PLAN_Z (two parallel plans separated by a play) is used to simulate the plan of slip. One chooses to take for generator of this plan axis OY, that is to say NORM_OBST: (0. , 1. , 0.). The origin of the obstacle is ORIG_OBST: (0. , 0. , 1.). It remains to define its play which gives it
half-spacing enters the plans.

So that there is a force of reaction of the plan on the system it is necessary that this last is slightly inserted in the plane obstacle of a distance N such as: F = K N
N
N.
Like F
Mg
N =

, one has then N = Mg/kN.
One considered a normal stiffness of shock of 20 N/m (fictitious stiffness which has direction only for to generate a force of reaction of the plan on the system), one thus has N = 0,5. Obstacle PLAN_Z having
for origin Z = 1 and the solid being in Z = 0; a play of 0,5m will create a depression N = 0,5 m from where
PLAY: 0.5

Tangential stiffness of shock: KT = 400.000 N/m: it is large in front of the stiffness of the oscillator so that the phase of stop is modelled correctly.

No the time used for temporal integration: 5.104s.

3.2
Characteristics of the grid

A number of nodes: 1
A number of meshs and types: 1 POI1

3.3 Functionalities
tested

Orders

AFFE_CHAM_NO SIZE
"DEPL_R"
PROJ_VECT_BASE VECT_ASSE

PROJ_MATR_BASE MATR_ASSE

STANDARD DEFI_OBSTACLE
"PLAN_Y"
"PLAN_Z"
DYNA_TRAN_MODAL DEPL_INIT_GENE

METHOD
"EULER"
REST_BASE_PHYS SHOCK

4
Results of modeling A

4.1 Values tested

Values of displacements (in meters) in the direction for the moments of change of sign speed over the period of time (0; 0.3 S).

Identification moment
(S) Reference Displacement difference %
Aster
DY = r2 cos45
X 102 4.596E4 4.595E4 0.02
DY = r3 cos45
2 X 102 3.182E4 3.181E4 0.045
DY = r4 cos45
3 X 102 1.768E4 1.767E4 0.07
DY = r5 cos45
4 X 102 3.536E5 3.550E5 0.41

One presents Ci below the evolution of displacement and speed at point NO1

Displacement of point NO1
Speed of point NO1

4.2 Parameters of execution

Version: STA 5.02

Machine: SGI ORIGIN2000

Time CPU To use: 2.21 seconds

Handbook of Validation V5.01 booklet: Nonlinear dynamics of the discrete systems HT-62/01/012/A

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5 Modeling B

5.1 Characteristics of modeling

In modeling B, one regards the shoe and the plan as two mobile structures. Each structure is then modelled by a node and an element of the type POI1. Node NO2 is supposed blocked, it materializes the plan of friction. One imposes conditions of relations between degrees of freedom with the node NO1 (which models the shoe) so that the movement is one-way in direction.

LIAISON_DDL: (NODE: NO1

DDL
:
("DX"
"DY")

COEF_MULT
:
(0.707
-0.707)

COEF_IMPO
:
0.)

An obstacle of the type BI_PLAN_Z (two mobile parallel plans separated by a play) is used for to simulate the slip surface. One chooses to take for generator of this plan axis OY, that is to say

NORM_OBST: (0. , 1. , 0.). By defect, the origin of the obstacle is located at semi distance from the nodes
NO1 and NO2. It remains to define parameters DIST_1 and DIST_2 which represent the thickness of matter around the nodes of shock.

So that there is a force of reaction of the plan on the system it is necessary that this last is slightly inserted in the plane obstacle of a distance N such as: F = K N
N
N.
Like F
Mg
N =
, one has then N = Mg/kN.
One considered a normal stiffness of shock of 20 N/m (fictitious stiffness which has direction only for to generate a force of reaction of the plan on the system), one thus has N = 0,5 Mr. Knowing that both nodes NO1 and NO2 are geometrically confused, one chooses for example DIST_1 = DIST_2 = N /2.

Tangential stiffness of shock: KT = 400.000 N/m: it is large in front of the stiffness of the oscillator so that the phase of stop is modelled correctly.

No the time used for temporal integration: 5.104 S.

5.2 Characteristics of the grid

A number of nodes: 2
A number of meshs and types: 2 POI1

5.3 Functionalities tested

Orders

AFFE_CHAM_NO SIZE
"DEPL_R"
PROJ_VECT_BASE VECT_ASSE

PROJ_MATR_BASE MATR_ASSE

STANDARD DEFI_OBSTACLE
"BI_PLAN_Z"
DYNA_TRAN_MODAL DEPL_INIT_GENE

METHOD
“EULER”
SHOCK
NOEUD_1
NOEUD_2
REST_BASE_PHYS

6
Results of modeling B

6.1 Values
tested

Values of displacements (in meters) in the direction of the oscillator for the moments of change of sign speed over the period of time (0; 0.3 S).

Identification moment
(S) Reference Displacement
difference %
Aster
DY = r2 cos45
X 102 4.596E4 4.595E4 0.02
DY = r3 cos45
2 X 102 3.182E4 3.181E4
-0.029

DY = r4 cos45
3 X 102 1.768E4 1.767E4 0.018
DY = r5 cos45
4 X 102 3.536E5 3.543E5 0.205

6.2 Parameters of execution

Version:
STA 5.02

Machine:
SGI ORIGIN2000

Time CPU To use:
2.3 seconds

---

7 Modeling C

7.1 Characteristics of modeling

This modeling corresponds to the direct transitory response of the rubbing shoe.

The normal direction of contact is the local axis X which corresponds in the case test to total axis Z. It slip surface is the local plan (Y, Z) that is to say the plan (X, Y) in the total reference mark. One thus directs
the element of shock to a node, with the key word ORIENTATION of operator AFFE_CARA_ELEM of following way:

ORIENTATION: (MESH: EL1 CARA: "VECT_X_Y"
VALE: (0. 0. -1. 0. 1. 0.))

To be able to obtain a force of reaction of the plan on the system it is necessary that this last is slightly inserted in the plane obstacle of a distance N such as: F = K N
N
N.
The reaction balances the weight of the shoe, one thus has: F
Mg
N =
i.e. N = Mg/kN.
One considered a normal stiffness of shock of 20 N/m (fictitious stiffness which has direction only for to generate a force of reaction of the plan on the system), one thus has N = 0,5 from where DIST_1 = 0.5.

The tangential stiffness of shock considered is KT = 400.000 N/m, the coefficient of Coulomb is worth 0,1.

The law of behavior of shock is thus in the following way defined in DEFI_MATERIAU:

DIS_CONTACT: (RIGI_NOR: 20.
DIST_1: 0.5
RIGI_TAN: 400000.
COULOMB: 0.1)

One uses a step of times of 5.104 S for temporal integration.

7.2
Characteristics of the grid

A number of nodes: 1
A number of meshs and types: 1 POI1

7.3 Functionalities

tested

Orders

DEFI_MATERIAU DIS_CONTACT

AFFE_CARA_ELEM ORIENTATION
VECT_X_Y
AFFE_CHAR_MECA LIAISON_DDL

AFFE_CHAM_NO

DYNA_NON_LINE ETAT_INIT DEPL_INIT

COMP_INCR
RELATION
DIS_CHOC
HHT

RECU_FONCTION

8
Results of modeling C

8.1 Values
tested

Values of displacements in the direction of the oscillator for the approximate moments of change of sign speed over the period of time (0; 0.2 S).

Identification moments
(S) Reference
displacement
difference %
Aster
DY = r2 cos45
X 102 4,585E04
4,58552E04 0,011
DY = r3 cos45
2 X 102 3,173E04
3,17331E04 0,01
DY = r4 cos45
3 X 102 1,754E04
1,75481E04 0,046
DY = r5 cos45
4 X 102 3,550E05
3,54945E05 0,016

8.2 Parameters
of execution

Version:
STA 5.02

Machine:
SGI ORIGIN2000

Time CPU To use:
94 seconds

Handbook of Validation

9
Summary of the results

The analytical solution of the problem with friction is reproduced with a very good precision (<0.5%). That asks for nevertheless the use of a parameter of tangent stiffness raised enough by report/ratio with the rigidity of the system as well as a step of relatively reduced time of integration. On this example, direct nonlinear calculation is much more expensive in computing times, factor 20, that that on modal basis.

Organization (S): EDF/RNE/AMV

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.101 document

SDND101 - To release of a system masses spring with shock

Summary

This problem corresponds to a transitory analysis by modal recombination of a nonlinear discrete system with a degree of freedom. Non-linearity consists of a contact with shock on a rigid level. The mass is launched with a nonnull initial speed against the obstacle. The initial play between the material point and the obstacle is null. It problem makes it possible to test the postprocessing of the forces of impact: velocity impact, duration of shock…

Version
5.0

Titrate:
SDND101 Lâcher of a system masses spring with shock

Date:
30/08/01
Author (S):
Fe WAECKEL, G. JACQUART Key
:
V5.01.101-B Page:
2/6

1
Problem of reference

1.1 Geometry

K
m
Kchoc
. Uo

1.2
Properties of materials

The system consists of a mass m and a spring of stiffness K. The thrust of shock has a stiffness equalize in Kchoc.

Mass
m = 100 kg
Stiffness
K = 104 N/m
Normal rigidity of shock
Kchoc = 106 N/m

1.3 Conditions
initial

The system is initially in position at rest (U0 = 0) and has an initial speed &

U0 > 0. One
will choose for the application an initial speed &
U0 = 1 m/s.

2
Reference solution

2.1
Method of calculation used for the reference solution

During the phase of impact, the system is solution of the differential equation:

m.u& + k.u + K U + = 0 with U = 0 and U
0
& = U
C
0
&.
0
X + indicates the positive value of X.

The analytical solution of this problem is:

U&

K + K
U =
0
(
sin T
C
c)
=

where C
.
C
m

Speed is cancelled for tu&= =
0
2 .
C
U&
The force of shock is then maximum and is worth F
= K U (T
) = K
0
max
C
u&=0
C.
C
By construction, the duration of the shock is worth T
= 2t
shock
u&=0.

The system returns to the position U = 0 with speed - &
U0.

In the field U < the 0 system has as an equation m.u& + k.u = 0 with for initial conditions
u1 = 0 and &u1 = - &
U.
0
U&
K
0

Its solution is U = -
if (
N .t
0
) where =
0

.
m
0

Speed is cancelled for: T
=
u&=0
2 .
0
By construction, the time of coasting flight is worth: Tvol = 2t u&=0.

The system is thus periodic with alternatively a phase of time of shock of Tchoc duration where the system describes an arch of sine in the field of U > 0 and one phase of coasting flight of duration Tvol where the system describes an arch of sine in the field of U < 0.

Tchoc
U&
2mU
0
&
The impulse with each impact is worth: I =
K U (T) dt = 2K

0
C
C
=
.
2

K
0
C
1 +

Kc

2.2
Results of reference

The results taken for reference are the values of the moments of maximum force, the value of force maximum, duration of the time of shock, the value of the impulse and impact speed as well as impact elementary for the first two oscillations of the system numbers.

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
G.JACQUART: Postprocessing of calculations of heart and interns REFERENCE MARK under request
seismic - HP-61/95/074/A.
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

---

3 Modeling
With

3.1
Characteristics of modeling

The system mass-arises is modelled by an element of the type POI1 to node NO1. It is fixed with to move according to axis X. Node NO1 is positioned out of O = (0. 0. 0.).

*An obstacle of the type PLAN_Z (two parallel plans separated by a play) is used to simulate them possible shocks of the system mass-arises against a rigid plan. One chooses to take axis OY for normal in the plan of shock, is NORM_OBST: (0. , 1. , 0.). Not to be obstructed by the rebound of the oscillator on the symmetrical level, one very pushes back this one far (cf [Figure. 3.1-a]). One thus chooses
to locate the origin of the obstacle in ORIG_OBS: (- 1. 0. 0.).*

Yloc
PLAY
K
m
Zloc
X
ORIG_OBS
NO1
(-1, 0, 0)
U0 (0,0,0)
Appear 3.1-a: Modelled geometry

*It remains to define the parameter PLAY which gives the half-spacing between the plans in contact. One
wish here a play real no one, from where PLAY: 1. If one wishes a real play of J, it is necessary, in the case of figure
presented, to impose PLAY: 1+ J.*

*Temporal integration is carried out with the algorithm of Euler and a step of times of 5.10-4 S. All them
no calculation are filed. It is considered that damping reduces I for the whole of the modes calculated is null.*

3.2
Characteristics of the grid

The grid consists of a node and a mesh of the type POI1.

3.3 Functionalities
tested

Orders

Keys Doc. V5
“MECHANICAL” AFFE_MODELE
“DIST_T”
[U4.41.01]
DISCRETE AFFE_CARA_ELEM
M_T_D_N

[U4.42.01]

K_T_D_N

AFFE_CHAR_MECA DDL_IMPO

[U4.44.01]
MODE_ITER_INV OPTION
NEAR

[U4.52.04]
AFFE_CHAM_NO SIZE
“DEPL_R”
[U4.44.11]
PROJ_VECT_BASE VECT_ASSE

[U4.63.13]
PROJ_MATR_BASE MATR_ASSE

[U4.63.12]
STANDARD DEFI_OBSTACLE
“PLAN_Z”
[U4.44.21]
DYNA_TRAN_MODAL ETAT_INIT
VITE_INIT_GENE

[U4.53.21]
SHOCK

POST_DYNA_MODA_T RESU_GENE

[U4.84.02]

4
Results of modeling A

4.1 Values
tested

For the first two shocks, one compares with the analytical values the computed values of the moment where the impact occurs, of the maximum force of shock, the time of shock, the impulse and speed of impact. One also tests the value of the absolute extremum force of impact.

First shock:

Time (S)
Reference
Aster %
difference
INST 1,5630E02
1,55000E02
-0,832
F_MAX 9,9500E+03
9,95269E+03 0,027

T_CHOC 3,1260E02 3,15000E02 0,768
IMPULSE 1,9805E+02 1,98093E+02
0,022
V_IMPACT 1.
1,00031E+00
0,031

Second shock:

Time (S)
Reference
Aster %
difference
INST 3,6100E01
3,61000E01
0
F_MAX 9,9500E+03
9,95478E+03
0,048
T_CHOC 3,1260E02
3,15000E02
0,768
IMPULSE 1,9805E+02
1,98093E+02
0,022
V_IMPACT 1,0000E+00
1,00031E+00
0,031

Time (S)
Reference
Aster %
difference
F_MAX_ABS 9,95E+03
9,95478E+03
0,048

4.2 Parameters
of execution

Version: STA 5.02
Machine: SGI Origin 2000

Time CPU to use: 2,2 seconds
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

5
Summary of the results

One notes, on the whole of the sizes, a very good agreement with the produced analytical solution.
The sizes the least best represented are the duration of shock and the moment of shock (to better than 1%
however). This problem is not related on the precision of calculation but to the only fact that a step of time
of integration of 5.10-4 S.A. be selected what over durations as short as 0,03 S produces already one
temporal inaccuracy of 1,66%. To supplement this synthesis, one could carry out a test of
convergence by decreasing the step of calculation.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.102 document

SDND102 - Seismic response of a system
mass-arises nonlinear multimedia

Summary

The problem consists in analyzing the response of a mechanical structure, modelled by two systems mass-arises not deadened, subjected to a seismic loading of harmonic type, with possibility of shock.

One tests the discrete element in traction and compression, the calculation of the clean modes and the static modes, it
calculation of the transitory response by nonlinear modal recombination of a structure subjected to one
accélérogramme (modeling A) as well as the calculation of the direct transitory seismic response of a structure
nonlinear (modeling B).
This case test is also used to validate a calculation with explicit resolution on accelerations and shock (modeling C)
by comparing the results resulting from DYNA_NON_LINE and DYNA_TRAN_EXPLI.

The results obtained are in very good agreement with the results of reference.
Handbook of Validation

---

1 Problem of reference

1.1 Geometry

One compares the seismic response of a system mass-arises with a degree of freedom which can impact
a fixed wall (problem 1) with that of two systems mass-arises identical being able
entrechoquer and subjected to the same seismic request (problem 2).

With K m
B
C
X
K
m
m K
X
1
1
2= -

Problem 1
Problem 2

1.2
Material properties

Stiffness of the springs: K = 98696 N/m.
Specific mass: m = 25 kg.

For problem 1 (impact on a rigid wall), the normal rigidity of shock is worth Kchoc = 5,76 107 N/m.
As for problem 2 (shock of two deformable structures), it is worth Kchoc = 2,88 107 N/m.
In both cases, the damping of shock is null.

1.3
Boundary conditions and loadings

Boundary conditions

Only authorized displacements are the translations according to axis X.
The points A, B and C are embedded: dx = Dy = dz = 0.

Loading

The points of anchoring A and B are subjected to an acceleration according to direction X: 1 (T) = sin T
with = 20. s1 and the point C with an acceleration 2 (T) = - sin T.

1.4 Conditions
initial

In both cases, the systems mass-arises are initially at rest:
with T = 0, dx (0) =0, dx/dt (0) = 0 in any point.
For problem 1, the mass is separated from the fixed wall of the play J = 5. 104 Mr. As for problem 2, the masses are separated from the play J = 2 J = 103 Mr.

2
Reference solution

2.1
Method of calculation used for the reference solution

It is a question of comparing the response of a symmetrical system consisted two systems mass-arises identical to the response of a system mass-arises. Two problems, explained in detail in reference [bib2], are requested by same the accélérogramme.

One calculates the Eigen frequencies initially fi, the standardized associated clean vectors compared to modal mass Ni and the static modes of the system (analytical values). One calculate then the generalized response of the system multimedia while solving analytically the integral of Duhamel [bib1]. Lastly, one restores on the physical basis the relative displacement of the nodes of shock what allows us, after having calculated the field of displacements of drive, of to calculate the field of absolute displacements.

One calculates the definite function diff as being the difference between absolute displacement of the node shocking on a mobile obstacle and that of the node shocking on a fixed obstacle. It is checked that it is quite null for various moments.

2.2
Results of reference

Displacements relating and absolute to the nodes of shock.

2.3
Uncertainty on the solution

Comparison between two equivalent modelings.

2.4 References

bibliographical

[1]
J.S. PRZEMIENIECKI: Structural Theory of matrix analysis New York, Mac Graw - Hill, 1968, p. 351-357.
[2]
Fe. WAECKEL: Use and validation of the developments carried out to calculate seismic response of multimedia structures - HP52/96.002.
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-66/03/008/A

---

3 Modeling
With

3.1
Characteristics of modeling

The systems mass-arises are modelled by discrete elements with 3 degrees of freedom DIS_T.

Modeling of problem 1:

Yloc
Y
I
J
Zloc
K
X

*orig_*
m
no1
no2
1

Appear 3.1-a: Modeling of a system mass-arises impacting a rigid wall

The node no1 is subjected to an imposed acceleration 1 (T). One calculates the relative displacement of the node
no2, its displacement of drive and its absolute displacement.
An obstacle of the type PLAN_Z (two parallel plans) is retained to simulate the impact of the system mass-arises on a rigid wall. The normal in the plan of shock is axis Z, NORM_OBST: (0. 0. 1.). Not to be obstructed by the rebound of the oscillator on the symmetrical level, one pushes back this one
very far (cf [Figure 3.1-a]).
From where:
· the origin of obstacle ORIG_OBST: (1. 0. 0.) ;
· and play corresponding play: 1.1005

Modeling of problem 2:

Y
dist_1
dist_2
J
K
K
X
m
m
NO1
NO2
NO3
NO4
1
2= -1

Appear 3.1-b: Modeling of two systems mass-arises which are entrechoquent

Node NO1 is subjected to an imposed acceleration 1 (T), node NO4 to 2 (T) = 1 (T). One calculates the relative displacement of nodes NO2 and NO3, their displacement of drive and their displacement absolute.
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems

The conditions of shock between the two systems mass-arises are simulated by an obstacle of the type BI_PLAN_Z (plane obstacle between two mobile structures). The normal in the plan of shock is selected according to axis Z, that is to say NORM_OBST: (0. 0. 1.).
The thicknesses of matter surrounding the nodes of shock in the direction considered are specified by operands DIST_1 and DIST_2. In the treated case, one chooses DIST_1 = DIST_2 = 0.4495 for that at the initial moment, the two nodes of shock are separated from the play J = 2 J = 103 mm (cf [Figure 3.1-
B]).

Temporal integration is carried out with the algorithm of Euler and a step of times of 2,5. 104s.
calculations are filed all the 8 steps of time.
One considers a reduced damping of 7% for the whole of the calculated modes.

3.2
Characteristics of the grid

One calls model the grid associated with the problem made up of a system mass-arises butting against a fixed wall and bichoc that which is associated problem 2.

Grid associated with the model model:

a number of nodes: 2;
a number of meshs and types: 1 DIS_T.

Grid associated with the model bichoc:

a number of nodes: 4;

a number of meshs and types: 2 DIS_T.

3.3 Functionalities tested

Orders

AFFE_MODELE GROUP_MA
"MECHANICAL"
"DIS_T"
DISCRETE AFFE_CARA_ELEM GROUP_MA M_T_D_N

GROUP_MA
K_T_D_L
AFFE_CHAR_MECA DDL_IMPO
GROUP_NO
MACRO_MATR_ASSE

MODE_ITER_SIMULT METHOD
JACOBI

CALC_FREQ
BANDAGE

NORM_MODE NORMALIZES
MASS_GENE

MODE_STATIQUE DDL_IMPO

CALC_CHAR_SEISME MONO_APPUI

MULTI_APPUI

MACRO_PROJ_BASE

DEFI_OBSTACLE PLAN_Z

BI_PLAN_Z

DYNA_TRAN_MODAL EXCIT
MULT_APPUI
"YES"
AMOR_REDUIT

METHOD
EULER

REST_BASE_PHYS MULT_APPUI
"YES"

RECU_FONCTION RESU_GENE

4
Results of modeling A

4.1
Values tested of modeling A

One calculates the definite function diff as being the difference between absolute displacement of the node
NO2 and that of the node no2. And it is checked that it is quite null for various moments.

Time (S)

Reference
Aster
Absolute error
0,1 0,0
5,8884E-07
5,89E-07
0,3 0,0
1,8891E-06
1,89E-06
0,5 0,0
1,5586E-07
1,56E-07
0,7 0,0
1,8213E-06
1,82E-06
1 0,0
1,7231E-06
1,72E-06

One also tests the value of the absolute displacement of node NO2 for various moments.

Time (S)
Reference
Aster
Absolute error
(problem 2)
0,05 3,58082E-04
3,5808E-04
1,71E-10
0,156 1,22321E-04 1,2232E-04
4,72E-10
0,25 1,8876E-04 1,8876E-04
1,96E-11
0,4 1,89772E-04
1,8977E-04
1,22E-10
0,5 6,84454E-05
6,8445E-05 4,72E-11
0,8 1,11982E-04
1,1198E-04
1,71E-11
0,9 1,20103E-04
1,2010E-04

1,37E-10
1 1,07178E-04
1,0718E-04
3,31E-10

One represents Ci below the pace of displacements relating and absolute to node NO2:

Absolute displacements
Relative displacements

---

5 Modeling B

5.1 Characteristics of modeling

The systems mass-arises are modelled, as in modeling A, by a discrete element with 3 degrees of freedom DIS_T.

Modeling of problem 1:
Y
Play
dist_1

K
m
NO1
NO2
1
elm1

Appear 5.1-a: Modeling of a system mass-arises impacting a rigid wall

Node NO1 is subjected to an imposed acceleration 1 (T). One calculates the relative displacement of the node
NO2, its displacement of drive and its absolute displacement.
An element of the type DIST_T on a mesh POI1 is retained to simulate the impact of the beam on one rigid wall: the possible shocks between the beam and the obstacle are taken into account as being forces intern with this element. One affects to him a nonlinear behavior of type shock (stiffness) via law of behavior DIS_CONTACT of order DEFI_MATERIAU.
The thickness of matter surrounding the node of shock in the direction considered is specified by operand DIST_1 of order DEFI_MATERIAU. In the treated case, one chooses DIST_1 = 0.4495 and PLAY = 0.45 so that at the initial moment, the node of shock and the obstacle are separated from the play J = 5. 104
mm (cf [Figure 5.1-a]).

The seismic loading, due to imposed displacements of node NO1, is calculated by the operator CALC_CHAR_SEISME. One creates then a concept charges starting from operand VECT_ASSE of order AFFE_CHAR_MECA.

One uses the diagram of integration of NEWMARK of DYNA_NON_LINE with a step of times of 103 S and default settings.

Modeling of problem 2:

Y
dist_1
dist_2
J
K
K
X
m
m
NO1
NO2
NO3
NO4

1
2= -1

Appear 5.1-b: Modeling of two systems mass-arises which are entrechoquent
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-66/03/008/A

Node NO1 is subjected to an imposed acceleration 1 (T), node NO4 to 2 (T) = 1 (T). One calculates displacements relative and absolutes of nodes NO2 and NO3, their displacement of drive and them absolute displacement.

The possible shocks between the two beams are taken into account as being internal forces with one element with two nodes. One assigns to this element a nonlinear behavior of type shock (stiffness) via key word RIGI_NOR of the law of behavior DIS_CONTACT of order DEFI_MATERIAU.
The normal direction of contact is the local axis X of the discrete element with two nodes.

The thicknesses of matter surrounding the nodes of shock in the direction considered are specified by operands DIST_1 and DIST_2 of order DEFI_MATERIAU. In the treated case, one DIST_1 chooses = DIST_2 = 0.4495 so that at the initial moment, the two nodes of shock are separate play J = 2. J = 103 m (cf [Figure 5.1-a]).

The seismic loading, due to imposed displacements of anchorings (node NO1 and NO4, is calculated by operator CALC_CHAR_SEISME. One creates a concept charges starting from the operand
VECT_ASSE of order AFFE_CHAR_MECA.

Temporal integration is carried out with the algorithm of Newmark and a step of times of 103 S. Them calculations are filed all the 8 steps of time.
One considers a reduced damping of 7% for the whole of the calculated modes (key word

AMOR_MODAL of operator DYNA_NON_LINE).

5.2
Characteristics of the grid

The grid associated with the model bichoc consists of 4 nodes and 3 meshs of the type DIS_T.

5.3 Functionalities
tested

Orders

AFFE_MODELE GROUP_MA
"MECHANICAL"
"DIS_T"
DISCRETE AFFE_CARA_ELEM
GROUP_MA M_T_D_N

GROUP_MA
K_T_D_L
DEFI_MATERIAU DIS_CONTACT
DIST_1

DIST_2

PLAY

AFFE_CHAR_MECA DDL_IMPO GROUP_NO
VECT_ASSE

MODE_STATIQUE DDL_IMPO

CALC_CHAR_SEISME MULTI_APPUI

DYNA_NON_LINE AMOR_MODAL

MODE_STAT

EXCIT

MULT_APPUI
"YES"
COMP_INCR
DIS_CHOC

RECU_FONCTION SIEF_ELGA

DEPL

DEPL_ABSOLU

CALC_FONCTION MAX

COMB

6
Results of modeling B

6.1
Values tested of modeling B

One calculates the definite function diff as being the difference between absolute displacement of the

node
NO2 and that of the node no2. And it is checked that it is quite null for various moments.

Time (S)
Reference
Aster
Absolute error
0,1 0,0
1,7144E-17
1,71E-17
0,2 0,0
5,1386E-16
5,14E-16
0,3 0,0
5,1365E-16
5,14E-16
0,4 0,0
2,1570E-15
2,16E-15
0,5 0,0
2,7105E-19
2,71E-19

One also tests the maximum value of the force of impact to node NO2.

Type of impact
Reference
Aster
Relative error
against a rigid wall
6,29287E+02
6,29292E+02
7,21E-06
between two mobile structures 6,29287E+02 6,29292E+02 7,21E-06

7 Modeling C

7.1 Characteristics of modeling

Modeling C is before a whole test of DYNA_TRAN_EXPLI, whose results are compared with DYNA_NON_LINE.
The systems mass-arises are modelled, as in modeling A, by a discrete element with 3 degrees of freedom DIS_T. Only modeling with a degree of freedom is tested.

Modeling of the problem:

Y
Play
dist_1
K
m
NO1
NO2
1
elm1

Appear 7.1-a: Modeling of a system mass-arises impacting a rigid wall

Node NO1 is subjected to an imposed acceleration 1 (T). One calculates the relative displacement of the node
NO2, its displacement of drive and its absolute displacement.
An element of the type DIST_T on a mesh POI1 is retained to simulate the impact of the beam on one rigid wall: the possible shocks between the beam and the obstacle are taken into account as being

forces intern with this element. One affects to him a nonlinear behavior of type shock (stiffness) via law of behavior DIS_CONTACT of order DEFI_MATERIAU.
The thickness of matter surrounding the node of shock in the direction considered is specified by operand DIST_1 of order DEFI_MATERIAU. In the treated case, one chooses DIST_1 = 0.4495 and PLAY = 0.45 so that at the initial moment, the node of shock and the obstacle are separated from the play J = 5. 104
mm (cf [Figure 5.1-a]).

The seismic loading, due to imposed displacements of node NO1, is calculated by the operator CALC_CHAR_SEISME. One creates then a concept charges starting from operand VECT_ASSE of order AFFE_CHAR_MECA.

One uses the diagram of integration of explicit NEWMARK of type DIFFERENCES CENTREES with a step of times of 103 S. calculation by DYNA_TRAN_EXPLI is carried out in modal space, non-linearity being due to the shock and thus resident local.

7.2
Characteristics of the grid

The grid associated with the model consists of 2 nodes, of a mesh SEG2 of the type DIS_T and one specific mesh POI1 of the type DIS_T.

7.3 Functionalities tested

Orders

AFFE_MODELE GROUP_MA
“MECHANICAL”
“DIS_T”
DISCRETE AFFE_CARA_ELEM
GROUP_MA M_T_D_N

GROUP_MA
K_T_D_L
DEFI_MATERIAU DIS_CONTACT
DIST_1

DIST_2

PLAY

AFFE_CHAR_MECA DDL_IMPO GROUP_NO
VECT_ASSE

MODE_STATIQUE DDL_IMPO

CALC_CHAR_SEISME MONO_APPUI
“YES”
DYNA_NON_LINE AMOR_MODAL

MODE_STAT

COMP_INCR
DIS_CHOC

DYNA_TRAN_EXPLI AMOR_MODAL

PROJ_MODAL

COMP_INCR
DIS_CHOC

RECU_FONCTION

---

8 Results of modeling C

8.1 Values tested of modeling C

Calculation is non-linear because of the shock and one does not have analytical solution. One thus tests calculation on values of not-regression on displacement according to X of node NO2.

Time (S)	**Reference**	***Aster***	**Relative error**
0,1	15,6520E-3	15,6520E-3	<1E-3%
0,2	51,4832E-3	51,4832E-3	<1E-3%
0,3	28,1291E-3	28,1291E-3	<1E-3%
0,4	44,9343E-3	44,9343E-3	<1E-3%
0,5	37,7508E-3	37,7508E-3	<1E-3%

One compares absolute displacements resulting from DYNA_TRAN_EXPLI with those given by DYNA_NON_LINE.

9
Summary of the results

The results obtained with *Code_Aster* are in conformity with those awaited (error lower than thousandths).
On this example, direct nonlinear calculation is much more expensive in computing times, of one factor 20, that that on modal basis.

Modeling C shows that one obtains many similar results with a method
of explicit temporal integration (DYNA_TRAN_EXPLI) and implicit (DYNA_NON_LINE).

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Organization (S): EDF/RNE/AMV, CS IF

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.103 document

SDND103 - Post subjected to a request
axial dynamics

Summary

It is a question of calculating the response of a post subjected to an unspecified seismic loading. The post is
modelled by a system mass-arises not deadened, its connection with the ground by a non-linearity of the type
effort-displacement.

The discrete element in traction and compression, the calculation of the clean modes and the calculation of the answer are tested
transient by modal recombination with taking into account of a non-linearity of the effort-displacement type.
initial speed is taken nonnull and the loading is of acceleration type imposed on the ground.

The results obtained are in very good agreement with the results of reference which are results analytical.

1
Problem of reference

1.1 Geometry

The system consists of a post resting on the ground and subjected to a seismic request. It is modelled by a mass, its connection with the ground by a spring k0 of which the relation of behavior translated a non-linearity of the effort-displacement type.

X
L
k0
Y

Characteristics of the post:

length: L = 2 m;
section: S = 0,3 m2.

1.2
Properties of materials

Mass post: m = 450 kg.
Stiffness within the competence of connection: k0 = 105 N/m.

1.3
Boundary conditions and loadings

Boundary conditions

Only authorized displacements are the translations according to axis X: Dy = dz = 0.

Corrective force FC due to nonthe linearity of the ground is defined by the following relation:
F (X
)

X
F (X)
threshold
F (X
C
=
-
) with, if X > X
, F (X) = K 1 -
. X.
X
threshold
0
threshold

x0
One takes xseuil = 10-6m, k0 = 105 N/m and x0 = 0,1 Mr.
One thus imposes under key word RELA_EFFO_DEPL of operator DYNA_TRAN_MODAL
K
function: F (X) = 0 X. [X - X
C
threshold].
x0

Loading

The ground is subjected to an acceleration (T) in direction X, built so that it
displacement of the system mass-arises is sinusoidal X = a.si (
N T
) with A = 0,01 and = /4.

1.4 Conditions initial

In the initial state, the system is released of its position of balance with a speed v0: with T = 0, dx (0) = 0,
v0= dx/dt (0) = A.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

This test is developed in detail in the reference [bib1].

The fundamental equation of dynamics, moving relative of the system mass-arises by
K (X)
report/ratio on the ground is written: +
X = (T)
&
X
.
m
For a displacement of the form X = a.si (
N T) and x& = - have 2

(
sin T), one obtains from
the equation of the movement the form of the accélérogramme:

K
sin T has
(T) = has (
sin
T)
( )

- 2 + 0 1-

.
m
X

0

1
K
The fundamental frequency F
0
0 of the oscillator not deadened are worth F 0 = 2
.
m

2.2
Results of reference

Fundamental frequency F 0 of the oscillator not deadened.
Displacements relating to moments 2, 6, 10, 14 and 18 seconds.

2.3
Uncertainty on the solution

No if one calculates the integral of Duhamel analytically [bib2].

2.4 References
bibliographical

[1]
P. LALUQUE, P. LABBE, S. PETETIN and A. TIXIER: Seismic response of a building engine PWR1300 by taking account of separation enters the foundation and the ground. Note SEPTEN TA83.06 (May 1984).
[2]
J.S. PRZEMIENIECKI: Theory of matrix structural analysis. New York, Mac Graw-Hill, 1968, p. 351-357.

---

3 Modeling
With

3.1
Characteristics of modeling

The system mass-arises is modelled by a discrete element DIS_T.

X
m
k0
Y

Numerical data:

for the system mass-arises: m = 450 kg
for the ground:
k0 = 105 N/m
for non-linearity:
x0 = 0,1 m; has = 0,01 and = /4.

Temporal integration is carried out with the algorithm of Euler or the algorithm of Devogelaere and one no times of 0,02 second. Calculations are filed all the steps of time.
One considers a damping reduces no one for the whole of the calculated modes.
I

3.2
Characteristics of the grid

The grid consists of a node and a mesh of the type POI1.

3.3 Functionalities
tested

Orders

Keys Doc. V5
FORMULATE

[U4.31.05]
CALC_FONC_INTERP

[U4.32.01]
AFFE_MODELE GROUP_MA
“MECHANICAL”
“DIS_T”
[U4.41.01]
AFFE_CHAR_MECA DDL_IMPO

[U4.44.01]
DISCRETE AFFE_CARA_ELEM
NET

M_T_D_N
[U4.42.01]

GROUP_MA
K_T_D_L

MODE_ITER_SIMULT CALC_FREQ
PLUS_PETITE
[U4.52.03]
CALC_CHAR_SEISME MONO_APPUI

[U4.63.01]
MACRO_PROJ_BASE

[U4.63.11]
DYNA_TRAN_MODAL ETAT_INIT

[U4.53.21]
RELA_EFFO_DEPL

POST_DYNA_MODA_T RESU_GENE

[U4.84.02]
RELA_EFFO_DEPL

REST_BASE_PHYS

[U4.63.21]
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

4
Results of modeling A

4.1 Values tested

One checks the Eigen frequency of the oscillator as well as displacements relative of node NO1 to various moments (for the algorithm of integration EULER).

Frequency (Hz)
Reference
***Code_Aster** Error*
(%)
2,37254
2,37254
0

Relative displacement of node NO1 with the numerical algorithm of integration of Euler:

Time (S)
Reference
***Code_Aster** Error*
(%)
2 0,01
9,99988E03
0,001
6 -0,01
9,99985E03
0,002
10 0,01
9,99990E03
0,001
14 -0,01

9,99985E03
0,001
18 0,01
9,99987E03
0,001

Relative displacement of node NO1 with the numerical algorithm of integration of Devogelaere:

Time (S)
Reference
Code_Aster *Error*
(%)
2 0,01
9,99991E03
8,88E06
6 -0,01
9,99981E03
-0,002
10 0,01
9,99992E03
7,72E06
14 -0,01
9,99988E03
-0,001
18 0,01
9,99982E03
-0,002

4.2 Parameters of execution

Version: STA5.02
Machine: SGI Origin 2000
Time CPU to use: 3,6 seconds
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5
Summary of the results

One notes a very good agreement with the analytical solution (error lower than 0,01%).

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.104 document

SDND104 - Calculation of the power of wear of one
mass rubbing under seismic excitation
harmonic

Summary:

One considers a mass in contact rubbing with a rigid plan on which one imposes a vibratory movement of
harmonic type. Friction is modelled by the law of Coulomb. The calculation of the response of the mass is of
nonlinear transitory type. One calculates the power of wear resulting from the phases of slip between
mass and the rigid plan. The calculation of the power of wear being developed in Aster only for calculations
modal, the analysis is carried out on the basis of modal system (commonplace). In order to avoid the numerical problems
resulting from the nullity of the single mode of rigid body of the mass, a spring far from stiff is introduced, flexible
mass at a point interdependent of the vibrating rigid plan.

The reference solution is a quasi analytical calculation of the transitory answer, of which estimates numerical are programmed with Maple.

Single Aster modeling retained tests the explicit algorithms of integration with constant step of Euler (order 1) and Devogeleare (order 4), as well as the algorithm with variable step ADAPT (order 2) developed in
order DYNA_TRAN_MODAL, for various amplitudes of the harmonic acceleration of excitation

seismic of the rigid plan of support. According to this amplitude, the mode of the response of the mass is of the type
member for any time (stick), successively member and slipping (stick-slip), or always slipping with inversion of the direction of slip (slipway-slipway).

Account is returned owing to the fact that in the case of a sufficiently low amplitude of excitation (first mode,
permanent adherence), the power of wear is strictly null.

1
Problem of reference

1.1 Geometry

The system considered consists of a simple heavy mass posed on a rigid support subjected to
an imposed vibration of type seismic, sinusoidal. The contact, as well as solid friction are
modelled by penalization. The system thus has two degrees of freedom of translation (horizontal and vertical).

RZ
RY
M
X-ray
F

A very weak spring of stiffness connects the mass to the support in the three directions. This spring is one
artifice of calculation, intended to avoid the nullity of the frequency associated with the rigid mode with translation
horizontal of the mass. Fascinating the Aster results account the presence of this spring are little different from the results which one would obtain without spring.

1.2
Properties of the model

Stiffness of the spring (according to the three directions):
K = 3.10-5 N/m,
mass:
m = 1 kg,
gravity:
G = 10 m/s2
coefficient of Coulomb:
µ = 0,1.

1.3
Boundary conditions, conditions initial and loadings

The mass rests on the rigid level with the dimension Z = 0.

The harmonic acceleration imposed on the base has as an equation has = has sin (T
). In particular, it is
0
null at the initial moment. The displacement of the support satisfies equation X (T) = - (A/2
) sin (T
), and
0
thus its movement starts towards the left, with nonnull initial speed &
X ()
0 = - has/.
0

The initial displacement (with T = 0) of the mass is taken null. The mass is regarded as in state of adherence at the initial moment. It thus has same nonnull speed as the support with T = 0.

Calculations are carried out for various values of maximum acceleration:

= 15 m/s 2 has, has = 15
, m/s 2, has = 1 0

, 1 m/s 2 and has = 0 9
, 9 m/s 2
0
0
0
0

and a value of pulsation: = 2.

2
Reference solution

The reference solution, which is analytical, is calculated in the following way.
That is to say X (T) the X-coordinate of the mass in the fixed reference mark and X (T) the X-coordinate of the vibrating support in it
even reference mark.

Initially, it is supposed that the mass is adherent on its support. It then remains to it certain
time after the initial moment T = 0. It undergoes of this fact the acceleration imposed by the rigid support, that is to say
&
X (T) = &X (T) = has sin T
. The tangential force exerted by the mass on the support is then
0
F = - mx& (T) = - my sin T

(null at the moment initial, which justifies the starting assumption
T
0
that initially, the mass is adherent on its support). The mass remains adherent as long as
F = my sin T

μ
μ
. If G has
μ, the mass thus remains indefinitely adherent on sound
0
F = Mg
T
NR
0
support, and its movement is exactly the same one as this one. By introducing the coefficient
μg
adimensional =
, the condition of permanent adherence is written 1. The curve of acceleration
a0
mass, like support, then takes the following form according to time:

4
2
0.2
0.4
0.6
0.8
-2
-4

As for speed, it takes the following form (single primitive of null average):

0.4
0.2
0.2
0.4
0.6
0.8
-0.2

-0.4

If a0 > G
μ, there exists a smaller time T = T such as F = my sin T

μ
. This the smallest
0
1 =
Mg
1
T
time is necessarily such as sint > 0, which makes it possible to remove the absolute value in
0
1
G
μ
1
the preceding expression, and to obtain expression clarifies T =
arcsin
= arcsin. In
1

has

0
T
2

private individual, T
=
=
1
4
4
2 .

After this moment, the mass slips towards the left compared to the support, therefore it checks the equation
dynamics &x (T) = G
µ, is &x (T) = G
µ (T - T)
. Its speed thus increases linearly with
1
+ &x (T) 1
has
has
time, while leaving to T the negative value X T
0
= -
T
0
2
= -
1 - (indeed,
1
& ()
cos
1
1

sint =).
1

X ''
driven G

X ''
T
- driven G
X'
x'
T1
t2 T3
t4
T

*Movement for > *, mode of "stick-slip", succession of adherence and slip*

Necessarily, for a certain value of time T satisfactory/
2 T
, speed
2

2 /
2
mass becomes again equal at the speed of the support. At this moment, the movement becomes again adherent if
and only if the acceleration which the mass at the beginning of adherence undergoes is lower in value absolute with µg. One examines the translation of this condition in the continuation. One expresses for
to begin the value of T.
2

5/12

has
has
Time T satisfies equation X T
= X T, is µg (T - T)
0
-
cos T
0
= -
cos T, or
2
& ()
2
& ()
2
2
1

1

2
still (T - T) - cost + cost = 0.
2
1
1
2

This equation, transcendent, allows the determination of T according to T and, that is to say finally,
2
1
taking into account the expression of T, the determination of T according to the physical parameters of
1
2
system and. If the acceleration of the support in T is lower in absolute value than µg, it
2
movement remains adherent then up to one moment T for which the acceleration of the support and of
3
mass reach the value - µg, moment which for reasons of clear symmetries on graphs Ci
above, exactly satisfied T = T +/. The mass starts a phase of slip then

3
1
up to one moment T, after which the movement reproduces periodically.
4

It is understood that for sufficiently small values of, the movement will not be able to become member as from time T, because the acceleration of the mass would exceed the threshold µg. There thus exists
2
*a value criticizes * such as for > *, the movement of the mass passes without phase of adherence of a slip to a shift in opposite meaning. A reflexion on the continuity of function response of speed of the mass compared to the parameter shows that for *, it later movement is always slipping (mode of "slipway-slipway", of alternate directions). For < *, it movement periodically alternates phases of adherence and slip.*

*The value criticizes * admits a simple analytical expression. Indeed, for = *, the moments T*
2
and
T are confused. Thus T - T = T - T =/and the equation
3
2
1
3
1
(T - T) - cost + cost = 0
2
*becomes * = 2*
T = 2 1
. While passing squared, one
1
*- **
cos
2
1
1
2
2
*2*2 obtains*
4

*4 *2*
= -
*, that is to say * =*
,

0 537 .
2 + 4

*For *, the movement is only asymptotically periodic. The continuation (T) of the moments of*
N
change of direction of slip checks T
/when N tends towards the infinite one. The figure
1 - T

n+
N
below shows the typical pace (broken line) the speed of the mass in the situation of slipway-slipway.

*Movement for *: mode of "slipway-slipway", no adherence*

Let us summarize the conclusions:
µg
2
There is the adimensional coefficient =
*and its value criticizes * such as * =*
,
0 537 .
has
2
0

+ 4

*If * < < 1 the established mode is of type “stick-slip”: alternation of phases of adherence and of slip;*

*If < *,*
the established mode is of type “slipway-slipway”: alternate permanent slip;
If > 1,

the established mode is of type “stick”: permanent adherence with the base.

In the results of analytical comparison calculation/Aster which follow, the choices of the amplitude have
0
are such as these three situations are visited. One takes m indeed = 1 kg, G = 10 m/s 2, µ = 0 1
, ,

= 15 m/s 2 has, has = 15
, m/s 2, has = 1 0
, 1 m/s 2 and has = 0 9
, 9 m/s 2.
0
0
0
0

The power of wear is physically null at the time of the phases of adherence.
In Aster, with operator DYNA_TRAN_MODAL used here, adherence is not detected bus
the integration of the movement is made by regularization of the law of friction. The respect of the null result
power of wear during phases of adherence required the introduction of a criterion on
speed of slip, so that in lower part of a certain value, it must regarded as null, and
the adherent movement. One can consult the reference material Opérateur of calculation of wear/Model of Archard [R7.04.10].

During the phases of slip, the power of wear follows the law P (T) = m
µ Steam Generator (T), where
U
R
V (T) = x& (T) - X& (T) is the relative speed of slip of the mass on the support. In the situation
R
mode of stick-slip, for which the movement becomes strictly periodic at the end of one
finished time, the energy of wear during a half-period is exactly

T
T
T
2
2
2
has
has
E =
mgV (T) dt

= Mg
X& (T

) - x& (T) dt = Mg (- 0 cos T
- (G
μ (T - T)
0

1
-
cos T))dt
U
R
T
T
T
1
1
1
1

a0
1
G
μ

=
2
Mg ((t2 - 1t) cos 1t - (sin T
2 -)) -

(t2 - 1t).

2

The transcendent formulation of T apparently does not make it possible to simplify the expression of this
2
energy of wear. The power of average wear P is simply the energy of wear E above
U
U
divided by the half-period from the answer T/2 =/.

In the case of a movement always slipping (*), the interval of integration to be taken is
form [T, T
with N sufficiently large, so that T
that is to say sufficiently near to
1 - T
N
n+1]
n+
N
value limits/. One can avoid numerical calculation by recurrence of this continuation, knowing that average asymptotic speed is null. Indeed, the continuation T - N/has a finished limit.
N
satisfied properties by are illustrated on the following figure:

The segment of right-hand side has as an equation
has
v = G
μ (T -) - W = G
μ (T -) - 0
cos
(
) ,

has
and for T = +/, speed v is to take the opposite value W = 0

cos (
), which gives
the equation
has
has
μ
G/- 0
0
cos
(
) = cos
(
) ,
that is to say
μ
G = 2a cos (
) ;
0

whose solution is
1
μg
1

=

arccos

= arccos

.

2a0

2

*Let us note that one finds although for = *, the acceleration of the support calculated at time T = give the value limits µg. Indeed*

sin has (

) = sin has (arccos (/2)) = has*

**2*

2

1 -

/4 = has 1 - 1

(

**2*

-

*) = has **

= G

µ.

0

0

0

0

0

In the case of the movement always slipping, the energy of wear during one asymptotic period is given exactly by the formula

+ /

E =

mgV T dt

( )

U

R

that one can clarify according to preceding calculation, by taking T = and T = +/, which gives

1
2

has
1
G
/
2
2
2
μ
2

μ
0
2 +
has
G

E = Mg
(T cos -
sin T
) -
(T -)
Mg 0 (
1
)
,
U

2

=
+
-
-
2

2

4

---

that is to say

mga
Mg
E =
0
2
2
2
2
2
2
4
4
µ
.
2
-
=
has
2
0 -
G
U

The power of average wear (over one period) asymptotic is then

E
mga
mga
4
P
U
0
2
2
0
2
U =
=
4 - =
.
2 -
/

Following the Maple program allows the calculation of the power of exact wear in an interval of specified time, as well as the layout of the graph showing the convergence of the function speed of mass towards a periodic function limits, for any value of the physical parameters and of excitation such that the mode is of slipway-slipway type (*), and the exact value of the average power of wear over one period (the only useful one for what interests us) in the case of the stick-slip.

```
# This program makes calculation, on the transitory part
# of the beginning of the signal, the power of exact wear,
# until a time specifies at the beginning of program.
Digits: = 20:
pi: = evalf (pi):
T: = 1: # period of the movement of the support
Omega: = 2*pi/T:
tmin: = 4:
tmax: = 12: # duration of the transient considers
ncycle: = floor (tmax/T) +2: # iteration count of Ti calculation [I] and tf [I]
Nmax: = 100*ncycle: # to replace the function sin by a line brisee
m: = 1:
```

```
G: = 10:
driven: = 0.1:
a0: = 1.5:
eta: = mu*g/a0:
Omega: = 2*pi/T:
etaetoile: = 2/sqrt (pi^2+4):
Ti [1]: = 1/omega*arcsin (eta):
dX: = T - > - a0/omega*cos (omega*t):
dxmoins [0]: = dX (T):
lignedx: = [Ti [1], dX (Ti [1])] :
Eusure: = 0: # wear is null on the phase of adherence [0, Ti [1]]
#
# Noter that Ti [i+1] is necessarily in the interval [i*T-T/4, i*T+T/2]
# and that tf [I] is necessarily in the interval [i*T-3*T/4, i*T].
# These two intervals overlap, but there is always tf [I] <ti [i+1].
#
yew eta<etaetoile then # mode of slipway-slipway
for I from 1 to ncycle C
dxplus [I]: = mu*g* (T-Ti [I]) + subs (t=ti [I], dxmoins [i-1]):
tf [I]: = fsolve (dX (T) =dxplus [I], t= (i*T-3*T/4). (i*T)) :
lignedx: = lignedx, [tf [I], dX (tf [I])] :
tinf: = max (Ti [I], tmin):
tsup: = min (tf [I], tmax):
yew tinf<tsup then
Eusure: = Eusure + int (m*g* (dX (T) - dxplus [I]), t=tinf. .tsup):
fi:
dxmoins [I]: = - mu*g* (t-tf [I]) + subs (t=tf [I], dxplus [I]):
Ti [i+1]: = fsolve (dX (T) =dxmoins [I], t= (i*T-T/4). (T/2+i*T)) :
lignedx: = lignedx, [Ti [i+1], dX (Ti [i+1])] :
tinf: = max (tf [I], tmin):
tsup: = min (Ti [i+1], tmax):
yew tinf<tsup then
```

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Code_Aster ®
Version
6.4

Titrate:
SDND104 - Calculation of the power of wear of a rubbing shoe
Date:

*Eusure: = Eusure + int (m*g* (dxmoins [I] - dX (T)), t=tinf. .tsup):*
fi:
od:
*# courbedX: = stud ([seq ([j*tmax/Nmax, dX (j*tmax/Nmax)], j=0. Nmax)]):*
 # courbedx: = stud ([lignedx]):
 # with (studs):
 # display ([courbedX, courbedx]);
*theta: = arccos (pi*eta/2) /omega:*
*dxinfini: = T - > mu*g* (T-theta) +dX (theta):*
Vginfini: = dxinfini - dX:
*Eumoyana: = - int (m*g*Vginfini (T), t=theta. (theta+pi/omega)) :*
*Eumoyanaana: = m*g*a0/omega^2*sqrt (4-eta^2*pi^2):*
*Pumoyana: = 2*Eumoyana/T:*
*Pumoyanaana: = 2*Eumoyanaana/T:*
Pusure: = Eusure/(tmax-tmin);
elif (eta>etaetoile and eta<1) then # mode of stick-slip
lignedx: = [Ti [1], dX (Ti [1])] :
*dxplus [1]: = mu*g* (T-Ti [1]) + subs (t=ti [1], dxmoins [0]):*
*tf [1]: = fsolve (dX (T) =dxplus [1], t= (T-3*T/4). T):*
dxplus: = unapply (dxplus [1], T):
Vg: = dxplus - dX:
*Have: = - int (m*g*Vg (T), t=ti [1]. .tf [1]):*
*Pusuremoy: = 2*Eu/T;*
else # mode of permanent adherence
Have: = 0;
fi:

The Aster solution considered is the calculation of the power of average wear during a phase going transient from 4 to 11,99 seconds (from 8 to 24). The energy of wear for this length of time transient differs somewhat from the energy of average wear (asymptotic) over this duration (such an amount of in situation of stick-slip that of slipway-slipway). It is thus appropriate, to precisely compare it with the results Aster, to make an exact calculation of this energy in the interval of time [4s, 11,99s].

For A = 15 m/s 2, the power of average wear asymptotic is 15,1146144886 Watt then
0

that the power of average wear on the temporal interval [4s, 11,99s] is 15,257521794 Watt.
It is this last value which constitutes the result of reference.

Note:

As a calculation of average power, power of wear calculated on an interval is not obligatorily increasing with the duration of the interval. If one adds to the interval one duration over which there is adherence, the power of average wear will be lower.

2.1 Results of reference

Value of max. acceleration a0 (ms-2)
Value of the average power of wear
On the interval [4s, 11,99s], in Watt
15 (slipway-slipway)
15,26709959
1,5 (stick-slip)
0,40906245
1,01 (stick-slip)
2,261641E-4
0,99 (stick)
0

2.2 Uncertainty on the solution

Quasi-analytical solution (presence of transcendent equations solved numerically with one arbitrary precision).

2.3 References bibliographical

[1]
B. WESTERMO, F. UDWADIA: Periodic Response of has sliding oscillator system to harmonic excitation. Earthquake Engineeering and structural dynamics Flight 14.135-146 (1983)
[2] Documentation

---

3 Modeling With

3.1 Characteristics of modeling

An element of the type DIS_T on a mesh POI1 is used to model the system.
Calculation is done on modal basis. One blocks displacements in Y and Z, the modal base thus contains that a mode.
One uses the dynamic operator of calculation on modal basis DYNA_TRAN_MODAL, with the key word SHOCK to model nonthe local linearity.
An obstacle of the type PLAN_Z (two parallel plans separated by a play) is used to simulate the plan of slip. One chooses to take for generator of this plan OY is NORM_OBST: (0. , 1. , 0.).
The origin of the obstacle is ORIG_OBST: (0. , 0. , 1.), its play which gives the half-spacing between plans is 0.5.
One places oneself in the relative reference mark (loading mono-support) and one applies a loading in acceleration with CALC_CHAR_SEISME.
One uses a step of times of 3.105 S for temporal integration to limit the computing time. It no time is quite lower than min (2/K/M, 2/K/M
4
)
10
.
7
-
=
S
NR
.

The tangential stiffness of friction is taken as large as possible to ensure the stability of diagram, is KT = 900000 N/m. the value KT = 1000000 N/m led to a numerical instability. Normal stiffness kN must be taken equal to 20 N/m to compensate for the weight exactly of mass. (the value of the play is of 0,50m). Any other value leads to aberrant results.

3.2
Characteristics of the grid

A number of nodes: 1
A number of meshs and types: 1 POI1

3.3 Functionalities
tested

Orders

STANDARD DEFI_OBSTACLE
"PLAN_Z"

DYNA_TRAN_MODAL SHOCK

"ADAPT"
"DEVOGE"
"EULER"
POST_DYNA_MODA_T WEAR

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster
Aster *DEVOGE Aster*
EULER % difference max
ADAPT
a0 = 15

15,2671
15,2660
15,2665
15,2668
0,007%
a0 = 1,5
0,409062
0,409077
0,409077
0,409077
0,004%
a0 = 1,01
2,26164E-4
2,26164E-4
2,26164E-4 2,26316E-4 0,072%
a0 = 0,99
0
0
0
0
0%

5
Summary of the results

The case-test validates the calculation of the power of wear with POST_DYNA_MODA_T after a

calculation on
DYNA_TRAN_MODAL, as well on a diagram with variable steps (ADAPT) as on diagrams with step constant (Euler and Devoggeleare). In particular the tangential microphone-speeds induced by model of contact by penalization, at the time of the phases of adherence, are correctly cancelled.

The influence of the added spring remains in on this side precise details obtained.

The tangential stiffness of the contact is the element limiting for a higher precision. Convergence results towards the reference solution was checked. The tangential stiffness was taken too large that possible to ensure the stability of the diagram with dt =104 S.

The tolerances in the tests-resu are taken just above the found differences.

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Organization (S): EDF/EP/AMV

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.110 document

SDND110 - To release of a system masses specific
with fluid force of blade

Summary:

This test implements a specific mass having a speed initial and subjected to a force of blade
fluid which slows down it. The fluid non-linearity of blade as well as the algorithm of point fixes which is associated are for them
thus tested. The reference solution is obtained in an analytical way for the uniform profile and by integration
numerical direct out of Code_Aster for the parabolic profile, with a step of very small time to ensure itself
convergence of the solution.

1 Problem of reference

1.1 Geometry

X
2L

M
·
X

X
F
O
Z

1.2 Material properties

specific mass:
m = 1000 kg
width:
2L = 100 mm
density of the fluid:
F = 1000 kg/m3
viscosity:
= 1.E6
· with a parabolic profile of flow in the fluid blade:
= -
=
= -
-
0 0833

0 19992
0 9996 10 6
.
,
.
,
.
.
, = 0
· with a uniform profile of flow in the fluid blade:
= -0 0833
.
, = 0 1666
.
, = 0, = 0

1.3
Boundary conditions and loadings

The mass is plunged in an incompressible fluid, and an indeformable obstacle is present in X = 0 and displacements only for X > 0 authorize.

1.4 Conditions
initial

Initial distance from the mass to the obstacle:
X = 6 mm
0
Initial speed:
X = -0.1 m/s
0

2
Reference solution
2.1
Method of calculation used for the reference solution
Analytical resolution for the uniform mode

For the uniform mode, the differential equation governing the movement of stop of the mass is written

2
X

X
the following way: MX
= +
X
X

By integrating once the differential equation, one obtains an expression the speed of the projectile in function of its position:

2
2

X

0 +
X
X = -
X
where

0

X

0

X +
= M

While integrating once again compared to time this differential equation it comes:

2
1
X

X
1

1
T =

0
X
0
2

0 - X +

2
Log

X
.

0 X0 +

X +
-
X X0

Numerical resolution for the streamline flow
The dynamic equation to which this system is subjected is as follows:

2
X

X
X
MX
= + +
X
X
X3
This equation cannot be solved in an analytical way, one uses a resolution by a diagram of integration temporal of the dynamic problem. One can rewrite the system in the form:

2
X
X
M -
X
T
T
= +

X
T

X
X 3
T
T
T
One uses the diagram of Euler modified to integrate this equation in time.
X, *X*
0
0 given to t0,
To repeat:
2
X
X
I
I
+ *3*

X
X
I
I
X =
I

M - *Xi*
T +*1* = *T* + *dt*
I
I
X +*1* = *X* + *dt X*
I
I
I

X +1 = X + dt X
I
I
i+1
as long as T
T
i+1 < fine.

2.2
Uncertainty on the solution

Analytical solution for the uniform profile, approximate for the other.

2.3 References
bibliographical

[1]
G.JACQUART "Modeling of the forces of fluid blade" - HP-61/94/159/A
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HP-51/96/032 - Ind A

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3 Modeling
With

3.1
Characteristics of modeling

For modeling, one uses two nodes NO1 and separate NO2 of a distance L = 1m, to which are affected two discrete elements of type POI1.
Node NO1 represents the mass, node NO2 represents the rigid plan. One is thus applied condition of embedding to node NO2.
An obstacle of the type BI_PLAN_Z (two parallel plans separated by a play) is used to simulate connection through the fluid.
One chooses to take OZ for generator of this plan is NORM_OBST: (0. , 0. , 1.).
Normal stiffness RIGI_NOR is assigned to an arbitrary value, because the contact takes place through fluid.

It remains to define parameters DIST_1 and DIST_2 which give the half-spacing between the plans in contact. One takes DIST_1 = DIST_2 = (L-play) /2 = 0.497 Misters.

NB:

These distances are fictitious and do not correspond to physical dimensions of the objects.

3.2

Characteristics of the grid

A number of nodes: 2

A number of meshs and types: 2

3.3 Functionalities

tested

Orders

Keys

AFFE_CHAM_NO

SIZE

DEPL_R

[U4.26.01]

PROJ_VECT_BASE

VECT_ASSE

[U4.55.02]

PROJ_MATR_BASE

MATR_ASSE

[U4.55.01]

DEFI_OBSTACLE

TYPE

BI_PLAN_Y

[U4.21.07]

DYNA_TRAN_MODAL

VITE_INIT_GENE

[U4.54.03]

DYNA_TRAN_MODAL

SHOCK

NOEU_2

[U4.54.03]

DYNA_TRAN_MODAL

SHOCK

LAME_FLUIDE

[U4.54.03]

DYNA_TRAN_MODAL

SHOCK

ALPHA

[U4.54.03]

DYNA_TRAN_MODAL

SHOCK

BETA
[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
CHI
[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
DELTA
[U4.54.03]

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% Difference
(m)
(m)
For the parabolic profile:
Ux (t=0.02)
1.98583e3
1.98582e3
0.005
Ux (t=0.04)
3.91819e3

3.91819e3
0.000
Ux (t=0.06)
5.61048e3
5.61068e3
0.004
Ux (t=0.2)
5.90398e3
5.90347e3
0.004
For the uniform profile:
Ux (t=0.02)
1.98828e3
1.98878e3
0.000
Ux (t=0.04)
3.93216e3
3.93216e3
0.000
Ux (t=0.06)
5.66658e3
5.6669e3
0.006
Ux (t=0.2)
5.99946e3
5.99914e3
0.005

4.2 Remarks

One observes in this case a very good precision in the reproduction by the calculation of displacement structure (less than 0.006% of difference with the analytical solution), and a good prediction of the position of stop of the system.

4.3 Parameters of execution

Version: 3.05
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
100 seconds
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems

5
Summary of the results

Good agreement between the results obtained and the values of reference.

Organization (S): EDF/EP/AMV

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.111 document
SDND111 - Forced vibrations of a system
mass-arises with fluid force of blade

Summary:

This test implements a system mass-arises specific subjected to a force of fluid blade which deadens it and one
harmonic external force. The fluid non-linearity of blade as well as the algorithm of point fixes which is

to them
associated are thus tested. The reference solution is obtained by direct numerical integration out of Code_Aster for the parabolic profile, with a step of very small time to ensure itself of the convergence of solution.
Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HP-51/96/032 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SDND111 Vibrations forced of a system mass-arises
Date:
12/01/98
Author (S):
G. JACQUART
Key:
V5.01.111-A Page:
2/6

1 Problem of reference

1.1 Geometry

X
Fext (T)
2L

M
·
X

X
F
O
Z

1.2 Material properties

specific mass:
m = 25 kg
stiffness of the spring:
K = 24674 N/m
width:
2L = 100 mm
density of the fluid:
F = 1000 kg/m3
viscosity:
= 1.E6
· with a parabolic profile of flow in the fluid blade:
= -
=
= -

-
0 0833
0 19992
0 9996 10 6
.
,
.
,
.
.
, = 0
· with a uniform profile of flow in the fluid blade:
= -0 0833
.
, = 0 1666
.
, = 0, = 0

1.3
Boundary conditions and loadings

The mass is plunged in an incompressible fluid, and an indeformable obstacle is present in X = 0 and displacements only for X > 0 authorize.

1.4 Conditions
initial

Initial distance from the mass to the obstacle:
X = 5 mm
0
Initial speed:
X = 0 m/s
0

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The dynamic equation to which the system is subjected is as follows:

2
X

X
X
X X
MX
+ *KX* = *F* + + +
+
ext.
X
X
X3
X 2

This equation cannot be solved in an analytical way, one uses a resolution by a diagram of integration temporal of the dynamic problem. One can rewrite the system in the form:

2
X
X
X X
T
T
M -
X + *KX* = *F*
T
T
+ +
+

X
T
T
ext.

X
X 3
X 2
T
T
T
T
One uses the diagram of Euler modified to integrate this equation in time.
X, *X*
0
0 given to t0,
To repeat:
2
X

X
X
X
T
I
F
- *KX*
I
I
+ +
+
ext.
I
3
2

X
X
X
I
I
I
X =
I

M - *Xi*
T +1 = *T* + *dt*
I

I
X +1 = *X* + *dt X*
I
I
I
X +1 = *X* + *dt X*
I
I
i+1
as long as *T*
T
i+1 < *fine*.

2.2
Uncertainty on the solution

Solution approached numerically by step of very small time.

2.3 References
bibliographical

[1]
G.JACQUART “Modeling of the forces of fluid blade” - HP-61/94/159/A

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3 Modeling
With

3.1
Characteristics of modeling

For modeling, one uses two nodes NO1 and separate NO2 of a distance L = 1m, to which are affected two discrete elements of type POI1.

Node NO1 represents the mass, node NO2 represents the rigid plan. One is thus applied condition of embedding to node NO2.

An obstacle of the type BI_PLAN_Z (two parallel plans separated by a play) is used to simulate connection through the fluid.
One chooses to take OZ for generator of this plan is NORM_OBST: (0. 0. 1.).
Normal stiffness RIGI_NOR is assigned to an arbitrary value, because the contact takes place through fluid.
It remains to define parameters DIST_1 and DIST_2 which give the half-spacing between the plans in contact. One takes DIST_1 = DIST_2 = (L-play) /2 = 0.497 Misters.

NB:

These distances are fictitious and do not correspond to physical dimensions of the objects
in contact.

3.2

Characteristics of the grid

A number of nodes: 2

A number of meshs and types: 2

3.3 Functionalities

tested

Orders

Keys

AFFE_CHAM_NO
SIZE
DEPL_R
[U4.26.01]
PROJ_VECT_BASE
VECT_ASSE
[U4.55.02]
PROJ_MATR_BASE
MATR_ASSE
[U4.55.01]
DEFI_OBSTACLE
TYPE
BI_PLAN_Y
[U4.21.07]
DYNA_TRAN_MODAL
SHOCK
NOEU_2
[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
LAME_FLUIDE
[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
ALPHA

[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
BETA
[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
CHI
[U4.54.03]
DYNA_TRAN_MODAL
SHOCK
DELTA
[U4.54.03]

---

4 Results of modeling A

4.1 Values tested

The displacements tested at the moments of cancellation speed give the following comparisons:

Identification
Reference
Aster
% Difference
(m)
(m)
For the parabolic profile:
Ux (t=0.13)
3.71678E3

3.71527E3
0.041
Ux (t=0.2684)
5.22565E3
5.20065E3
0.478
Ux (t=0.3902)
3.99499E3
3.99034E3
0.116
Ux (t=0.531)
4.68796E3
4.64597E3
0.896
For the uniform profile:
Ux (t=0.1282)
3.54435E3
3.54283E3
0.019
Ux (t=0.2651)
5.99203E3
5.96578E3
0.438
Ux (t=0.3876)
3.78488E3
3.78001E3
0.129
Ux (t=0.5263)
5.66919E3
5.61641E3
0.931

4.2 Remarks

One observes in this case a very good precision in the reproduction by the calculation of displacement structure (less than 0.9% of difference with the quasi-analytical solution).

4.3 Parameters of execution

Version: 3.05
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
16 megawords
Time CPU To use:

250 seconds

5
Summary of the results

Good agreement between the results obtained and the values of reference.

Organization (S): EDF/AMA

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.112 document

SDND112 - Fluid blade between two mobile masses

Summary

One considers the unidimensional system made up of 2 mobile masses separated by a fluid blade, and attached each one to a point fixes via a spring.

The response of the system is studied when one of the masses is isolated of its position of balance. A law of
fluid behavior of blade is modelled.

The reference solution is a Matlab calculation. One validates operator DYNA_TRAN_MODAL, and in particular them
temporal methods of integration EULER and ADAPT, by comparing absolute displacements of both masses by Matlab and Aster.

Titrate:

SDND112 - Fluid blade between two mobile masses

Date:
07/05/02
Author (S):
Key H. ANDRIAMBOLOLONA
:
V5.01.112-A Page:
2/10

1
Problem of reference

1.1 Geometry

The figure below specifies the system considered:

k1 m1
k2
m2
fluid blade

1.2
Characteristics of the various elements of the model

Mechanical characteristics of the system mass-arises:

m1 = 25 kg
m2 = 25 kg
k1 = 98696 N/m
k2 = 98696 N/m

Coefficients of fluid blade (see the formulation in [R5.06.05]):

= -0,08325
= 0,07493
= -0,9996 10-6
= -0,1665

Characteristics of shock:

Play with balance between m1 and m2: 0.001 m

Normal stiffness of shock: 2.88 1010 N/m
Normal damping = 0 Ns/m

1.3
Boundary conditions

Boundary conditions:

Only authorized displacements are the translations according to the axis of the springs. Two nodes extremes are embedded.

1.4 Conditions
initial

m2 is isolated of its position of balance of a distance from 1 mm and released with a null speed.
m1 is in its position of balance, at null speed.

2
Reference solution

2.1
Method of calculation used for the reference solution

The dynamic response taken for reference is that calculated by Matlab (see script below). It
use a diagram of integration of the Runge-Kutta type to orders 2 and 3 with control of error and not

adaptive.

2.2 Results of reference

Absolute displacements with the nodes in several moments (extremum of displacement).

2.3 Uncertainty on the solution

Comparison enters the codes Matlab and Aster.

2.4 Matlab script for the reference solution

```
%cas test for fluid blade 2
alpha = -0.08325;
mobile structures
beta = 0.07493;
clear;
khi = -0.9996e-6;
closed all;
delta = -0.1665;
%----direct calculation----
%
%initialisation of the parameters of
%----direct resolution----
calculation
yy = y (2) there (1) +y0;
t0 = 0;
% blade fluid
tfinal = 1. ;
%creation of the matrices D state
not = 0.001;
U = [1 0 0 0;
tspan = t0: not: tfinal;
0 1 0 0 ;
y0 = [0. 0.001 0 0];
0 0 m1-alpha/yy alpha/yy;
y0 = y0';
0 0 alpha/yy m2-alpha/yy];
options = [];
= [0 0 -1 0 have;
```

direct %integration
0 0 0 -1 ;
[T, y] =
*k1 0 - khi/(yy*yy*yy)*
ode23 ("fonction2", tspan, y0, options);
*khi/(yy*yy*yy);*
depl1 = y (: , 1: 1);
*0 k2 khi/(yy*yy*yy) -*
depl2 = y (: , 2: 2);
*khi/(yy*yy*yy)];*
vit1 = y (: , 3: 3);
G = [0;
vit2 = y (: , 4: 4);
0 ;

- beta ((y (4) there (3))/yy) ^2 -*
function YP = fonction2 (T, y, flag)
delta (y (4) there (3))*abs (y (4) -*
% initialization provisional
*y (3))/(yy*yy);*
%y0: play
beta ((y (4) there (3))/yy) ^2 +*
y0 = 0.001;
delta (y (4) there (3))*abs (y (4) -*
m1 = 25. ;
*y (3))/(yy*yy)];*
m2 = 25. ;
%
k1 = 98696. ;
%calcul of the derivative
k2 = 98696. ;
*YP = - inv (U) *a*y + inv (U) *g;*
%

---

3 Modeling With

3.1 Characteristics of modeling

The springs are modelled by discrete elements with 2 ddl DIS_T.

Mass 2 is isolated of its position of balance of a distance from 1 mm at null initial speed.

An obstacle of the type BI_PLAN_Z is retained to simulate the impact between the two masses.

In DYNA_TRAN_MODAL, the normal rigidity of shock was selected very high (2.88 1010 N/m) in order to
to take into account only the effect of the fluid blade. Two methods of calculation "ADAPT" and "EULER" were tested. Calculation is launched on 1 second with a step of time of 10-5 second and a step of filing of 100. Syntax used is presented below.

tran_ge1 = DYNA_TRAN_MODAL (MASS_GENE: massegen RIGI_GENE: rigidgen

METHOD: "ADAPT" %OU "EULER"
AMOR_REDUIT: (0.0.0.0)
ETAT_INIT: (DEPL_INIT_GENE: deplini1)
NMAX_ITER: 100
LAMBDA: 10.
RESI_RELA: 1.e-5
SHOCK: (GROUP_NO_1: masses1
GROUP_NO_2: masses2
OBSTACLE: roast %BI_PLAN_Z
NORM_OBST: (0. 0. 1.)
DIST_1: 0.4495
DIST_2: 0.4495
RIGI_NOR: 2.88E10
AMOR_NOR: 0.

RIGI_TAN: 0.
COULOMB: 0.
LAME_FLUIDE: "YES"
ALPHA: -0.08325
BETA: 0.07493
CHI: -0.9996E-6
DELTA: -0.1665
)
INCREMENT: (INST_INIT: 0. INST_FIN: 1.
NOT: 0.00001)
FILING: (PAS_ARCH: 100)
);

3.2
Characteristics of the grid

Model associated with the grid bichoc:

A number of nodes: 4 (whose two extremes are fixed),

A number of meshs: 2,
Type of mesh: DIS_T.

3.3 Functionalities

tested

Orders

LIRE_MAILLAGE

AFFE_MODELE GROUP_MA
“MECHANICAL”
“DIS_T”

DISCRETE AFFE_CARA_ELEM
GROUP_NO M_T_D_N

GROUP_MA
K_T_D_L

AFFE_CHAR_MECA DDL_IMPO GROUP_NO

MACRO_MATR_ASSE

CALC_VECT_ELEM

ASSE_VECTEUR

MODE_ITER_SIMULT METHOD
JACOBI

CALC_FREQ
BANDAGE

AFFE_CHAM_NO

MACRO_PROJ_BASE

DEFI_LIST_REEL

DEFI_OBSTACLE BI_PLAN_Z

DYNA_TRAN_MODAL SHOCK
LAME_FLUIDE
“YES”

METHOD
ADAPT

METHOD
EULER

REST_BASE_PHYS

4
Results of modeling

4.1
Values tested of modeling

One calculates the response of the system over one duration of 1 second. One compares then the results with
those resulting from Matlab calculation in some points which correspond to some extremum of the evolution
displacement. On the figures which follow, the results resulting from Aster are in continuous feature and those
calculated with matlab in features dotted lines.

Results obtained with method ADAPT:
For mass 1:

Time (S)
Matlab (m)
Aster (m)
Relative error (%)
0.05 0.675e3
-0.675
E3 0.091
0.1 0.544e3
0.547

E3 0.537
0.45 0.473e3
-0.488
E3 3.177
0.95 0.468e3
-0.499
E3 6.823

For mass 2:

Time (S)
Matlab (m)
Aster (m)
Relative error (%)
0.05 0.322e3
-0.324
E3 0.740
0.1 0.450e3
0.453
E3 0.683
0.45 0.497e3
-0.512

E3 3.011
0.95 0.468e3
-0.500
E3 6.850

Results obtained with method EULER:
For mass 1:

Time (S)
Matlab (m)
Aster (m)
Relative error (%)
0.05 0.675e3
-0.674
E3 0.101
0.1 0.544e3
0.548
E3 0.531
0.45 0.473e3
-0.488
E3 3.179

0.95 0.468e3
-0.499
E3 6.824

For mass 2:

Time (S)
Matlab (m)
Aster (m)
Relative error (%)
0.05 0.322e3
-0.326
E3 0.720
0.1 0.450e3
0.452
E3 0.691
0.45 0.497e3
-0.512
E3 3.011
0.95 0.468e3
-0.500
E3 6.851

4.2 Parameters of execution

Version: 5.01

Machine: claster

Obstruction memory: 128 megabytes
Time CPU To use:
33.84 seconds

---

5 Summary of the results

The results obtained with Code_Aster are in conformity with those awaited (relative error lower than 7%).

HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
Transitory SDND120 Response of an antiseismic device

Date:
14/09/01
Author (S):
Fe** Key **WAECKEL
:
V5.01.120-A Page:
1/8

Organization (S): EDF/RNE/AMV

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
V5.01.120 document

SDND120 - Transitory response of a device antiseismic

Summary

An antiseismic device was tested on a mobile plate. This case test aims to reproduce numerically this test. The device is modelled by two systems mass-arises not deadened, separate by nona linearity of the antiseismic device type.

One tests the discrete element in traction and compression, the calculation of the clean modes, the static modes and it calculation of the transitory response by nonlinear modal recombination of the structure subjected to one accélérogramme. Nonthe linearity is of type ANTI_SISM.

The result of reference is a program MATLAB.

The results obtained are in very good agreement with the results of reference.

One also compares the results calculated with the efforts and displacements measured on a device experimental (qualitative comparison only).

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

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1 Problem of reference

1.1 Geometry

An antiseismic device is placed between two jaws (right-angled hatched on the following figure) themselves posed on a mobile plate subjected to an acceleration imposed in direction X. It by nona linearity of the type "antiseismic device" placed on both sides one is modelled *system mass-arises.*

X
D

B
Antiseismic device
Y
F measured in A
C

1.2
Material properties

The jaws which insert the device are modelled each one by a system mass-arises:

stiffness of connection: K = 1010 N/m;
specific mass: m = 25 kg.

The device tested is an antiseismic device of BULGE type. Its characteristics are them following:

.
K1 = 6. 106 N/m (RIGI_K1),
.
K2 = 0,53 106 N/m (RIGI_K2),
.
Py = 1200 (SEUIL_FX),
.
C = 0,07 105 (C),
.
alpha = 0,2 (PUIS_ALPHA),
.
xmax = 0,03 m (DX_MAX).

1.3
Boundary conditions and loadings

Boundary conditions

Only authorized displacements are the translations according to axis X. the points C and D are embedded: dx = Dy = dz = 0. The other points are free in translation according to dx: Dy = dz = 0.

Loading

The point D is subjected to a transverse acceleration in the direction X 1 (T) = 0,66 sin (T) m/s2 with = 2, the point C is fixed.

1.4 Conditions
initial

At the initial moment, the device is at rest: with T = 0, dx (0) =0, dx/dt (0) = 0 in any point.

2
Reference solution

2.1
Method of calculation used for the reference solution

One compares the numerical values with the experimental statements and the solution taken for reference
obtained thanks to a script matlab.
The expression of the force of dissipation in such a device is provided by the following formula [Peckan]:
(K - K

1
2) X
X
F

K X
+ C sign (x&) X
D =
+
2
&
.
2
X
K X
max
1+ 1

Py

script matlab:

%cas test for antiseismic device
function YP = fonctsism1 (T, y, flag)
clear;
% initialization provisional
closed all;
m1 = 25. ;
%----direct calculation----
m2 = 25. ;
%initialisation of the parameters of
k1 = 1.e10;
calculation
k2 = 1.e10;
t0 = 0;
kk1 = 6.e6;
tfinal = 1. ;
kk2 = 0.53e6;
not = 0.01;
py = 1200;
tspan = t0: not: tfinal;
C = 0.07e5;
y0 = [0 0 0 0];
xmax = 0.03;
y0 = y0';
alpha = 0.2;
options = [];
Omega = 2*pi;
direct %integration

```
%
[T, y] =
%----direct resolution----
ode23 ("fonctsism1", tspan, y0, options);
x0 = (0.66*sin (omega*t))/(omega*omega);
depl1 = y (: , 1: 1);
depl21 = y (2) there (1);
depl2 = y (: , 2: 2);
vit21 = y (4) there (3);
vit1 = y (: , 3: 3);
g1n = (kk1-kk2) *depl21;
vit2 = y (: , 4: 4);
g1d = sqrt (1+ ((kk1/py) *depl21) ^2);

g1 = g1n/g1d;
kk1 = 6.e6;
g2 =
kk2 = 0.53e6;
c*sign (vit21) * (ABS (vit21*depl21/xmax))^
py = 1200;
alpha;
C = 0.07e5;
g0 = kk2*depl21;
xmax = 0.03;
gg = g0 + g1 + g2;
alpha = 0.2;


%creation of the matrices D state
for tt = 1:1: length (tspan)
U = [1 0 0 0;
depl21 = depl2 (tt) - depl1 (tt);
0 1 0 0 ;
vit21 = vit2 (tt) - vit1 (tt);
0 0 m1 0;
g1n = (kk1-kk2) *depl21;
0 0 0 m2];
g1d = sqrt (1+ ((kk1/py) *depl21) ^2);
= [0 0 -1 0 have;
g1 = g1n/g1d;
0 0 0 -1 ;
g2
= k1 0 0 0;
c*sign (vit21) * (ABS (vit21*depl21/xmax))^
```

```
0 k2 0 0];
alpha;
G = [0;
g0 = kk2*depl21;
0 ;
F (tt) = g0 + g1 + g2;
gg + k1*x0;
end
- gg];
F = f';
%
depl = depl2 - depl1;
%calcul of the derivative
YP = - inv (U) *a*y + inv (U) *g;
```

2.2
Results of reference

Maximum values and RMS of relative displacements and absolutes out of B, and of the effort due to the device
antiseismic.

2.3
Uncertainty on the solution

The excitation imposed on the system mass-arises is an approximation of the displacement imposed on
experimental device.

Uncertainty on the reference solution MATLAB is weak.

2.4 References bibliographical

[1]
G. PEKCAN, J.B. MANDER, Mr. EERI: The seismic response of has 1: 3 scale model R.C. structure with elastomeric spring dampers. - Earthquake Spexctra, vol. 11, N°2, p.249-267 - May 1995

---

3 Modeling With

3.1 Characteristics of modeling

Y
m

m
K
K
X
NO1
NO2
NO12
NO11
1 = 0.66 sin (2. T)
2= 0

Appear 3.1-a: Modeling of the seismic anti device

The jaws which insert the device are modelled each one by a discrete element with 3 degrees of freedom DIS_T.
The antiseismic device is simulated via the key word factor ANTI_SISM of the operator DYNA_TRAN_MODAL.

Node NO1 is subjected to an imposed acceleration 1 (T), node NO11 to 2 (T) = 0. It is calculated relative displacement of node NO2 and its absolute displacement.

Temporal integration is carried out with the algorithm of Euler and a step of time of 1,25. 105 second. Calculations are filed all the 80 steps of time.
One considers a damping reduces no one for all two calculated mode.
I

3.2
Characteristics of the grid

The grid consists of 4 nodes and 4 meshs of the type DIS_T.

3.3 Functionalities
tested

Orders

AFFE_MODELE GROUP_MA
"MECHANICAL"
"DIS_T"
DISCRETE AFFE_CARA_ELEM
GROUP_NO
M_T_D_N

GROUP_MA

K_T_D_L
AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

MACRO_MATR_ASSE

MODE_ITER_SIMULT METHOD
JACOBI

CALC_FREQ
BANDAGE

MODE_STATIQUE DDL_IMPO

FORMULATE

CALC_FONC_INTERP

CALC_CHAR_SEISME MODE_STAT

MACRO_PROJ_BASE

DYNA_TRAN_MODAL EXCIT
MULT_APPUI “YES”
METHOD
EULER

ANTI_SISM

RECU_FONCTION RESU_GENE

MULT_APPUI
“YES”

“NOT”

CALC_FONCTION MAX

RMS

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

---

4 Results of modeling A

4.1 Values tested of modeling A

One calculates the absolute displacement of node NO2: NO2_DX_A and effort in the device antiseismic. One compares the values with those calculated by a function MATLAB.

	Reference	***Code_Aster***	***Absolute error (%)***
Effort max (NR)	*1,266E+04*	*1,266E+04*	*-0,003*
Effort RMS	*7,912E+03*	*7,894E+03*	*-0,232*
NO2_DX_A max (m)	*1,670E02*	*1,672E02*	*0,101*
NO2_DX_A RMS	*1,180E02*	*1,183E02*	*0,276*

NO2_DX_R max (m)
1,266E06
1,264E06
-0,129
NO2_DX_R RMS
7,798E07
7,894E07
1,239

One traces the evolution of the force which is exerted in the device according to the absolute displacement of
node NO2. One compares with the measured sizes.

F
(D
dispo
calc)
calc
F
(D
dispo
exp
exp
)

Taking into account the approximation of the excitation imposed on the mobile plate in a sine, the model established in Code_Aster is representative of the device tested.

Handbook of Validation
V5.01 booklet: Nonlinear dynamics of the discrete systems
HT-62/01/012/A

Code_Aster ®
Version
5.0

Titrate:
Transitory SDND120 Response of an antiseismic device

Date:
14/09/01
Author (S):

One also traces the temporal evolution of the displacement of the device:

Relative displacement
device (m)

Time (S)

4.2 Parameters
of execution

Version:
STA5.02

Machine:
SGI ORIGIN2000

Time CPU To use:
100,4 seconds

5
Summary of the results

The results, in term of efforts and displacements, obtained with Code_Aster are comparable with those calculated by a script MATLAB. Differences raised between the calculated sizes and them experimental sizes are related to the approximation carried out on the excitation.

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
V5.02.032 document

SDNL32 - Impact of a girder hinged on elastic support

Summary:

This problem corresponds to a transitory analysis by modal superposition of a non-linear system made up of a flexible beam rotulée with one of its ends. It is animated of a rotational movement of body solid at the initial moment and meets an elastic thrust with unilateral contact. The problem has one reference solution suggested by Commission VPCS.

There is a modeling with elements POU_D_T. Operator DYNA_TRAN_MODAL [U4.54.03] is tested. variations with the reference solution do not exceed 0.8%.

---

1 Problem of reference

1.1 Geometry

L
y
B
X
X

With
K
Beam square section:
C = 0.014 m
L: length of the beam
L = 0.783 m
Measure deformation
X = 0.462 m

1.2 Material properties

Young modulus:
E = 6.7 E 10 Pa
Density:
= 2.400 kg/m3
Poisson's ratio:
= 0.
Stiffness of the spring:
case n°1 K = 18.000 N/m
case n°2 K = 45.000N/m

1.3 Boundary conditions and loadings

At point a:

U = v = 0 (kneecap)
At point b:
loose lead before impact (T < 0)
Loading:
Not other loading.
The effects of gravity are negligible at first approximation.
1.4 Conditions
initial
For T < 0 in any point of X-coordinate X
· dv/dt = .x
· = 3.8 rd/s
For T = 0, v (L, 0) = 0: contact of the loose lead with the spring.

---

2 *Reference solution*

2.1 *Method of calculation used for the reference solution*

The reference solution was established by commission VPCS.
One refers for the moment with results communicated by J.P. TEASES (Central School of Lyon) using code ANSYS, as well as the code PLEXUS of the ECA.
The solution is calculated for an analysis in small displacements.

2.2 *Results of reference*

Value of transverse displacements of the end of the beam at various moments (DY).

2.3 *Uncertainty on the solution*

Average of the results of various codes.

2.4 References

bibliography graphical

[1]
J.P.LAINE "Run of dynamics of the structures" (TP) Central School Lyon.

---

3 Modeling
With
3.1
Characteristics of modeling

Modeling POU_D_T.
10 elements of beam are used:
in all the nodes:
DDL_IMPO: (ALL: "YES" DZ: 0, DRX: 0, DRY: 0)
with node a:
(NODE: WITH DX: 0, DY: 0)
with node b: conditions of shock (operator DYNA_TRAN_MODAL)
SHOCK: (
NOEUD_1: B
OBSTACLE: plan
ORIG_OBST: (0.783, 0.1, 0.)
NORM_OBST: (1. , 0. , 0.)
PLAY: 0.1
RIGI_NOR: 0.
RIGI_TAN: K
AMOR_NOR: 0.
COULOMB: 0.
)
Modal synthesis with 10 clean modes, not of time used dt = 1.E-5 S.
Numerical algorithm of integration: "EULER"

3.2
Characteristics of the grid
A number of nodes: 11
A number of meshs and types: 10 SEG2
3.3 Functionalities
tested
Orders
Keys
DEFI_OBSTACLE
TYPE
"PLAN_Y"
[U4.21.07]
PROJ_MATR_BASE
[U4.55.01]
PROJ_VECT_BASE
[U4.55.02]
DYNA_TRAN_MODAL
SHOCK
[U4.54.03]
REST_BASE_PHYS
[U4.64.01]
3.4 Remarks
A number of modes used for the modal superposition: 10.

4
Results of modeling A
4.1 Values
tested

Transverse displacements of the end of the beam for the first 12 steps of computing time.

Identification

Reference

Aster

% Difference

K = 18.000 N/m

2.66 E-3

2.66 E-3

0.10

4.33 E-3

4.33 E-3

0.12

4.92 E-3

4.95 E-3

0.67

4.78 E-3

4.78 E-3

0.04

3.82 E-3

3.82 E-3

0.11

2.87 E-3

2.87 E-3

0.16

2.71 E-3

2.71 E-3

0.00

3.09 E-3

3.09 E-3

0.07

3.41 E-3

3.41 E-3

0.10

3.36 E-3

3.36 E-3

0.12

2.64 E-3

2.64 E-3

0.08

7.42 E-4

7.43 E-4

0.10

K = 45.000 N/m

2.25 E-3
2.25 E-3
0.00
2.66 E-3
2.65 E-3
0.11
1.96 E-3
1.96 E-3
0.23
1.15 E-3
1.16 E-3
0.51
1.24 E-4
1.23 E-4
1.20
3.64 E-4
3.63 E-4
0.15
2.01 E-3
2.01 E-3
0.03
2.74 E-3
2.74 E-3
0.02
1.89 E-3
1.89 E-3
0.19
3.52 E-4
3.52 E-4
0.01
+ 1.70 E-3
+ 1.70 E-3
0.26
+ 4.99 E-3
+ 4.99 E-3
0.08

4.2 Parameters of execution

Version: NEW 3.05.22
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:

16 megawords
Time CPU To use:
7.33 seconds

5
Summary of the results

One really notes in concord with the this and reference solution (1.2%) in spite of the presence of a non-linearity of shock and the use of a method of modal recombination with 1 base modal reduced to 10 modes. The strongest difference is observed for the non-linear thrust more stiff.

Organization (S): EDF/IMA/MMN

Handbook of Validation

V5.02 booklet: Nonlinear dynamics of the linear structures
Document: V5.02.100
SDNL100 - Simple pendulum in great oscillation
Summary:

The object of this test is to calculate the movement of a heavy bar articulated at a point fixes by one of its ends, free elsewhere and oscillating with great amplitude in a vertical plane.
Interest: to test the element of cable with two nodes - which is in fact an element of bar - in dynamics and sound operation in operator DYNA_NON_LINE [U4.32.02].

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HI-75/98/040 - Ind A

---

1 Problem of reference

1.1 Geometry

Z

X
P
O
.
.
G
1

()
A rigid pendulum COp length 1 and centre of gravity G oscillates around the point O.
The angular position of the pendulum is located by: = -

1.2 Material properties

Linear density of the pendulum: 1. kg/m
Axial rigidity (produced Young modulus by the surface of the cross-section): 1.108 NR

1.3 Boundary conditions and loadings

The pendulum is articulated at the point fixes O. Under the action of gravity, its end P oscillates on half-circle () of centre O and 1. There is no friction.

1.4 Conditions initial

The pendulum is released without speed of horizontal position COp.

= +
= 0
2

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The period T of a mobile pendulum without friction around the point fixes O, whose mass is concentrated in the centre of gravity G (OG = L) and whose maximum angular amplitude is 0 is given by the series [bib1]:

2n
L

T = 2
1+
2
has
0
sin

G
N

2

n=1

with
2 *N* - 1

has =
N
2 *N*

2.2
Results of reference

For L = 0.5 m, G = 9.81 m/s2 and 0 = /2, one finds: *T* = 1.6744 S

2.3
Uncertainty on the solution

One summoned the terms of the series until N = 12 inclusively, the last term taken into account being lower than 10-5 times the calculated sum.

2.4 References
bibliographical

[1]
J. HAAG, “movements vibratory”, P.U.F. (1952).

---

3 Modeling
With

3.1
Characteristics of modeling

The pendulum is modelled by an element of cable with 2 nodes, identical to an element of bar of constant section.

Discretizations:

· space: an element of cable MECABL2
· temporal: analyze movement over one period supplements T per step of times equal to T/40.

3.2 Functionalities
tested

Order

DYNA_NON_LINE for great displacements.

3.3

Characteristics of the grid

A number of nodes:
2
A number of meshs and types:
1 mesh SEG2

4

Results of modeling A

4.1 Values
tested

Moment	**Size**	**Reference**	**Aster**	**% difference**	**Tolerance**
T/4 0.4186	DXp	-1.	0.97518	2.48	rel 2.5
	DZ	-1.	0.99969	0.03	

rel 0.05
p
T/2 0.8372
DXp
-2.
2.00000
0.0
rel 0.01
DZ
0.
6.29E4
-
ABS 0.0007
p
3T/4 1.2558
DXp
-1.
1.07453
7.45
rel 7.5
DZ
-1.
0.99722
0.28
rel 0.3
p
T 1.6744
DXp
0.
6.50E7
-
ABS 1.E-6
DZ
0.
1.40E3
-
ABS 1.5E-3
p

4.2 Remarks

· Temporal integration is done by the method of NEWMARK (rule of the trapezoid),
· A each step of time, convergence is reached in less than 8 iterations.

4.3 Parameters of execution

Version: 3.06.11
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
55.6 seconds

---

5 Summary of the results

One sees on this case-test that temporal integration by the "rule of the trapezoid" of Newmark does not modify
that very slightly the frequency and does not bring parasitic damping, since at the end of one
period one returns to very little close with the initial position.

J.L. *Key* ***FLEJOU***
:

Organization (S): EDF/ERMEL/PEL

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear systems
Document: V5.02.102

SDNL102 - Beam subjected to a field speed of wind

Summary:

This test relates to the validation of the application of the loadings of wind on the linear elements. loading is described by fields speeds of wind.

This problem makes it possible to test:

.
linear finite elements [bars, cables, beams (except the curved beams)] with loadings follower of nature "wind",
.
loadings using speeds of wind:
- reading of the data of the fields of wind,
- projection of the fields of wind attached to the group of dots on the grid deformed of

structure,
- calculation relative speed,
·
the taking into account of the function giving the force distributed according to the relative speed of structure,
·
the reactualization of the geometry to take account of great displacements and large rotations.

---

1 Problem of reference

1.1 Geometry

y
Kbx
B1
Wp
W2
Kby
+o
B
G
Kax A1
O

X
Kay
Wind
With

Length of the beam: 1.5m
Stiffnesses of the discrete ones: Kax, kay, kbx, kby

1.2
Properties of material

Material for the linear element: E = 2.0E+10, = 1000.0

Characteristics mechanics of the beam: section = "CIRCLE", radius = 0.1, ep = 0.1

Stiffness of the springs:
Kxa Kya Kxb Kyb
10 N/m
20 N/m
25 N/m
22 N/m

1.3
Boundary conditions and loadings

At points A and b: blockings of the DDL: DX, DY, DZ

At the points A1 and B1: blockings of the DDL: DZ, DRX, DRY

The springs are modelled by the discrete ones without dimensions. The nodes A and A1, B and B1 are geometrically confused.

Characteristics of the field speed of wind, along the axis y:

Vy = 20.Sin (.t), with = 2. .f and F = 0.2 Hz

1.4 Conditions
initial

The beam forms an angle of 30° (0 = 30°) compared to the axis "X".
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear systems
HR-17/02/019/A

Code_Aster ®

Version
6.0

Titrate:
SDNL102 - Beam subjected to a field speed of wind

Date:
12/04/02
Author (S):
J.L. Key FLEJOU
:
V5.02.102-A Page:
3/6

2
Reference solution

2.1 Equations
of balance

The study is carried out around the initial position of the structure in the xy plan. The equations are written in the centre of gravity of the beam.

Effort of inertia

M.x "

Mr. = Mr. y
G
"

Mr. L

2
."

12

Effort at the A1 point

- kxa. teststemxà

with displacements of the A1 point

F =
- kya. ya

X
= L.Co (S has

O
)/2 - L.Co (S O
+)/2 + X

L
= .
/ 2 - .
+ / 2 +
. (y
a.kya.
(
Cos +) - X
a.kxa.
(
Sin +)
ya
L If
/2
(N

O)
L If (
N O
)
y
O

O

Effort at the B1 point

- kxb. xb

with displacements of the B1 point

Bfr =
- kyb. yb

X
B = - L.Co (S

O
)/2 + L.Co (S O
+)/2 + X

L
= - .
/ 2 + .
+ / 2 +
. (- y
b.kyb.
(
Cos +) + xb.kxb.
(
Sin +)
yb
L If
/2
(N

O)
L If (
N O
)
y
O
O

Effort due to the wind

.
Relative speed of a point M
Vvx + S. (
Sin
.' '
O +)
- X

V = Vvy

- S.
(
Cos O
+). '- y
R
'

0

with
S: the curvilinear X-coordinate of the point M on the beam S [L/2, L/2]

Vvx, Vvy: speed of the wind following the axis "X" and centers it "y".

.
Speed relating perpendicular to the bar to the point M:

(
Sin

O
+). (- Vvy.
(
Cos O

+) +Vvx. (
Sin O
+) + S
. '-
(
Sin O
+) .x'+
(
Cos O
+) .y) '

V =
(
Cos
.
.

.

. '

. '

O +) (Vvy
(
Cos O +) - Vvx
(
Sin O +) - S +
(
Sin O +) X - Co (
S O +) .y
p
)'

0

Force due to the wind in a point M
V
Fvent
p
(
=
=
M)
F (
cx M).
in our case one chooses FC (
X M)
Vp
Vp
one thus obtains
(
Fvent) = V
M
p

.
Resultant of the force due to the wind on the bar
L.S (
in

O
+). (- Vvy + y) '.
(
Cos O
+) + (Vvx - X) '. S (
in O
+)

Fvent = L.Co (
S O
+). (Vvy - y) '. Co (S O
+) + (- Vvx + X) '. If (
N O
+)

- L3

. '/12

Final equation of dynamics
Mr. = F + Bfr + Fvent
G

2.2
Sizes and results of reference

Displacements and rotation of the point G at the moments: 2.0sec, 3.0sec, 4.0sec, 5.0sec and 6.0sec.

2.3
Uncertainties on the solution

None. The resolution of the equilibrium equation is done by a method of integration of Runge Kutta of order 4.

3 Modeling
With

3.1
Characteristics of modeling and the grid

The linear element: "beam" cut out in 12 meshs.
The discrete ones: "DIS_T"

3.2 Functionalities
tested

Orders

LIRE_RESU EVOL_CHAR VITE_VENT
AFFE_CARA_ELEM BEAM
FCX
AFFE_CHAR_MECA EVOL_CHAR

DEFI_FONCTION NOM_PARA
QUICKLY
DYNA_NON_LINE TYPE_CHARGE
SUIV
DEFORMATION
PETIT_REAC

4 Summary of the results

4.1 Sizes tested and results

Time
Analytical
Code_Aster
Absolute error
Relative error
2.0sec
X (m)
-0.27571
-0.27500
0.00070
0.00255
y (m)
0.46478
0.46358
0.00120
0.00259
Rz (rd)
-0.04851
-0.04850
0.00001
0.00027
Time
Analytical
Code_Aster
Absolute error
Relative error
3.0sec
X (m)
-0.43640
-0.43522
0.00118
0.00271
y (m)
0.68149
0.67959
0.00190
0.00279

Rz (rd)
-0.16767
-0.16688
0.00079
0.00472
Time
Analytical
Code_Aster
Absolute error
Relative error
4.0sec
X (m)
-0.21266
-0.21223
0.00043
0.00201
y (m)
0.07494
0.07605
0.00111
0.01476
Rz (rd)
-0.15769
-0.15743
0.00026
0.00163
Time
Analytical
Code_Aster
Absolute error
Relative error
5.0sec
X (m)
0.30290
0.30182
0.00108
0.00357
y (m)
-0.98487
-0.97951
0.00536
0.00544
Rz (rd)

0.11188
0.11162
0.00027
0.00241
Time
Analytical
Code_Aster
Absolute error
Relative error
6.0sec
X (m)
0.59847
0.59815
0.00032
0.00054
y (m)
-1.24735
-1.24413
0.00322
0.00258
Rz (rd)
0.44284
0.44534
0.00251
0.00566
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear systems
HR-17/02/019/A

0.800
Displacement (m)
Rotation (Rd)
0.600
0.400
0.200
0.000
0.0
1.0
2.0
3.0
4.0
5.0
6.0
-0.200
Time
(dryness)
-0.400
-0.600
-0.800
-1.000
X Theoretical
Y Theoretical
Rz Théorique
-1.200
X Aster
Y Aster
Rz Aster

-1.400

Comparison enters the theoretical results and those of Code_Aster.

4.2 Parameters
of execution

Version:
6.0

Machine:
IRIX64

Obstruction memory: 30 Megawords
Time CPU To use: 75.0 seconds

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
Document: V5.02.103

SDNL103 - Dynamics of a modelled gantry
by elements of beam in great rotation.
Comparison with an analysis in small rotation

Summary:

One analyzes the response of a gantry, embedded in feet and subjected to a dynamic force applied to the medium
of its span and perpendicular to its plan. Displacements are small. One compares two modelings of beams: POU_D_T_GD and POU_D_T.

Interest: to test the element of beam in great rotation MECA_POU_D_T_GD and the order DYNA_NON_LINE [U4.32.02].
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HI-75/01/010/A

Code_Aster ®
Version
5.0

Titrate:
SDNL103 - Dynamics of a gantry modelled by elements
Date:
17/12/01
Author (S):
J.M. PROIX, Key Mr. AUFAURE
:

1
Problem of reference

1.1 Geometry

2 m
F
Z
12 m
X
y

1.2
Material properties

For the span:
E = 7. E10 Pa;
= 0.3 ;
= 2700 kg/m3
For the posts:
E = 5. E10 Pa;
= 0.3 ;
= 2500 kg/m3

1.3
Boundary conditions and loadings

Embedding in foot of posts.

Evolution of the force F:

F (NR)
500
T (S)
0

0.1
0.2

1.4 Conditions
initial

Static position of balance; null speed.

2
Reference solution

2.1
Method of calculation used for the reference solution

This problem does not have an analytical solution. But, as displacements are small, one takes for reference modeling by elements of beam POU_D_T.

2.2
Results of reference

Displacement of the medium of the span, in direction X at the moments:

0.14 S; 0.26 S; 0.36 S and 0.47 S.

---

3 Modeling
With

3.1
Characteristics of modeling

Characteristics of the span:

To = 2.24 E3 m2; Iy = Iz = 3.7 E6 m4; Jx = 7.4 E6 m4;
Ay = Az = 1.2

Characteristics of the posts:

To = 3.14 E2 m2; Iy = Iz = 4.5 E5 m4; Jx = 9.0 E5 m4;
Ay = Az = 1.2

The analysis relates to 0.5 S in 100 steps of equal times.

3.2
Characteristics of the grid

The span is modelled by 12 elements of beam; each post by 2 elements. All these elements have 1m of longor.

3.3 Functionalities
tested

Orders
Key word factor
Key word
Argument
Keys
AFFE_MODELE AFFE
MODELING
POU_D_T_GD [U4.22.01]
DYNA_NON_LINE
COMP_ELAS RELATION ELAS_POUTRE_GD
[U4.32.02]
DEFORMATION
GREEN

4
Results of modeling A

4.1 Values
tested

Identification
POU_D_T
POU_D_T_GD
% difference
Aster
DX in T = 1.4 E1
2.9706 E2
2.9069 E2
-2.1
DX in T = 2.6 E1
2.6290 E2
2.5376 E2
-3.5
DX in T = 3.6 E1
2.5126 E2
2.5147 E2
0.08
DX in T = 4.7 E1
2.5488 E2
2.5390 E2
-0.4

4.2 Parameters
of execution

Version: 4.1
Machine: CRAY C90

Obstruction memory:
8 MW
Time CPU To use:
183 seconds

5
Summary of the results

The variation compared to the reference solution is to the maximum of 3,5% during the transient. reference solution being obtained with elements POU_D_T, in small displacements, this variation is thus explainable and remains weak in the course of time.

Organization (S): EDF/EP/AMV

V5.02.104 document

SDNL104 - Under-structuring transitory nonlinear: shock of a beam on 1 support

Summary:
The applicability of this test relates to the dynamics of the structures, and more particularly the calculation of

nonlinear transitory response by dynamic under-structuring.
It is a question of calculating the nonlinear transitory response of a beam in inflection with shock on an elastic support and
subjected to a constant force as from the initial moment. The beam is modelled by elements of the type POU_D_E (model beam of Euler).
The results of reference result from a direct transitory calculation by modal recombination. This test allows
thus to validate the computational tools of response transitory per under-structuring, in the case of the catch in
count non-linearities of the shock type on a fixed obstacle.
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HP-51/96/033 - Ind A

1
Problem of reference
1.1 Geometry
F
y
With
Play
X
Kc
The length of the beam is worth: L = 1 m
The section of the beam is full circular of ray: R = 0.1 m
The play between the beam and the elastic support is worth: J = 1 104 m
1.2
Material properties
E = 1 1010 Pa
= 0.3
= 1.106 kg/m3

The stiffness within the competence of contact is worth: Kc = 1.108 N/m
1.3
Boundary conditions and loadings
On all the structure: DX = DZ = DRY = DRX = 0.
At point a: DY = DRZ = 0.
At the loose lead of the beam: as from the moment T = 0 S, Fy = 1000. NR
1.4 Conditions
initial
Structure initially at rest.

2
Reference solution
2.1
Method of calculation used for the reference solution
The reference solution is given by a direct transitory calculation by modal recombination (modeling A).
2.2
Results of reference
Value of displacements, speed and acceleration of the loose lead of the beam according to the direction Y and
at the moment T = 1 S.
Displacement
Speed
Acceleration
(m)
(m.s1)
(m.s2)
Diagram of integration of Euler

1.255 104
8.352 104
3.640 101
Diagram of integration of Devogelaere
1.254 104
8.410 104
2.855 101
Diagram of integration to step of time
1.255 104
8.480 104
3.620 101
adaptive
2.3
Uncertainty on the solution
Numerical solution.
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HP-51/96/033 - Ind A

---

3 Modeling With

3.1 Characteristics of modeling

The beam is with a grid in segments to which are affected of the elements of the type "POU_D_E".
The dealt with transitory problem, projected on the basis of clean mode the first 5 of the structure, is solved directly by the transitory operator of calculation by modal recombination (DYNA_TRAN_MODAL [U4.54.03]).

3.2 Functionalities tested

This modeling is used as reference of the case test. It does not have thus as an aim to test them functionalities of Code_Aster.

3.3 Characteristics of the grid

A number of nodes: 11
A number of meshs and types: 10 SEG2

Code_Aster ®
Version
4.0
Titrate:
Nonlinear SDNL104 transitory Under-structuring
Date:
12/01/98
Author (S):
G. ROUSSEAU, C. VARE
Key:

4
Results of modeling A
4.1
Actual values: references for modeling B

Identification
Aster

Diagram of integration of Euler
Displacement (m)
1.255 104
Speed (m.s1)
8.352 104
Acceleration (m.s2)
3.640 101
Diagram of integration of
Devogelaere
Displacement (m)
1.254 104
Speed (m.s1)
8.410 104
Acceleration (m.s2)
2.855 101
Diagram of integration to step of
adaptive time
Displacement (m)
1.255 104
Speed (m.s1)
8.480 104
Acceleration (m.s2)
3.620 101

4.2 Parameters
of execution

Version: 3.05.23
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
16.43 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

The beam is cut out in 2 parts of equal size. Each substructure considered is
with a grid in segments to which are affected of the elements of the type "POU_D_E".
=
+
The structure is studied using the method of under-structuring with interfaces of the type "Craig-Bampton" (blocked interfaces).
The base of the first 5 clean modes of the complete structure is calculated by under-structuring.
Then, the transitory problem, projected on this basis, is solved by the transitory operator of calculation by modal recombination (DYNA_TRAN_MODAL).

5.2 Functionalities
tested

Order
Keys
DYNA_TRAN_MODAL
METHOD
"EULER"
[U4.54.03]
"DEVOGE"
"ADAPT"
SHOCK
SOUS_STRUC_1
LOCATE

5.3
Characteristics of the grid

A number of nodes: 6
A number of meshs and types: 5 SEG2

---

6 Results of modeling B

6.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
Diagram of integration of Euler			
Displacement (m)	1.255 104	1.255 104	0.043
Speed (m.s1)	8.352 104	8.289 104	0.75
Acceleration (m.s2)	3.640 101	3.870 101	6.32
Diagram of integration of Devogelaere			
Displacement (m)	1.254 104	1.255 104	0.042
Speed (m.s1)			

8.410 104
8.320 104
1.076
Acceleration (m.s2)
2.855 101
3.079 101
7.85
Diagram of integration to step of
adaptive time
Displacement (m)
1.255 104
1.255 104
0.028
Speed (m.s1)
8.480 104
8.508 104
0.328
Acceleration (m.s2)
3.620 101
3.926 101
8.448

6.2 Remarks

In the case of a nonlinear transitory calculation, it is not abnormal to obtain uncertainties important on not realised sizes. The variation from 6 to 8% between the reference solution and solution obtained by under-structuring for acceleration thus does not invalidate the method tested, more especially as the results in displacements are excellent (variation < 0.1%).

6.3 Parameters of execution

Version: 3.05.23
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
20.7 seconds

---

7 Summary of the results

The precision on displacements of the loose lead of the beam at the moment T = 1. S is excellent (relative error < 0.1%).

This test thus validates the operators of non-linear transitory calculation by dynamic under-structuring.

The values of acceleration with the diagram of Devogelaere are to be analyzed.

Organization (S): EDF/EP/AMV

Handbook of Validation

V5.02 booklet: Nonlinear dynamics of the linear structures

V5.02.105 document

SDNL105 - Under-structuring transitory nonlinear: shock of 3 beams between them

Summary:

The applicability of this test relates to the dynamics of the structures, and more particularly the calculation of
nonlinear transitory response by dynamic under-structuring.

It is a question of calculating the nonlinear transitory response of 3 beams in inflection with shocks to the center of the beams.

The beams are modelled by elements of the type “POU_D_E” (model of Euler).

The results of reference result from a direct transitory calculation by modal recombination. This test

allows
thus to validate the computational tools of response transitory per under-structuring, in the case of the catch in
count non-linearities of the shock type between mobile structures.
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HP-51/96/033 - Ind A

Code_Aster ®
Version
4.0
Titrate:
Nonlinear SDNL105 transitory Under-structuring
Date:
12/01/98
Author (S):
G. ROUSSEAU, C. VARE
Key:
V5.02.105-A Page:
2/8

1 Problem of reference

1.1 Geometry

X
Play
F
y
X
X
X
Kc

The length of the beams is worth: L = 1 m
The beams are of circular section:
· of ray: R = 0.1 m
· thickness: ep = 0.01 m
The play between the beams is worth: Play = 1 103 m

1.2 Material properties

E = 1 1010 Pa
= 0.3
= 1.108 kg/m3
The stiffness within the competence of contact is worth: Kc = 1.108 N/m

1.3

Boundary conditions and loadings
On all the structure: DX = DZ = DRX = DRY = 0.
With the superior ends and inferior of the beams: DY = DRZ = 0.
In the middle of the beam of left: as from the moment T = 0 S, Fy = 1.106 NR
1.4 Conditions
initial
Structure initially at rest.
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HP-51/96/033 - Ind A

Code_Aster ®
Version
4.0
Titrate:
Nonlinear SDNL105 transitory Under-structuring
Date:
12/01/98
Author (S):
G. ROUSSEAU, C. VARE
Key:
V5.02.105-A Page:
3/8
2
Reference solution
2.1
Method of calculation used for the reference solution
The reference solution is given by a direct transitory calculation by modal superposition
(modeling A).
2.2
Results of reference
Value of displacements and speed of the nodes of the 3 beams according to the direction Y and at the
moment T = 1 S.
Displacement
Speed
(m)
(m.s1)
Diagram of integration of Euler
Beam of left
1.64 102
2.54 102
Beam medium
1.12 102

4.49 102
Beam of right-hand side
5.90 103
1.05 101
Diagram of integration of Devogelaere
Beam of left
1.64 102
2.54 102
Beam medium
1.12 102
4.41 102
Beam of right-hand side
5.89 103
1.05 101
Diagram of integration to step of adaptive time
Beam of left
1.64 102
2.55 102
Beam medium
1.12 102
4.41 102
Beam of right-hand side
5.91 103
1.05 101

2.3
Uncertainty on the solution

Numerical solution.

---

3 Modeling
With
3.1
Characteristics of modeling
The beam is with a grid in segments to which are affected of the elements of the type "POU_D_E".
The dealt with transitory problem, projected on the basis of clean mode the first 15 of the structure, is solved directly by the transitory operator of calculation by modal recombination
(DYNA_TRAN_MODAL
[U4.54.03]).
3.2 Functionalities
tested
This modeling is used as reference of the case test. It does not have thus as an aim to test them functionalities of Code_Aster.
3.3
Characteristics of the grid
A number of nodes: 41
A number of meshs and types: 42 SEG2

4
Results of modeling A
4.1
Actual values: reference for modeling B
Identification
Aster
Diagram of integration of Euler
Beam of left: Displacement (m)
1.64 102
Speed (m.s1)

2.54 102
Beam of medium: Displacement (m)
1.12 102
Speed (m.s1)
4.43 102
Beam of right-hand side: Displacement (m)
5.90 103
Speed (m.s1)
1.05 101
Diagram of integration of Devogelaere
Beam of left: Displacement (m)
1.64 102
Speed (m.s1)
2.54 102
Beam of medium: Displacement (m)
1.12 102
Speed (m.s1)
4.41 102
Beam of right-hand side: Displacement (m)
5.89 103
Speed (m.s1)
1.05 101
Diagram of integration to step of time
adaptive
Beam of left: Displacement (m)
1.64 102
Speed (m.s1)
2.55 102
Beam of medium: Displacement (m)
1.12 102
Speed (m.s1)
4.41 102
Beam of right-hand side: Displacement (m)
5.91 103
Speed (m.s1)
1.05 101

4.2 Parameters of execution

Version: 3.05.32
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:

29.61 seconds
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
HP-51/96/033 - Ind A

---

5 Modeling B

5.1 Characteristics of modeling

=
X 3

The dynamic under-structuring makes it possible to calculate the vibratory behavior of the 3 beams to be left
dynamic characteristics of only one beam. This one is with a grid in segments to which are affected elements of the type "POU_D_E".

The structure is studied using the method of under-structuring with interfaces of the type "Craig-Bampton" (blocked interfaces).

The base of the first 15 clean modes of the complete structure is calculated by under-structuring.
Then the transitory problem, projected on this basis, is solved by the transitory operator of calculation by modal recombination (DYNA_TRAN_MODAL).

5.2 Functionalities tested

Order
Keys
DYNA_TRAN_MODAL
METHOD
"EULER"
[U4.54.03]
"DEVOGE"
"ADAPT"
SHOCK
SOUS_STRUC_1
SOUS_STRUC_2

5.3 Characteristics of the grid

A number of nodes: 15

---

6 Results of modeling B

6.1 Values tested

Identification
Reference
Aster
% difference
Diagram of integration of Euler
Beam of left: Displacement (m)
1.64 102
1.64 102
Speed (m.s1)
2.54 102
2.54 102
Beam of medium: Displacement (m)
1.12 102
1.12 102
< 0.01 %
Speed (m.s1)
4.43 102
4.43 102
Beam of right-hand side: Displacement (m)
5.90 103
5.90 103
Speed (m.s1)

1.05 101
1.05 101
Diagram of integration of Devogelaere
Beam of left: Displacement (m)
1.64 102
1.64 102
Speed (m.s1)
2.54 102
2.54 102
Beam of medium: Displacement (m)
1.12 102
1.12 102
< 0.01 %
Speed (m.s1)
4.41 102
4.41 102
Beam of right-hand side: Displacement (m)
5.89 103
5.89 103
Speed (m.s1)
1.05 101
1.05 101
Diagram of integration to step of time
adaptive
Beam of left: Displacement (m)
1.64 102
1.64 102
Speed (m.s1)
2.55 102
2.55 102
Beam of medium: Displacement (m)
1.12 102
1.12 102
< 0.01 %
Speed (m.s1)
4.41 102
4.41 102
Beam of right-hand side: Displacement (m)
5.91 103
5.91 103
Speed (m.s1)
1.05 101
1.05 101

6.2 Parameters of execution

Version: 3.05.32
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
38.98 seconds

---

7 Summary of the results

Precision on displacements and speeds of the nodes mediums of the 3 beams at the moment T = 1 S is excellent (relative error < 0.01s).

This test thus validates the operators of non-linear transitory calculation by dynamic under-structuring.

***S. LAMARCHE**, G. JACQUART Key*
:
V5.02.111-B Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
V5.02.111 document

SDNL111 - Impact of two beams

Summary:

This problem is a problem of impact of two beams in traction and compression. A first free beam is animated an initial speed parallel with the axis of the two beams and comes to run up against one embedded second against its
base. Non-linearity comes from the conditions of contact between the two structures. This test comprises a solution
analytical of reference.

Initially, one uses a transitory analysis by modal recombination of a non-linear system constituted of structures of beams (modelings has and b).
The beams are discretized by finite elements of type POU_D_T. Operators DEFI_OBSTACLE [U4.44.21] and DYNA_TRAN_MODAL [U4.53.21] are tested. The variations with the values of

reference do not exceed
not 4.5%.

In the second time, one makes a direct calculation on physical basis, with elements 3D (modelings C, D
and E). The operators tested are: DYNA_NON_LINE, AFFE_CHAR_MECA/CONTACT with the methods
CONSTRAINT, LAGRANGE and CONTINUOUS.

1
Problem of reference

1.1 Geometry

X
has
B
B (A)
Z
- V
L
has
O

y
With
OJ
C
L
D
Z
y
Length of the beams

L = 1. m
Side of the section of the beams
= 2. cm have

1.2
Material properties

:
Beam
modulate

:
Young
E = 2.1011Pa
coeffician
:
Poisson

of
T
= 0.pour modélisati

for

0.3

and

1D,

one

modélisati

3D

one

3
voluminal

mass
= 7800kg/m

1.3
Boundary conditions and loadings

The problem is one-way according to X.
The beam CD is embedded in D, beam AB is completely free in translation according to X.

1.4 Conditions
initial

All the nodes of beam AB are imposed according to axis X:

.
an initial speed: v0 = -1 m/s

The nodes of the beam CD have a speed and an initial displacement no one.
The points A and C are separated from an initial play OJ very weak: OJ = 105 Mr.

2
Reference solution

2.1
Method of calculation used for the reference solution

Drawn from [bib1].

F (T)
ESVo
F (T): force contact in A;
2c p

V (X, T): speed;
T

U (X, T): displacement;
O
O + 2
= OJ;
V (X, T)
O
Vo
Vo

2 L
=
V
Duration of shock = 2;
O 2
C

p
T
O +
O
O + 2

- V
C
;
O /2
p
=
E (1 -)
(1+)(1 - 2)
- Vo
S = a2 section.
U (X, T)
for point A
OJ
T
O
O +
O + 2
- Vo/2

2.2 References bibliographical

[1]
Algorithms of fast dynamics theoretical Description and examples of applications. Report/ratio EDF/DER HP-61/93.115

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3 Modeling
With

3.1
Characteristics of modeling

Discretization of the two beams by meshs SEG2 (50 each one) and finite elements of type POU_D_T.

A modal base of 40 clean modes (20 by beams) is used for the modal superposition.
A contractual reduced modal damping by 0.1% is applied to each clean mode.

The conditions initial speeds are imposed by building a field on the nodes of displacement via groups of nodes:

GROUP_NO: BARRE1 (initial speed DX = -1.)
GROUP_NO: BARRE2 (initial speed DX = 0.)

and by projecting this field with the nodes on the modal basis by specifying TYPE_VECT: "QUICKLY".

The vector generalized thus calculated can be introduced into order DYNA_TRAN_MODAL behind key word VITE_INIT.

The parameters of modeling of the law of shock used are:

The first modeling (possible):

- ***the normal in the plan of the shock is selected according to Z: NORM_OBST: (0. 0. 1.)***
- ***an obstacle of the type BI_PLAN_Z is selected***

The second modeling:

- ***the normal in the plan of the shock is selected according to Y: NORM_OBST: (0. 1. 0.)***
- ***an obstacle of the type BI_PLAN_Y is selected***

The third modeling:

·
the normal in the plan of the shock is selected according to Y: NORM_OBST: (0. 1. 0.)
·
an obstacle of the type BI_CERCLE is selected

·
Stiffness of shock: RIGI_NOR: 5.109 N/m
·
Damping of shock: AMOR_NOR: 2.104 Ns/m

The values of DIST_1 and DIST_2 which are fictitious here and only to model the contact are chosen equal to DIST_1=DIST_2= Jo/2 so that there is contact at the beginning of calculation.

Temporal integration is carried out with the algorithm of Euler and a step of times of 106 S.

3.2
Characteristics of the grid

A number of nodes: 102

A number of meshs and types: 100 SEG2

3.3 Functionalities

tested

Orders

STANDARD DEFI_OBSTACLE
“BI_PLAN_Z”
“BI_PLAN_Y”
“BI_CERCLE”
DYNA_TRAN_MODAL SHOCK
NOEU_2
DIST_1
DIST_2
ENTITLE
VITE_INIT_GENE

METHOD
“EULER”

3.4 Values
tested

Identification Reference
Aster %
difference
DX at point A t=2.0e-4 S
1.E-4
1.008E-4
0.78
DX at point A t=4.0e-4 S
2.E-4
1.939E-4
-3.071
DX at point A t=6.0e-4 S
1.E-4
9.558E-5
-4.417
DX at point A t=8.0e-4 S
0. 8.036E-6
ABS:
8.04E-6
DX at point A t=1.0e-3 S
2.E-4
2.063E-4

3.138

4 Modeling B

4.1 Characteristics of modeling

Discretization of the two beams by meshs SEG2 (50 each one) and finite elements of type POU_D_T.

A modal base of 40 clean modes (20 by beams) is used for the modal superposition. A contractual reduced modal damping by 0.1% is applied to each clean mode.

The conditions initial speeds are imposed by building an initial field speed applied with beams POUTRE1 and POUTRE2.

The parameters of modeling of the law of shock used are:

- ***the normal in the plan of the shock is selected according to Z: NORM_OBST: (0. 1. 0.)***
- ***an obstacle of the type BI_CERC_INT is selected***
- ***Stiffness of shock: RIGI_NOR: 5.109 N/m***
- ***Damping of shock: AMOR_NOR: 2.104 Ns/m***

Temporal integration is carried out with the algorithm of Euler and a step of times of 106 S.

4.2 Characteristics of the grid

A number of nodes: 102

A number of meshs and types: 100 SEG2

7.3

Titrate:
SDNL111 - Impact of two beams

Date:
01/01/04
Author (S):
S. LAMARCHE, G. JACQUART Key
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4.3 Functionalities
tested

Orders

STANDARD DEFI_OBSTACLE
“BI_CERC_INT”
DYNA_TRAN_MODAL SHOCK
NOEU_2

DIST_1

DIST_2

ENTITLE
VITE_INIT_GENE

METHOD
“EULER”

4.4 Values
tested

Identification Reference
Aster %
difference
DX at point A t=2.0e-4 S
1.E-4
1.008E-4

0.8
DX at point A t=4.0e-4 S
2.E-4
1.937E-4
-3.15
DX at point A t=6.0e-4 S
1.E-4
9.558E-5
-4.42
DX at point A t=8.0e-4 S
0. 6.565E-6
ABS:
6.56E-6
DX at point A t=1.0e-3 S
1.E-4
1.069E-4
6.9
DX at point A t=1.2e-3 S
2.E-4
1.914E-4
-4.3
DX at point A t=1.4e-3 S
1.E-4
9.335E-5
-6.65
DX at point A t=1.6e-3 S
0.
-8.948E-6
ABS: 8.95E-6

5 Modeling
C

5.1
Characteristics of modeling

The two beams are modelled with meshs QUAD4 (50 by beam) and of the finite elements 3D. The behavior is elastic.

The conditions initial speeds are imposed by building a field initial speed applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by loads of contact. One uses AFFE_CHAR_MECA with the key word CONTACT.
Pairing is of master-slave type. The method used IS FORCED.

Temporal integration is carried out with method HHT (= -0.1) and a step of times of 106 S.
The subdivision of step of time is authorized. For the solvor, one uses method MULT_FRONT.

5.2
Characteristics of the grid

A number of nodes: 408

A number of meshs and types: 50 QUAD4
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V5.02 booklet: Nonlinear dynamics of the linear structures
HT-66/04/005/A

Code_Aster ®
Version
7.3

Titrate:
SDNL111 - Impact of two beams

Date:
01/01/04
Author (S):
S. LAMARCHE, G. JACQUART Key
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5.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
CONSTRAINT

CREA_CHAMP OPERATION "AFFE"
TYPE_CHAM

“NOEU_DEPL_R”

AFFE
GROUP_NO
“POU1”
“POU2”
NOM_CMP
“DZ”
DYNA_NON_LINE METHOD
HHT

ETAT_INIT
QUICKLY

5.4 Values
tested

Identification Reference
Aster %
difference
DZ at point A t=2.0e-4 S
1.050E-4
1.050E-4
0.00
DZ at point A t=4.0e-4 S
1.550E-4
1.552E-4
0.16
DZ at point A t=6.0e-4 S
5.540E-5
5.541E-5
0.01
DZ at point A t=8.0e-4 S
9.920E-5
9.550E-5
-3.73
DZ at point A t=1.0e-3 S
2.990E-4
2.955E-4
-1.15

tps_job 320 mem_job 800Mo ncpus1

6 Modeling
D

6.1
Characteristics of modeling

The two beams are modelled with meshs QUAD4 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial speeds are imposed by building a field initial speed
applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by loads of contact. One uses AFFE_CHAR_MECA with the key word
CONTACT.
Pairing is of master-slave type. The method used is LAGRANGE, without friction.

Temporal integration is carried out with method HHT (= -0.1) and a step of times of 106 S.
The subdivision of step of time is authorized. For the solvor, one uses method MULT_FRONT.

6.2
Characteristics of the grid

A number of nodes: 408

A number of meshs and types: 50 QUAD4

6.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
LAGRANGE

CREA_CHAMP OPERATION "AFFE"

TYPE_CHAM
"NOEU_DEPL_R"

AFFE
GROUP_NO
"POU1"
"POU2"
NOM_CMP
"DZ"
DYNA_NON_LINE METHOD
HHT

ETAT_INIT
QUICKLY

6.4 Values

tested

Identification Reference
***Aster** %*
difference
DZ at point A t=2.0e-4 S
1.050E-4
1.050E-4
0.00
DZ at point A t=4.0e-4 S
1.550E-4
1.552E-4
0.16
DZ at point A t=6.0e-4 S
5.540E-5
5.541E-5
0.01
DZ at point A t=8.0e-4 S
9.920E-5
9.550E-5
-3.73
DZ at point A t=1.0e-3 S
2.990E-4
2.955E-4
-1.15

tps_job 720 mem_job 800Mo ncpus1

7 Modeling
E

7.1
Characteristics of modeling

The two beams are modelled with meshs QUAD4 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial speeds are imposed by building a field initial speed
applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by loads of contact. One uses AFFE_CHAR_MECA with the key word CONTACT.
Pairing is of master-slave type. The method used is CONTINUOUS, without friction.

Temporal integration is carried out with method HHT (= -0.1) and a step of times of 106 S.
The subdivision of step of time is authorized. For the solvor, one uses method MULT_FRONT.

7.2
Characteristics of the grid

A number of nodes: 408

A number of meshs and types: 50 QUAD4

7.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
CONTINUOUS

INTEGRATION
NODE

CREA_CHAMP OPERATION “AFFE”

TYPE_CHAM
“NOEU_DEPL_R”

AFFE
GROUP_NO
“POU1”
“POU2”
NOM_CMP
“DZ”
DYNA_NON_LINE METHOD
HHT

ETAT_INIT
QUICKLY

7.4 Values
tested

Identification Reference
***Aster** %*
difference
DZ at point A t=2.0e-4 S
1.050E-4
-1.050E-4
0.00
DZ at point A t=4.0e-4 S
1.550E-4
-1.522E-4
-1.82
DZ at point A t=6.0e-4 S
5.540E-5
-5.537E-5
-0.05
DZ at point A t=8.0e-4 S
9.920E-5
9.550E-5
-3.73
DZ at point A t=1.0e-3 S
2.990E-4
2.950E-4
-1.33

tps_job 2100 mem_job 800Mo ncpus 1

---

8 *Summary of the results*

For modelings has and B (with DYNA_TRAN_MODAL):
The precision of calculation is relatively average what is due to the choice of the coefficients of penalization used to model the contact. The increase in the stiffness of contact improves considerably the field of displacement but generates the important oscillations of the field of speed around the analytical solution.

For modelings C, D and E (with DYNA_NON_LINE):
The precision of calculation is very good (4% of maximum change). In this case, three methods used results of comparable quality give. For this size of problem, the computing time is more length with the method CONTINUES.

Titrate:
SDNL111 - Impact of two beams

Date:
04/05/06
Author (S):
***NR. GREFFET,** S. LAMARCHE, G. JACQUART Key*
:
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Organization (S): EDF-R & D /AMA, Industrie/CNPE EDF-Pole of Tricastin

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
V5.02.111 document

SDNL111 - Impact of two beams

Summary:

This problem is a problem of impact of two beams in traction and compression. A first free beam is animated an initial speed parallel with the axis of the two beams and comes to run up against one embedded second against its
base. Non-linearity comes from the conditions of contact between the two structures. This test

comprises a solution
analytical of reference.

Initially, one uses a transitory analysis by modal recombination of a non-linear system
constituted of structures of beams (modelings has and b).
The beams are discretized by finite elements of type POU_D_T. Operators DEFI_OBSTACLE
[U4.44.21] and DYNA_TRAN_MODAL [U4.53.21] are tested. The variations with the values of
reference do not exceed
not 4.5%.

In the second time, one makes a direct calculation on physical basis, with elements 3D (modelings C,
D
and E). The operators tested are: DYNA_NON_LINE, AFFE_CHAR_MECA/CONTACT with the
methods
CONSTRAINT, LAGRANGE and CONTINUOUS.

1
Problem of reference

1.1 Geometry

X
has

B
B (A)
Z
- V
L
has
O
y
With
OJ
C
L
D
Z
y
Length of the beams

L = 1. m
Side of the section of the beams
= 2. cm have

1.2
Material properties

:
Beam
modulate

:
Young
E = 2.1011Pa
coeffician
:
Poisson

of
T
= 0.pour modélisati

for

0.3

and

1D,

one
modélisati

3D

one

3
voluminal

mass
= 7800kg/m

1.3
Boundary conditions and loadings

The problem is one-way according to X.
The beam CD is embedded in D, beam AB is completely free in translation according to X.

1.4 Conditions
initial

All the nodes of beam AB are imposed according to axis X:

.
an initial speed: v0 = -1 m/s

The nodes of the beam CD have a speed and an initial displacement no one.
The points A and C are separated from an initial play OJ very weak: OJ = 105 Mr.

2
Reference solution

2.1
Method of calculation used for the reference solution

Drawn from [bib1].

F (T)
ESVo
F (T): force contact in A;
2c p

V (X, T): speed;
T

U (X, T): displacement;
O
O + 2
= OJ;
V (X, T)
O
Vo
Vo

2 L
=
V
Duration of shock = 2;
O 2

C

p
T
O +
O
O + 2
- V
C
;
O /2
p
=
E (1 -)
(1+)(1 - 2)
- Vo
S = a2 section.
U (X, T)
for point A
OJ
T
O
O +
O + 2
- Vo/2

2.2 References bibliographical

[1]
Algorithms of fast dynamics theoretical Description and examples of applications. Report/ratio EDF/DER HP-61/93.115

Handbook of Validation
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Titrate:

SDNL111 - Impact of two beams

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04/05/06
Author (S):
NR. GREFFET, S. LAMARCHE, G. JACQUART Key
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3 Modeling
With

3.1
Characteristics of modeling

Discretization of the two beams by meshs SEG2 (50 each one) and finite elements of type POU_D_T.

A modal base of 40 clean modes (20 by beams) is used for the modal superposition.
A contractual reduced modal damping by 0.1% is applied to each clean mode.

The conditions initial speeds are imposed by building a field on the nodes of displacement via groups of nodes:

GROUP_NO: BARRE1 (initial speed DX = -1.)
GROUP_NO: BARRE2 (initial speed DX = 0.)

and by projecting this field with the nodes on the modal basis by specifying TYPE_VECT: "QUICKLY".

The vector generalized thus calculated can be introduced into order DYNA_TRAN_MODAL behind key word VITE_INIT.

The parameters of modeling of the law of shock used are:

The first modeling (possible):

- *the normal in the plan of the shock is selected according to Z: NORM_OBST: (0. 0. 1.)*
- *an obstacle of the type BI_PLAN_Z is selected*

The second modeling:

•
the normal in the plan of the shock is selected according to Y: NORM_OBST: (0. 1. 0.)
•
an obstacle of the type BI_PLAN_Y is selected

The third modeling:

•
the normal in the plan of the shock is selected according to Y: NORM_OBST: (0. 1. 0.)
•
an obstacle of the type BI_CERCLE is selected

•
Stiffness of shock: RIGI_NOR: 5.109 N/m
•
Damping of shock: AMOR_NOR: 2.104 Ns/m

The values of DIST_1 and DIST_2 which are fictitious here and only to model the contact are chosen equal to DIST_1=DIST_2= Jo/2 so that there is contact at the beginning of calculation.

Temporal integration is carried out with the algorithm of Euler and a step of times of 106 S.

3.2
Characteristics of the grid

A number of nodes: 102

A number of meshs and types: 100 SEG2

3.3 Functionalities
tested

Orders

STANDARD DEFI_OBSTACLE
“BI_PLAN_Z”
“BI_PLAN_Y”
“BI_CERCLE”
DYNA_TRAN_MODAL SHOCK
NOEU_2
DIST_1
DIST_2
ENTITLE
VITE_INIT_GENE

METHOD
“EULER”

3.4 Values
tested

Identification Reference
Aster %
difference
DX at point A t=2.0e-4 S
1.E-4
1.008E-4
0.78
DX at point A t=4.0e-4 S
2.E-4
1.939E-4
-3.071
DX at point A t=6.0e-4 S
1.E-4
9.558E-5

-4.417
DX at point A t=8.0e-4 S
0. 8.036E-6
ABS:
8.04E-6
DX at point A t=1.0e-3 S
2.E-4
2.063E-4
3.138

4 Modeling
B

4.1
Characteristics of modeling

Discretization of the two beams by meshs SEG2 (50 each one) and finite elements of type POU_D_T.

A modal base of 40 clean modes (20 by beams) is used for the modal superposition.
A contractual reduced modal damping by 0.1% is applied to each clean mode.

The conditions initial speeds are imposed by building an initial field speed applied
with beams POUTRE1 and POUTRE2.

The parameters of modeling of the law of shock used are:

·
the normal in the plan of the shock is selected according to Z: NORM_OBST: (0. 1. 0.)
·
an obstacle of the type BI_CERC_INT is selected

·
Stiffness of shock: RIGI_NOR: 5.109 N/m
·
Damping of shock: AMOR_NOR: 2.104 Ns/m

Temporal integration is carried out with the algorithm of Euler and a step of times of 106 S.

4.2
Characteristics of the grid

A number of nodes: 102

A number of meshs and types: 100 SEG2
Handbook of Validation
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4.3 Functionalities
tested

Orders

STANDARD DEFI_OBSTACLE
"BI_CERC_INT"
DYNA_TRAN_MODAL SHOCK
NOEU_2

DIST_1

DIST_2

ENTITLE
VITE_INIT_GENE

METHOD
"EULER"

4.4 Values

tested

Identification Reference
Aster %
difference
DX at point A t=2.0e-4 S
1.E-4
1.008E-4
0.8
DX at point A t=4.0e-4 S
2.E-4
1.937E-4
-3.15
DX at point A t=6.0e-4 S
1.E-4
9.558E-5
-4.42
DX at point A t=8.0e-4 S
0. 6.565E-6
ABS:
6.56E-6
DX at point A t=1.0e-3 S
1.E-4
1.069E-4
6.9
DX at point A t=1.2e-3 S
2.E-4
1.914E-4
-4.3
DX at point A t=1.4e-3 S
1.E-4
9.335E-5
-6.65
DX at point A t=1.6e-3 S
0.
-8.948E-6
ABS: 8.95E-6

5 Modeling
C

5.1

Characteristics of modeling

The two beams are modelled with meshs QUAD4 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial speeds are imposed by building a field initial speed
applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by loads of contact. One uses AFFE_CHAR_MECA with the key word CONTACT.
Pairing is of master-slave type. The method used IS FORCED.

Temporal integration is carried out with the method of modified average acceleration (key word HHT with = -0.1 and MODI_EQUI=' NON': default value) and a step of times of 106 S.
The subdivision of step of time is authorized. For the solvor, one uses method MULT_FRONT.

One tests then another algorithm of temporal integration: - method (key word HHT with = -0.3 and MODI_EQUI=' OUI') and a step of unchanged time of 106 S. the solvor is also unchanged.

5.2
Characteristics of the grid

A number of nodes: 408

A number of meshs and types: 50 QUAD4

5.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
CONSTRAINT

CREA_CHAMP OPERATION "AFFE"
TYPE_CHAM
"NOEU_DEPL_R"

AFFE
GROUP_NO
"POU1"
"POU2"
NOM_CMP
"DZ"
DYNA_NON_LINE METHOD
HHT

ETAT_INIT
QUICKLY

5.4 Values tested

Identification Reference
Aster %
difference
HHT
HHT
HHT
HHT
MODI_EQUI= MODI_EQUI= MODI_EQUI= MODI_EQUI=
"NOT"
"YES"
"NOT"
"YES"
DZ at point A

1.050E-4
1.050E-4
1.050E-4
0.00 0.00
t=2.0e-4 S
DZ at point A
1.550E-4
1.552E-4
1.554E-4
0.16 0.26
t=4.0e-4 S
DZ at point A
5.540E-5
5.541E-5
5.541E-5
0.01 0.01
t=6.0e-4 S
DZ at point A

9.920E-5
9.550E-5 9.707E-5
-3.73 -2.15
t=8.0e-4 S
DZ at point A

2.990E-4
2.955E-4 2.960E-4
-1.15 -1.00
t=1.0e-3 S

tps_job 520 mem_job 512Mo ncpus1

6 Modeling
D

6.1
Characteristics of modeling

The two beams are modelled with meshs QUAD4 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial speeds are imposed by building a field initial speed
applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by loads of contact. One uses AFFE_CHAR_MECA with the key word CONTACT.
Pairing is of master-slave type. The method used is LAGRANGE, without friction.

Temporal integration is carried out with method HHT (= -0.1) and a step of times of 106 S.
The subdivision of step of time is authorized. For the solvor, one uses method MULT_FRONT.

6.2
Characteristics of the grid

A number of nodes: 408

A number of meshs and types: 50 QUAD4
Handbook of Validation
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6.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
LAGRANGE

CREA_CHAMP OPERATION "AFFE"

TYPE_CHAM
"NOEU_DEPL_R"

AFFE
GROUP_NO
"POU1"
"POU2"
NOM_CMP
"DZ"
DYNA_NON_LINE METHOD
HHT

ETAT_INIT
QUICKLY

6.4 Values

tested

Identification Reference
***Aster** %*
difference
DZ at point A t=2.0e-4 S
1.050E-4
1.050E-4
0.00
DZ at point A t=4.0e-4 S
1.550E-4
1.552E-4
0.16
DZ at point A t=6.0e-4 S
5.540E-5
5.541E-5
0.01
DZ at point A t=8.0e-4 S
9.920E-5
9.550E-5
-3.73
DZ at point A t=1.0e-3 S
2.990E-4
2.955E-4
-1.15

tps_job 720 mem_job 800Mo ncpus1

7 Modeling
E

7.1
Characteristics of modeling

The two beams are modelled with meshs QUAD4 (50 by beam) and of the finite elements 3D.
The behavior is elastic.

The conditions initial speeds are imposed by building a field initial speed
applied to the two beams: DZ = -1.0 for POU1 and DZ = 0.0 for POU2.

The shock is modelled by loads of contact. One uses AFFE_CHAR_MECA with the key word
CONTACT.
Pairing is of master-slave type. The method used is CONTINUOUS, without friction.

Temporal integration is carried out with method HHT (= -0.1) and a step of times of 106 S. The subdivision of step of time is authorized. For the solvor, one uses method MULT_FRONT.

7.2
Characteristics of the grid

A number of nodes: 408

A number of meshs and types: 50 QUAD4
Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear structures
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Code_Aster ®
Version
8.3

Titrate:
SDNL111 - Impact of two beams

Date:
04/05/06
Author (S):
NR. GREFFET, *S. LAMARCHE, G. JACQUART Key*
:
V5.02.111-C Page:
9/10

7.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
CONTINUOUS

INTEGRATION
NODE

CREA_CHAMP OPERATION “AFFE”

TYPE_CHAM
“NOEU_DEPL_R”

AFFE
GROUP_NO
“POU1”
“POU2”
NOM_CMP
“DZ”
DYNA_NON_LINE METHOD
HHT

ETAT_INIT
QUICKLY

7.4 Values
tested

Identification Reference
***Aster** %*
difference
DZ at point A t=2.0e-4 S
1.050E-4
-1.050E-4
0.00
DZ at point A t=4.0e-4 S
1.550E-4
-1.522E-4
-1.82
DZ at point A t=6.0e-4 S
5.540E-5
-5.537E-5
-0.05
DZ at point A t=8.0e-4 S
9.920E-5
9.550E-5
-3.73
DZ at point A t=1.0e-3 S
2.990E-4
2.950E-4
-1.33

8
Summary of the results

For modelings has and B (with DYNA_TRAN_MODAL):
The precision of calculation is relatively average what is due to the choice of the coefficients of penalization used to model the contact. The increase in the stiffness of contact improves considerably the field of displacement but generates the important oscillations of the field of speed around the analytical solution.

For modelings C, D and E (with DYNA_NON_LINE):
The precision of calculation is very good (4% of maximum change). In this case, three methods used results of comparable quality give. For this size of problem, the computing time is more length with the method CONTINUES.

Moreover, for modeling C, one also tested two types of diagrams of integration in time implicit: modified average acceleration (key word HHT with option MODI_EQUI=' NON': option by defect) and "complete" HHT (key word HHT with option MODI_EQUI=' OUI').
With "complete" diagram HHT, the maximum variation observed with the reference solution drops slightly: 2,15% against 3,73% with the modified average acceleration. Other values tested are impacted very little, with the choice of values of the parameter of the diagrams employed in it case-test (=-0,1 for the modified average acceleration and =-0,3 for HHT).

Code_Aster ®
Version
7.1

Titrate:
SDNL130 - Seismic response of a beam BA to nonlinear behavior Dates:
15/10/03
Author (S):
S. MILL, *L. DAVENNE, F.GATUINGT*
Key:
V5.02.130-A Page:
1/10

Organization (S): EDF-R & D /AMA, LMT Cachan

Handbook of Validation
V5.02 booklet: Nonlinear dynamics of the linear systems
Document: V5.02.130

SDNL130 - Seismic response of a beam in reinforced concrete (rectangular section) with behavior nonlinear

Summary:

The problem consists in analyzing the seismic response of a concrete beam reinforced via one modeling beam multifibre [R3.08.08]. The behavior of the beam BA is nonlinear. The concrete is modelled with the law of behavior of Borderie in its version 1D [R7.01.07].

Handbook of Validation
Booklet: V5.02: Nonlinear dynamics of the linear systems
HT-66/03/008/A

---

1 Characteristics
general

1.1 Geometry

The geometry is identical to that of the cases test SSNL119 and safe SDLL130 for the reinforcements longitudinal which is identical: 4 HA32

y
X
5.400 mm
500 mm
Frameworks HA8 separated by 100 mm
5.000 mm
20 mm
44 mm
20 mm
32 mm
28
y

500 mm
Z
Tally HA8 spaced 100 mm
232
200 mm
44 mm

Appear 1.1-a: Geometry of the structure

NB: the transverse reinforcements are not taken into account in calculations

1.2
Material properties

· concrete: E = 37.272 MPa, = 0.2,
1
ft = 3.9 MPa, FC = 38.3 Mpa, FC = 2.0.10-3, Gf = 110 J/m,
= 2400 kg/m3

· steel: E = 200.000 MPa, = 0.33, E = 400 MPa, AND = 3.280 MPa, = 7800 kg/m3

· Amortissement: of type Rayleigh (K+M), with 5% on modes 1 and 2

1.3
Boundary conditions and loadings

Simple support in b: Dy = 0
Support "doubles" in a: dx = Dy = 0
To avoid the clean modes except plan, one blocks the following degrees of freedom on all the beam:
X-ray = ry = dz = 0

Loading: seism ac_s2_c_1 [Figure 1.3-a], in axis OY applied to the two supports (factor of amplification of the signal = 45).

3
2
1
0
-1
-2
-3
0
2
4
6
8
10
12
14
16
Time (S)

Appear 1.3-a: Accélérogramme ac_s2_c_1 imposed on the structure

2
Reference solution

The reference solution is a calculation carried out using the computer code EFICOS [bib1]. It is about one
calculation multi-layer (2D) with the same models for materials. The elements do not comprise
that a point of Gauss according to their axis and the total resolution is made by an algorithm with matrix
secant.
To have comparable results in terms of localization and terms of local results
(constraints and deformations at the point of Gauss nearest to the medium of the beam), calculation with
EFICOS (1 point by element) is carried out with 10 elements per half bay whereas calculation with
Code_Aster (2 points per element) is carried out with 8 elements per half bay.
This difference in integration is the principal source of the differences noted in

paragraph [§4].

---

3 Modeling

3.1
Characteristics of modeling

Longitudinal grid of the beam:
It is composed of 17 nodes and 16 pairs of elements POU_D_EM (16 elements for the concrete and 16 for
steel).

Cross section of the beam:
The concrete is modelled by a grid (AFFE_SECT) composed of 2 X 20 quadrilaterals (40 fibres)

Appear 3.1-a: discretization of the section

Steel is modelled by 4 specific fibres (AFFE_FIBRE)

The coefficients and for damping are calculated using the following formula:

1 2
1
1 1
=

2

2
2

-
2
1

2
1
2

-
2
1

where
1
and 2 are the first two own pulsations (F =
2
) and 1 and 2 is them
depreciation wished on the first two modes.
With F
9
,
39
Hz
1 =
and F

157,6 Hz
2 =
(calculated with ASTER), for modal depreciation
from 5%, we find:
5

10
.
8
-
=
and = 20.

For the calculation of the temporal answer, the step of selected time is 1/100ème of second.

3.2 Functionalities tested

Orders

CREA_MAILLAGE
CREA_GROUP_MA

AFFE_MODELE GRID

AFFE
ALL
“YES”
PHENOMENON
“MECHANICAL”
MODELING
“POU_D_EM”
DEFI_MATERIAU
“ELAS”

“LABORD_1D”
“ECRO_LINE”
AFFE_MATERIAU
GROUP_MA

MATER
AFFE_CARA_ELEM BEAM
GROUP_MA

SECTION

ORIENTATION
GROUP_MA

CARA
“ANGL_VRIL”
AFFE_SECT
GROUP_MA

MAILLAGE_SECT
“YES”

TOUT_SECT

AFFE_PONCT
GROUP_MA
“SURFACE”
CARA
VALE
MODEL AFFE_CHAR_MECA

DDL_IMPO
GROUP_NO
VECT_ASSE
CALC_MATR_ELEM OPTION
"RIGI_MECA"

"MASS_MECA"

"AMOR_MECA"
NUME_DDL MATR_RIGI

METHOD
"LDLT"
RENUM
"WITHOUT"
ASSE_MATRICE MATR_ELEM

NUME_DDL
CALC_CHAR_SEISME MONO_APPUI
"YES"
DIRECTION
MODEL DYNA_NON_LINE

CHAM_MATER

CARA_ELEM

INCREMENT

NEWMARK

NEWTON
STAMP
"TANGENT"

PREDICTION
"ELASTIC"
EXCIT
CHARGE

FONC_MULT

COMP_INCR
RELATION
“LABORD_1D”

`VMIS_CINE_LINE

'
CONVERGENCE
RESI_GLOB_RELA

ITER_GLOB_MAXI

FILING
CHAM_EXCLU
“QUICKLY”

“ACCE”
LIST_INST

CALC_NO OPTION

“REAC_NODA”

V5.02.130-A Page:
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4 Results

The curves of reaction according to time and arrow in the center according to time are presented on the figures [Figure 4-a] with [Figure 4-d].

80
60
40
20
0
-20
-40
-60
-80
0
5
10
15
ASTER
EFICOS
Time (S)

Appear 4-a: Reaction to the first supports according to time

50
30
10
-10
-30
-50
-70
1,6
1,8
2
2,2
2,4
2,6
2,8
3
Time (S)

ASTER
EFICOS

Appear 4-b: Detail of the reaction between 1,6 and 3 seconds

7
5
3
1
-1
-3
-5
-7
0
5
10
15
Time (S)
ASTER
EFICOS

Appear 4-c: Arrow in the center according to time

6
5
4
3

2
1
0
-1
-2
-3
-4
1,6
1,8
2
2,2
2,4
2,6
2,8
3
Time (S)
ASTER
EFICOS

Appear 4-d: Detail of the arrow between 2,5 and 2,8 seconds
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Note:

Solution EFICOS is more oscillating because the step of time chosen with this code was 1/1000ème of second.

60
2,87s
2,04s
40
20
0
-20
-40
-60
1,75s
-80
2,68s
-4
-2
0
2
4
6
Time (S)
ASTER
EFICOS

Appear 4th: Curve reaction-arrow for the 3 first second

One carries out tests of results (TEST_RESU) for the reaction on the first support and the arrow with center. One tests these values for some extremums in the 3 first second of seism,
i.e. in the neighbourhoods of times 1,75s (any beginning of the nonlinear field), then 2,04s, 2,68s and 2,87s when the structure is already strongly damaged.

Note:

To have a case test not consuming unnecessarily time CPU, only the 3 first seconds of seism are tested.

ARROW
EFICOS
ASTER
Relative error %

1,75 S
1,5.10-3
1,7.10-3
13,3

2,04 S
-1,3.10-3
-1,1.10-3
13,1

2,68 S
5,2.10-3
4,7.10-3
9,6

2,87 S
-3,4.10-3
-3,1.10-3
7,9

REACTION
EFICOS
ASTER
Relative error %

1,75 S
-3,7.104
-4,2.104
14,3

2,00 S
3,5.104
3,5.104

0,3

2,69 S
-6,8.105
-6,7.105
1,7

2,87 S
4,8.105
4,8.105
0,2

It is noted that the differences in effort in the nonlinear field are very weak, whereas there is an unquestionable difference for displacements. This difference is doubtless due to the effects damping which exploits a great part displacements.

5 Bibliography

[1]
GHAVAMIAN HS., MAZARS J.
: Strategy of calculations simplified for the analysis of
behavior of the reinforced concrete structures: code EFICOS. French review of civil engineering
1998 ; 2 : 61-90.

6
Summary of the results

The results obtained with *Code_Aster* are in rather good agreement with those of code EFICOS.

Author (S):
G. JACQUART

Organization (S): EDF/EP/AMV

Handbook of Validation
V5.03 booklet: Nonlinear dynamics of the voluminal structures
V5.03.100 document

SDNV100 - Impact of a beam on a rigid wall

Summary

This problem corresponds to a direct transitory analysis of a non-linear system modelled in elements voluminal. A first slim structure (beam) of square section is animated an initial speed and comes to run up against a rigid wall. Non-linearity comes from the conditions of contact between the structure and the wall. This test comprise a reference solution and a modeling.

---

1 Problem of reference

1.1 Geometry

Z
B
has
y
L
B (A)
has
- Vo
X
With
Uo

Length of the beam L = 20 cm
Side of the section
= 2 cm have
y
X

1.2 Material properties

Beam:
Young modulus:
***E* = 2 1011**
.
Pa
Poisson's ratio:
= 0 3
.
density:
= 8000
3

.kg/*m*
Finite elements of contact:
coefficients of penalization:
E* = 1014 *Pa
N
***E* =**
T
0
coefficient of Coulomb:
µ = 0
1.3
Boundary conditions and loadings
The problem is one-way according to Z.
One considers a quarter of the beam with the conditions of symmetry: displacements are blocked according to *X* on the plan *X* = 0 and displacements according to *y* on the plan *y* = 0.
1.4 Conditions
initial
All the nodes of the mesh of the beam are imposed according to axis Z:
· initial displacement: *U* = *mm*
0
2
· initial speed: *v* = -
m/s
0
100

2
Reference solution

2.1
Method of calculation used for the reference solution
F (T)
F (T) force of contact in A;
V (Z, T) speed;
ESVo
U (Z, T) displacement;
CP
U

0
=
;
0
V0
T
= + L;
1

0

C *p*
V (Z, T)
- = 2L lasted of shock;
C *p*
Vo
***E* (1 -)**
***C* =**
p
(1+)(1- 2 ;
)

1
T
***S* = *a2* section.**

- Vo
for point A
for point B
U (Z, T)
U
T

1

- V
2.2
Results of reference
2.3 References
bibliographical

[1]
R.J. GIBERT, "Vibrations of the structures", School of numerical summer of analysis, 1988, (Edition
EYROLLES).

---

3 Modeling
With
3.1
Characteristics of modeling

Discretization 3D of the beam with element HEXA8. The contact beam-wall is modelled by 1 finite element of contact a null thickness.
The initial conditions and the boundary conditions are imposed via groups of nodes:

GROUP_NO:
WALL
(embedding of the lower nodes of the element of contact)
PLANSYMX
(conditions of symmetry according to X)
PLANSYMY

(conditions of symmetry according to y)
NOBARRE
(initial displacements and speeds).
The mechanical characteristics of materials are assigned to the groups of the meshs:
GROUP_MA:
BAR
(solid material)
CONTACT
(characteristics of the contact)
Numerical parameters used in operator DYNA_NON_LINE:
Precision:
RESI_GLOB_RELA: 0.01
RESI_INTE_RELA: 1.d-8
Parameters of the diagram of NEWMARK:
ALPHA = 0.28
DELTA = 0.55
3.2
Characteristics of the grid
A number of nodes: 88
A number of meshs and types: 21 HEXA8
3.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
CONTACT
IN
[U4.23.01]
AND
COULOMB
DYNA_NON_LINE
ETAT_INIT
DEPL_INIT
[U4.32.02]
VITE_INIT
DYNA_NON_LINE
COMP_INCR
RELATION
“COULOMB”
[U4.32.02]

4 Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
DZ at the point B t=4.0e-5 S	2.0e3	1.999e3	0.0
DZ at the point B t=8.0e-5 S	1.0e3	0.987e3	1.27
DZ at the point B t=1.2e-4 S	3.0e3	2.948e3	1.71
VZ at the point B t=4.0e-5 S	1.0e+2	9.999e+2	0.005
VZ at the point B t=8.0e-5 S	1.0e+2	1.052e+2	5.26
VZ at point A t=1.2e-4 S	1.0e+2	0.988e+2	

1.15
VZ at the point B t=1.2e-4 S
1.0e+2
1.079e+2
7.85
4.2 Parameters
of execution
Version:
Machine: CRAY C90
UNICOS 8.0
Obstruction memory: 16 MW
Time CPU To use: 150 seconds

5
Summaries of the results

The precision of calculation is relatively average what is due to the choice of the coefficients of penalization
used to model the contact. The increase in the stiffness of contact improves considerably
the field of displacement but generates the important oscillations of the field speed around
analytical solution.

Titrate:
SDNV103 - Impact of an elastoplastic bar of Taylor

Date:
15/04/03
Author (S):
NR. TARDIEU Key
:
V5.03.103-A Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.03 booklet: Nonlinear dynamics of the voluminal structures
Document: V5.03.103

SDNV103 - Impact of a bar of Taylor elastoplastic

Summary:

One studies the impact rubbing of an elastoplastic bar on a rigid solid mass in nonlinear dynamics. modeling includes/understands: contact, friction, elastoplasticity, great deformations.

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---

1 *Problem of reference*

1.1 Geometry

6.4 mm

B

32.4 mm

With

1.2
Properties of material

E = 117. E3 MPa
naked = 0.35
And
= 8.93 E-9 g/mm3
Y
Y = 100. MPa
AND = 400. MPa

Coefficient of friction of Coulomb:
E
μ = 0.25

1.3
Boundary conditions and loadings

The rigid foundation is completely blocked throughout calculation.
The bar is free of any blocking.
There is a relation between unilateral contact and friction of Coulomb between the face inferior of the bar
and the higher face of the rigid foundation.

1.4 Conditions
initial

The bar is subjected at initial 227. E3 mm/s.

Titrate:

2
Reference solution

2.1
Method of calculation

The reference solution comes from [bib1]. They are explicit axisymmetric calculations carried out with various codes. One is unaware of almost all modeling: presence of contact, presence of friction, coefficient of friction? In this measurement, one uses this reference in manner indicative. The other tests will be of nonregression.

2.2
Sizes and results of reference

The sizes tested are:
93
.
3
+ 86
.
3
+ 72
.
3
+ 88
.
3
+ 96
.
3
· radial displacement of point a:
= 87

.
3
mm
5
-
24
.
13
-
63
.
13
-
62
.
13
-
57
.
13
-
24
.
13
· vertical displacement of point b:
= - 46
.
13
mm
5

2.3 Uncertainties on the solution

Uncertainties on the reference solution are very important (see [§2.1]).

2.4 References bibliographical

[1]
L. STAINIER, P.Ph. PONTHOT: "Year improved broad one-point integration method for strain elastoplastic analysis", Comput. Methods Appl. Mech. Engrg. 118 (1994).

---

3 Modeling
With

3.1
Characteristics of modeling

3.2
Characteristics of the grid

A number of nodes: 2850

Numbers and types of elements: 480 HEXA20, 200 PENTA15, 224 QUAD8, 6 TRIA6, 280 SEG3,

1 HEXA8, 6 QUAD4, 8 SEG2,101 POI1

3.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”

METHOD
“PENALIZATION”
CREA_CHAMP OPERATION
“AFFE”

TYPE_CHAM
“NOEU_DEPL_R”

AFFE
ALL
“YES”

NOM_CMP
(“DX”, “DY”, “DZ”)
DYNA_NON_LINE COMP_INCR
RELATION
“VMIS_ISOT_LINE”

DEFORMATION
“SIMO_MIEHE”
INCREMENT
SUBD_PAS
4
ETAT_INIT
QUICKLY

3.4 Sizes tested and results

Being given the heaviness of modeling, one takes only some steps of time and one carries out only tests of not-regression.

3.5 Parameters of execution

Version: 6.3.07

Machine: CLASTER

System: IRIX64
Obstruction memory:
300 megawords
Time CPU To use: 720 seconds

4 Modeling B

4.1 Characteristics of modeling

4.2 Characteristics of the grid

A number of nodes: 359
Numbers and types of elements: 101 QUAD8, 55 SEG3

4.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"

METHOD
"PENALIZATION"
CREA_CHAMP OPERATION
"AFFE"

TYPE_CHAM
"NOEU_DEPL_R"

AFFE
ALL
"YES"

NOM_CMP
("DX", "DY", "DZ")
DYNA_NON_LINE COMP_INCR RELATION
"VMIS_ISOT_LINE"

DEFORMATION
“SIMO_MIEHE”
INCREMENT
SUBD_PAS
4
ETAT_INIT
QUICKLY

4.4
Sizes tested and results

Size tested
Reference:
Code_Aster
Difference (%)
radial displacement of
3.87 2.92
24.55
not A
vertical displacement of
-13.46 -12.69
5.72
not B

4.5 Parameters
of execution

Version: 6.3.07

Machine: CLASTER

System: IRIX64
Obstruction memory:
16 megawords
Time CPU To use: 434. seconds

---

5 Modeling C

5.1 Characteristics of modeling

5.2 Characteristics of the grid

A number of nodes: 74

Numbers and types of elements: 4 HEXA20, 4 PENTA15, 10 QUAD8, 2 TRIA6, 14 SEG3,

1 HEXA8, 6 QUAD4, 8 SEG2,17 POI1

5.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION "COULOMB"
METHOD
"PENALIZATION"
CREA_CHAMP OPERATION

"AFFE"
TYPE_CHAM
"NOEU_DEPL_R"

AFFE
ALL
"YES"

NOM_CMP
("DX", "DY", "DZ")
DYNA_NON_LINE COMP_INCR
RELATION
"VMIS_ISOT_LINE"
DEFORMATION
"SIMO_MIEHE"
INCREMENT
SUBD_PAS
4
ETAT_INIT
QUICKLY

5.4
Sizes tested and results

For this very reduced modeling which has only one role of algorithmic control, one only tests values of not-regression.

5.5 Parameters of execution

Version: 6.3.07

Machine: CLASTER

System: IRIX64
Obstruction memory:
300 megawords
Time CPU To use: 185 seconds

6 Modeling D

6.1 Characteristics of modeling

6.2 Characteristics of the grid

A number of nodes: 29
Numbers and types of elements: 5 QUAD8, 12 SEG3

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Code_Aster ®
Version
6.2

Titrate:
SDNV103 - Impact of an elastoplastic bar of Taylor

Date:

6.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”

METHOD
“PENALIZATION”
CREA_CHAMP OPERATION
“AFFE”

TYPE_CHAM
“NOEU_DEPL_R”

AFFE
ALL
“YES”

NOM_CMP
(“DX”, “DY”, “DZ”)
DYNA_NON_LINE COMP_INCR RELATION
“VMIS_ISOT_LINE”

DEFORMATION
“SIMO_MIEHE”
INCREMENT
SUBD_PAS
4
ETAT_INIT
QUICKLY

6.4
Sizes tested and results

For this very reduced modeling which has only one role of algorithmic control, one only tests values of not-regression.

6.5 Parameters
of execution

Version: 6.3.07

Machine: CLASTER

System: IRIX64
Obstruction memory:
16 megawords
Time CPU To use: 37. seconds

7
Summary of the results

Present modelings differ from the reference of the literature by the taking into account from not

additional linearities (contact, friction), which explains the differences between their results respective.
It is also noted that calculation 3D presents a overcost of enormous time CPU compared to the axisymetry, which is explained at the same time by the greatest number of degrees of freedom but also by treatment of the friction which is much more complex in 3D than in 2D.

SDNV104 - Dynamic response of a rubbing shoe rigid subjected to a pressure and a force of recall

Summary

One considers a mass in contact rubbing with a rigid plan. It is retained by a spring and one imposes to him
a side pressure. Friction is modelled by the law of Coulomb. Calculation is a dynamic calculation direct.

The reference solution is analytical.

Modelings suggested use DYNA_NON_LINE with an elastic law of behavior in 2D, for two solveurs. The contact is managed by various methods available in AFFE_CHAR_MECA.

Handbook of Validation
V5.03 booklet: Nonlinear dynamics of the voluminal structures
HT-66/05/005/A

1
Problem of reference

1.1 Geometry

The system considered consists of a shoe: square of 1m on 1m, posed on a support. It is subjected with its weight, with the force of recall of a spring of stiffness K and with a side pressure. The contact is one rubbing contact.

K
m
PTAN
y

X

1.2
Properties of the model

Mass:
7.103 kg
Stiffness of the spring:
24.103 N/m
Coefficient of Coulomb:

0,3
Gravity:
70.000 Pa
Side pressure:
200.000 Pa
Young modulus of the shoe:
2,1. 1011 Pa
Young modulus of the solid mass:
1,0. 1011 Pa
Poisson's ratio:
0

1.3
Boundary conditions, conditions initial and loadings

The mass rests on the rigid level with the dimension X = 0.

The loadings of weight and side pressure are applied with a slope which reaches sound maximum in 0,07 second.

The support is embedded in X and Y.

2
Reference solution

The reference solution is analytical.

If one regards the shoe as sufficiently stiff not vibrating (rigid movement of body), there is an analytical solution with the problem.

One can then write the equation of the movement as follows:

m x&+ K X = T
F ± F
F = µ N
F
K
One notes: =

m

Stage 1:

X
m &+ kx = F - F

with a X-coordinate and a null speed. One has then:

F - F
X (T) =
1
(- cos (.t))
K

this result is valid as long as x& 0, i.e. until T. =.
F - F
The first extremum of curve X (T) is X =.
2
1
.
K
Stage 2:

X
m &+ kx = F + F

the initial X-coordinate is worth 1
X, and speed is null. One has then, by posing the new X-coordinate of times with/:

F + F
F - 3 F
X (T) =
+
cos (.t), until T. =.
K
K

4 F
The second extremum of curve X (T) is x2 =
.
K

Stage N:

One separates the movement according to the sign speed.

One obtains in a general way:

2 p -1
(
2 Ft - (2 p -)
1 F)
PF
x2p 1
- T =
T =
x2p = (T = Pt) 2
.
2
,

2

K
K
K
with

2
T =
and =
.

m

F
F
F
F
The stop of the movement occurs when X
T -
T +
N is included/understood enters
and
.
K
K

2.1 Results of reference

Modeling proposed Ci below correspond to the analytical solution until the stop of the shoe.
By preoccupations with a saving in computing time, one tests only the two first extremum.

Time (S)	***Displacement in X (m)***
1,697	*14,917*
3,393	*3,500*

2.2 Uncertainty on the solution

The analytical solution gives an exact result for the assumption where the bodies are infinitely rigid.

3 Modeling With

3.1 Characteristics of modeling

The problem is D_PLAN. The shoe and the support are modelled by surfaces with a grid in QUAD4. An element 2D_DIS_T represents the spring, its component nonnull is in direction X.

One uses operator DYNA_NON_LINE to carry out dynamic calculation. The efforts of contact are taken into account by AFFE_CHAR_MECA/CONTACT, with the method LAGRANGIAN.

3.2 Characteristics of the grid

A number of nodes:
42
a number of meshs and types:
26 QUAD4
26 SEG2

3.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
AFFE_CHAR_MECA CONTACT
METHOD “LAGRANGIAN”
AFFE_CHAR_MECA CONTACT

PAIRING
“MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_BOUCLE”
AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
DYNA_NON_LINE SOLVEUR “MULT_FRONT”

DYNA_NON_LINE NEWTON
STAMP
“TANGENT”

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
AFFE_CHAR_MECA CONTACT
METHOD “LAGRANGIAN”
AFFE_CHAR_MECA CONTACT
PAIRING
“MAIT_ESCL”

AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT
REAC_GEOM
"CONTROL"
DYNA_NON_LINE SOLVEUR "LDLT"
DYNA_NON_LINE NEWTON
STAMP
"TANGENT"

4 Results of modeling A

4.1 Values tested for the method LAGRANGIAN, MULT_FRONT

T	Reference	Aster	% difference
1,697	14,91	14,84	-0,5%
3,393	3,50	3,62	3,6%

4.2 Values tested for the method LAGRANGIAN, LDLT

T	Reference	Aster	% difference
1,697	14,91	14,83	-0.5%
3,393	3,50	3,62	3,6%

tps_job 200 mem_job 64MB ncpus1

5 Modeling B

5.1 Characteristics of modeling

The problem is D_PLAN. The shoe and the support are modelled by surfaces with a grid in QUAD4. An element 2D_DIS_T represents the spring, its component nonnull is in direction X.

One uses operator DYNA_NON_LINE to carry out dynamic calculation. The efforts of contact are taken into account by AFFE_CHAR_MECA/CONTACT, with the method PENALIZATION.

5.2 Characteristics of the grid

A number of nodes:
42
a number of meshs and types:
26 QUAD4
26 SEG2

5.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT FRICTION

"COULOMB"
AFFE_CHAR_MECA CONTACT METHOD
"PENALIZATION"
AFFE_CHAR_MECA CONTACT PAIRING
"MAIT_ESCL"
AFFE_CHAR_MECA CONTACT SEEKS "NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT REAC_GEOM "CONTROL"
DYNA_NON_LINE SOLVEUR "MULT_FRONT"

DYNA_NON_LINE NEWTON STAMPS "TANGENT"

Orders

AFFE_CHAR_MECA CONTACT FRICTION
"COULOMB"
AFFE_CHAR_MECA CONTACT METHOD
"PENALIZATION"
AFFE_CHAR_MECA CONTACT PAIRING
"MAIT_ESCL"
AFFE_CHAR_MECA CONTACT SEEKS "NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT REAC_GEOM "CONTROL"
DYNA_NON_LINE SOLVEUR "LDLT"

DYNA_NON_LINE NEWTON STAMPS "TANGENT"

6
Results of modeling B

6.1
Values tested for the method PENALIZATION, MULT_FRONT

T Reference
***Aster** %*
difference
1,697 14,91 14,84 -0.5%
3,393 3,50 3,62 3,6%

6.2
Values tested for the method PENALIZATION, LDLT

T Reference
***Aster** %*
difference
1,697 14,91 14,83 -0,5%
3,393 3,50 3,62 3,6%

tps_job 1000 mem_job 100MB ncpus1

7 Modeling
C

7.1
Characteristics of modeling

The problem is D_PLAN. The shoe and the support are modelled by surfaces with a grid in QUAD4. An element 2D_DIS_T represents the spring, its component nonnull is in direction X.

One uses operator DYNA_NON_LINE to carry out dynamic calculation. The efforts of contact are taken into account by AFFE_CHAR_MECA/CONTACT, with the method CONTINUES.

7.2
Characteristics of the grid

A number of nodes:
42

a number of meshs and types:
26 QUAD4
26 SEG2

7.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT FRICTION "COULOMB"
AFFE_CHAR_MECA CONTACT METHOD "CONTINUES"
AFFE_CHAR_MECA CONTACT PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT SEEKS "NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT REAC_GEOM "CONTROL"
DYNA_NON_LINE SOLVEUR "MULT_FRONT"

DYNA_NON_LINE NEWTON STAMPS "TANGENT"

Orders

AFFE_CHAR_MECA CONTACT FRICTION
“COULOMB”
AFFE_CHAR_MECA CONTACT METHOD
“CONTINUES”
AFFE_CHAR_MECA CONTACT PAIRING
“MAIT_ESCL”
AFFE_CHAR_MECA CONTACT SEEKS “NOEUD_BOUCLE”
AFFE_CHAR_MECA CONTACT REAC_GEOM “CONTROL”
DYNA_NON_LINE SOLVEUR
“LDLT”

DYNA_NON_LINE NEWTON STAMPS “TANGENT”

8
Results of modeling C

8.1
Values tested for the method CONTINUES, MULT_FRONT

T	Reference	Aster	% difference
1,697	14,91	14,84	-0,5%
3,393	3,50	3,62	3,6%

8.2
Values tests for the method CONTINUES, LDLT

T	Reference	Aster	% difference
1,697	14,91	14,83	-0,5%
3,393	3,50	3,62	3,6%

tps_job 400 mem_job 64MB ncpus1

---

9 Modeling D

9.1 Characteristics of modeling

The problem is D_PLAN. The shoe and the support are modelled by surfaces with a grid in QUAD8. An element 2D_DIS_T represents the spring, its component nonnull is in direction X.

One uses operator DYNA_NON_LINE to carry out dynamic calculation. The efforts of contact are taken into account by AFFE_CHAR_MECA/CONTACT, with the method LAGRANGIAN.

9.2 Characteristics of the grid

A number of nodes:
110
a number of meshs and types:
26 QUAD 8
24 SEG3
2 SEG 2

9.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT FRICTION
"COULOMB"

AFFE_CHAR_MECA CONTACT METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT PAIRING
"MAIT_ESCL"
AFFE_CHAR_MECA CONTACT SEEKS "NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT REAC_GEOM "CONTROL"
DYNA_NON_LINE SOLVEUR "MULT_FRONT"

DYNA_NON_LINE NEWTON STAMPS "TANGENT"

Orders

AFFE_CHAR_MECA CONTACT FRICTION
"COULOMB"
AFFE_CHAR_MECA CONTACT METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT PAIRING
"MAIT_ESCL"
AFFE_CHAR_MECA CONTACT SEEKS "NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT REAC_GEOM "CONTROL"
DYNA_NON_LINE SOLVEUR "LDLT"

DYNA_NON_LINE NEWTON STAMPS "TANGENT"

---

10 Results of modeling D

10.1 Values tested for the method LAGRANGIAN, MULT_FRONT

T Reference
Aster %
difference
1,697 14,91
14,83 -0.,5%
3,393 3,50 3,62 3,6%

10.2 Values tested for the method LAGRANGIAN, LDLT

T Reference
Aster %
difference
1,697 14,91
14,83 -0.,5%
3,393 3,50
3,62 3,6%

tps_job 400 mem_job 64MB ncpus1

11 Modeling
E

11.1 Characteristics of modeling

The problem is D_PLAN. The shoe and the support are modelled by surfaces with a grid in QUAD8. An element 2D_DIS_T represents the spring, its component nonnull is in direction X.

One uses operator DYNA_NON_LINE to carry out dynamic calculation. The efforts of contact are taken into account by AFFE_CHAR_MECA/CONTACT, with the method PENALIZATION.

11.2 Characteristics of the grid

A number of nodes:
110
a number of meshs and types:
26 QUAD 8

11.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT FRICTION
"COULOMB"
AFFE_CHAR_MECA CONTACT METHOD
"PENALIZATION"
AFFE_CHAR_MECA CONTACT PAIRING
"MAIT_ESCL"
AFFE_CHAR_MECA CONTACT SEEKS "NOEUD_BOUCLE"
AFFE_CHAR_MECA CONTACT REAC_GEOM "CONTROL"
DYNA_NON_LINE SOLVEUR
"MULT_FRONT"

DYNA_NON_LINE NEWTON STAMPS "TANGENT"

Orders

AFFE_CHAR_MECA CONTACT FRICTION
“COULOMB”
AFFE_CHAR_MECA CONTACT METHOD
“PENALIZATION”
AFFE_CHAR_MECA CONTACT PAIRING
“MAIT_ESCL”
AFFE_CHAR_MECA CONTACT SEEKS “NOEUD_BOUCLE”
AFFE_CHAR_MECA CONTACT REAC_GEOM “CONTROL”
DYNA_NON_LINE SOLVEUR
“LDLT”

DYNA_NON_LINE NEWTON STAMPS “TANGENT”

12 Results of modeling E

12.1 Values tested for the method PENALIZATION, MULT_FRONT

T Reference
Aster %
difference
1,697 14,91 14,83 -0.,5%
3,393 3,50 3,62 3,6%

12.2 Values tested for the method PENALIZATION, LDLT

T Reference
Aster %
difference
1,697 14,91 14,83 -0.,5%
3,393 3,50 3,62 3,6%

tps_job 1000 mem_job 100MB ncpus1

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HT-66/05/005/A

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13 Summary of the results

The results obtained on the whole of this case test are satisfactory, as well into linear in quadratic. The values obtained are with less than 1% from/to each other; and less than 4% of reference solution.

It is noted that the value of reference of the second point is lower than the two others, which increase the percentage of error artificially.

The choice of the coefficients of the penalized method is delicate. But it is noted that once them coefficients chosen, the result is stable with respect to the choice of the finite elements and the solvor.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.03 booklet: Nonlinear dynamics of the voluminal structures
Document: V5.03.106

SDNV106 Analyzes with the eigenvalues in
DYNA_NON_LINE (stability and oscillatory modes)

Summary:

This case test makes it possible to validate the analysis of buckling, as well as the vibratory modal analysis in
DYNA_NON_LINE.

Only one modeling is used:

Massive modeling A 3D made up of meshs HEXA8.

---

1 Problem of reference

1.1 Geometry

One considers a cube on side length 2 m subjected to a uniform traction according to the direction vertical Z:

Z
Y
X

For reasons of symmetry, one will considèrera only one eighth of the structure, which will be with a grid by one only cubic linear voluminal element.

1.2 Properties of material

The structure is supposed to be homogeneous, composed of an isotropic elastoplastic material, with work hardening isotropic linear:

- *E = 2x104 MPa*
- = 0.49999
- *= 7900 kg/m3*
- *y = 0,1 Mpa (elastic threshold SY)*
- *AND = 200 Mpa (tangent module plastic D_SIGM_EPSI)*

One thus chooses a material which remains always almost incompressible, that one is in mode rubber band or plastic. Moreover, one imposes a relationship 100 between the elastic stiffness and the stiffness plastic tangent.

1.3
Boundary conditions

One imposes a uniform loading of traction type imposed according to Z on the higher face of the cube.
This force imposed, initially null, grows linearly with time.

The other boundary conditions are of Dirichlet type and translate the conditions of symmetries of problem (according to the 3 orthogonal plans (xOy), (xOz) and (yOz)).
These boundary conditions are sufficient to block all the movements of rigid body of system.

1.4 Conditions initial

The first calculation being quasistatic, one imposes just an initial displacement no one.

2
Reference solution

2.1
Method of calculation

One wants to check two types of quantities:

· the first critical load buckling,
· the first Eigen frequency of the system in vibration.

The value of reference of the critical load required is obtained by a quasistatic calculation (word key CRIT_FLAMB of STAT_NON_LINE). One takes this value obtained with the last step of calculation
quasistatic, which corresponds at the moment T = 1 S.
The number stored under CHAR_CRIT in the structure of data result (it is the coefficient minimal multiplier of the loading forced to obtain the buckling load) being proportional with the imposed loading which is monotonous growing linearly with time, one corrects it to have the true value at the first moment of transitory dynamic calculation, is 1,001 S.
One has, by definition of multiplying coefficient CHAR_CRIT:
F
= TANK _ CRIT T F T
critical
(I) ext. (I)
The external force is proportional to time: F T = F T, therefore F
= TANK _ CRIT T F T.
critical
(I)
ext. (I)
ext.
I
ext.
I
The assumption is made that on a step, the loading evolves/moves very slowly and thus that one can to compare the result of dynamic calculation to a quasistatic evolution during this step. One can then to write, for the first dynamic step, which follows quasistatic calculation:
F
= TANK _ CRIT
T F T TANK CRIT
T
F T
critical
STAT _ NOT _ LINE (I)
_
ext.
I
DYNA _ NOT _ LINE (I 1
+)
ext.
I 1
+

T
TANK _ CRIT
T
TANK CRIT
T I = TANK CRIT
T
DYNA _ NOT _ LINE (I 1
+)
_
STAT _ NOT _ LINE (I)
STAT _ NOT _ LINE (I)
1
_
T
,
1 001
I 1
+

For the vibratory analysis, one will make two tests:

· by using the elastic matrix of stiffness,
· by using the matrix of tangent stiffness plastic.

The two values of reference are obtained by two linear modal calculations carried out with operator MODE_ITER_SIMULT.
To obtain the first Eigen frequency corresponding to the elastic case, one makes an elastic design linear with definite initial Young MODE_ITER_SIMULT and material above (of being worth modulus
2.104 Mpa).
To obtain the first Eigen frequency corresponding to the tangent plastic case, a calculation is made linear rubber band with MODE_ITER_SIMULT and a fictitious elastic material of which the Young modulus
is worth the definite plastic tangent module above: 200 Mpa, is 100 times less than the module real rubber band. One will thus have an Eigen frequency 10 times weaker than the preceding one.

One knows also the analytical solution of our problem (cubic length 1 made up of only one linear finite element) which is brought back to a case 1D of traction compression:

rad
358128
,

0
/S
rubber band,

material
:

= 2nd

0358128
,
0
rad/S
plastic.

material
:

2.2
Sizes and results of reference

Sizes Values
Unit
Multiplying coefficient of the first
2.85714E+01/1.001

critical load buckling
First elastic Eigen frequency
3.58128E-01
Hz
First plastic Eigen frequency
3.58128E-02
Hz

---

3 Modeling With

3.1 Characteristics of the grid

A number of meshs: 1 HEXA8
A number of nodes: 8

3.2 Functionalities tested

One tests the key word factor CRIT_FLAMB and MODE_VIBR of DYNA_NON_LINE.
One also tests in postprocessing the recovery of scalars CHAR_CRIT and FREQ at moments given, in an object of the evol_noli type which is the result of DYNA_NON_LINE:

Orders
Key word factor
Single-ended spanner word
Argument
DYNA_NON_LINE CRIT_FLAMB
NB_FREQ
1
CHAR_CRIT
(-100.0,100.)
DYNA_NON_LINE MODE_VIBR
NB_FREQ
3
MATR_RIGI
"TANGENT"
"ELASTIC"
TEST_RESU RESU
PARA
"CHAR_CRIT"

"FREQ"

3.3
Sizes tested and results

Identification Reference
Aster
% difference
Eigen frequency
Tps = 1.01
3.58128E-02 3.5812661359567D-02 -3.87E-04
vibratory plastic
Tps
=
1.06
3.58128E-02 3.5812661359997D-02 -3.87E-04
Tps
=
1.25
3.58128E-02 3.5812661358541D-02 -3.87E-04
Tps
=
1.49
3.58128E-02 3.5812661355801D-02 -3.87E-04
Eigen frequency
Tps = 1.51
3.58128E-01 3.5812779545194D-01 -5.71E-05
vibratory rubber band
Tps
=
1.52
3.58128E-01 3.5812779545194D-01 -5.71E-05
Tps
=
1.56
3.58128E-01 3.5812779545194D-01 -5.71E-05
Tps
=
1.75
3.58128E-01 3.5812779545194D-01 -5.71E-05
Tps
=
1.99

3.58128E-01 3.5812779545194D-01 -5.71E-05
Coefficient of
Tps = 1.001 2.854285714E+01 2.8570189972986E+01
0.096
first critical load

4
Summary of the results

This test makes it possible to validate calculations of critical loads of buckling and Eigen frequencies vibratory in DYNA_NON_LINE.
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HT-62/06/005/A

Code_Aster ®
Version
8.3

Titrate:
SDNV107 - Plastic beam in dynamically condensed traction) Date

29/08/2006
Author (S):
G. DEVESA Key
:
V5.03.107-A Page:
1/6

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.03 booklet: Nonlinear dynamics of the voluminal structures
Document: V5.03.107

Plastic SDNV107 Beam in condensed traction
dynamically

Summary:

This test implements the dynamic resolution of several fields on the basis of Ritz by the operator DYNA_TRAN_EXPLI with calculation transitory reduced to the nonlinear fields and taken into account once for
very of linear fields already condensed dynamically by this base of Ritz containing the modes clean of each under-field as well as the static modes of connection between under-fields.
One presents to it like case of application a beam with plastic law of behavior subjected to a force of sinusoidal traction applied in its end. Nonlinear dynamic calculation applies only to the third extreme of the beam, the remainder being condensed dynamically.
The maximum displacements obtained in end are compared with those obtained by a dynamic calculation
direct with DYNA_NON_LINE on the whole of the beam which constitute the results of reference.

1
Problem of reference

1.1 Geometry

One considers a right beam length 30 m, of square section 1m X 1m, split in 3 pennies 10 m length models each one.

Figure 1.1-1:
Geometry of the whole of the beam in traction.

1.2
Properties of materials

One considers a material of which characteristics of linear behavior (Young modulus E, Poisson's ratio, density) are summarized in the table hereafter:

Material

(Pa)
(kg/m3)
- 4.0 E11 1000 0.3
Table 1.2-1: Linear mechanical characteristics of material.
These linear characteristics are assigned to the first two sub-models. The third under model also has these characteristics as well as characteristics of behavior linear isotropic plastic with a plastic module of 4.0 E10 Pa beyond of a limit of constraint from 80 MPa.

1.3
Boundary conditions and loadings mechanical

The beam is embedded at the left of sub-model 1 and free end at the right end of under model 3. For the calculation of the clean modes of each substructure as well as static modes connections between substructures 1 and 2d' a share, 2 and 3d' another share, one also embed with level of these connections.
The excitation of the structure is carried out by applying at the right end P3 of sub-model 3 one force sinusoidal traction in time in the horizontal direction X of frequency 50 Hz and of modulate 100 MNewtons.

2
Reference solution

2.1
Method of calculation used for the reference solution

The field of modelled calculation includes/understands a nonlinear field of calculation I and one series of
external linear fields with calculation E which will be condensed dynamically. Here field I is it sub-model 3 and the fields E are sub-models 1 and 2.
The matrices M, C, K, the forces F can break up into a part associated with the field I and one part associated with (X) the field (S) E. balance of the structure of total displacement X by DYNA_TRAN_EXPLI can be written then:
(SEMI + ME) X '' = FIext + FEext FIint KE X - (Ci + EC) X'

[1]
That is to say a modal base of Ritz orthogonalized by elementary under-structuring on the whole of fields I and E. One uses the transform of Ritz then: X = Q and thus while projecting [1] per T with left one obtains:
(SEMI + ME) Q '' = T FIext + FEext T (FIint + Ci X') - KE Q - EC q'
[2]
tiny room to I becomes and X reduced to I thus becomes X [2] becomes for each step of time:
M Q '' = T FIext T (FIint + Ci x') + FEext - KE Q - EC q'
[3]
One thus needs the generalized matrices M diagonal as well as full matrices KE and EC and

vector generalized FEext which takes part under the terms complementary to the reduced standard problem
with I and solved without dynamic condensation by DYNA_TRAN_EXPLI:
M Q '' = T FIext T (FIint + Ci x')
With each step of time, one evaluates and adds the complementary terms resulting from condensation dynamics with those of the standard problem without dynamic condensation and one solves in manner
traditional in generalized co-ordinates Q. The knowledge of the modal base of Ritz orthogonalized will then allow to obtain at the same time X on the under-field of resolution and X on the whole of under
fields.

2.2
Results of reference

One retains like results of reference the maximum displacements obtained in right end of sub-model 3 by a direct dynamic calculation with DYNA_NON_LINE on the whole of under models.

---

3 Modeling
With

3.1
Characteristics of modeling

Each sub-model is with a grid by solid elements HEXA20 with 4 X 4 elements for *to represent the square section of 1m X 1m and 10 elements according to the length of 10 Mr.*

3.2
Characteristics of the grid

Each of the 3 sub-models thus makes up of 160 meshs HEXA20 including/understanding 515 nodes is
1545 degrees of freedom. The unit includes/understands 480 meshs, 1415 nodes and 4245 degrees of freedom.

3.3
Parameters of calculation

Dynamic calculation is carried out on a 0.02 second interval per step of times of 1.667 E-5
second. Filing is carried out for each step of time of 5. E-4 second.

3.4
Functionalities tested

Orders
Key words
MODE_ITER_SIMULT
MODE_STATIQUE
CREA_CHAMP ADZE
CREA_RESU
DEFI_BASE_MODALE RITZ
REST_BASE_PHYS
NUME_DDL_GENE
PROJ_MATR_BASE
DYNA_TRAN_EXPLI
PROJ_MODAL: MASS_GENE, RIGI_GENE

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4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster Difference
P3 DX (0.005s)
1.13478E-2 m
1.12284E-2 m
1.05 %
P3 DX (0.014 S)
-0.99345E-2 m
-1.00389E-2 m
1.04 %

5
Summary of the results

Results of reference of the first two maximum obtained by direct answer (red curve) are well found by calculation on the basis of modal Ritz without static correction (green curve) with 1.1 % approximately for a saving of time of calculation of report/ratio approximately 4. Addition of a mode of correction statics due to the request in traction brings back this variation to less than 0.3%.

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SDNS01 - Nonparametric probabilistic model

Date:
01/07/03
Author (S):
***S. CAMBIER**, C.DESCELIERS Key*
:
V5.06.001-A Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V5.06 booklet: Nonlinear dynamics of the hulls and plates
Document: V5.06.001

SDNS01 - Nonparametric probabilistic model - parametric of a flexbeam with not localised linearities of shock

Summary:

This case-test relates to the nonparametric and parametric probabilistic models of uncertainties in linear dynamics with possibly of nonthe localised linearities. The mechanical model used is one rectangular plate with an elastic thrust of shock. Random generators of matrices and variables random (operators GENE_MATR_ALEA and GENE_VARI_ALEA) are tested and validated in this

case test.
statistical postprocessings (CALC_FONCTION) are also tested.
This case-test has two modelings. The first uses a damping proportional. The second
use a definite reduced damping by key word CALC_AMOR_GENE of COMB_MATR_ASSE testing thus this
functionality.
Handbook of validation
V5.06 booklet: Nonlinear dynamics of the hulls and plates
HT-66/03/008/A

1
Problem of reference

1.1 Geometry

X

3

X2

Q

P

Concentrated stiffness

Impulse load

0.23

Mass

0.15
concentrated

Stop

O

R
X1

0.06

0.15
0.40

0.21

0.31

0.50 m

Thickness of the plate: E = 0.0004 Mr.
Play enters the thrusts: play = ±0.002 Mr.

1.2
Material properties

Plate:

Poisson's ratio: 0.3
11
Young modulus: 2.1 10 N/m2
Density: 7800 kg/m2
Concentrated stiffness: 2.388 107 N/m
Mass concentrated: 4 kg
Stiffness of shock: 25000 N/m
Handbook of validation
V5.06 booklet: Nonlinear dynamics of the hulls and plates
HT-66/03/008/A

1.3
Boundary conditions and loadings

The flexbeam is in simple on 3 edges and free support on its 4th edge GOLD. Degrees of freedoms blocked are thus:

· on COp and QR, displacements according to X1, X2, X3 and rotations according to X1, X3.
· on PQ, displacements according to X1, X2, X3 and rotations according to X2, X3.
· on GOLD, displacements according to X1, X2.

The plate is subjected to a vertical impulse load E (T) on 9 nodes of the plate according to X3 direction. The loading E (T) is such as, for t<0 and t>2t1, E (T) =0 and for 0t2t1:
E (T) = ((T-T1))- 1 {sin {(c+/2) (T-T1)}- sin {(C/2) (T-T1)}}.
with t1= 2, =2×40 rad/s, C =2×20 rad/s.

The energy of the function E (T) is mainly distributed in the frequential band [0,60] Hz, which contains 8 elastic modes of the linearized dynamic system.

1.4 Conditions
initial

The dynamic system is initially at rest.

2
Reference solution

2.1
Method of calculation used for the reference solution

We study the transitory response of a nonlinear dynamic system subjected to a load impulse determinist due to a shock on the structure. Nonthe linearity of the system is due to one butted elastic of high rigidity comprising a certain play. Spectra of frequency response standardized are used in order to study the transitory response of this system. Equations of dynamics are discretized by the method with the finite elements. The grid of the structure is supposed sufficient fine to collect all the dynamic phenomena of this mechanical system in term of field of displacement for the impulse loading considered. Random uncertainties of dynamic system are modelled by using the nonparametric probabilistic model uncertainties. Consequently, the transitory answer is a nonstationary stochastic process whose statistical estimates are evaluated.
The results of reference are given in the form of graphs in the article referred below, consultable on http://www.resonance-pub.com.

2.2 Reference
bibliographical

[1]
C. SOIZE: Not linear dynamical Systems with Nonparametric Model of Random Uncertainties ", Uncertainties in Engineering Mechanics (2001) 1 (1), 1-38, http://www.resonance-pub.com

---

6.4

Titrate:
SDNS01 - Nonparametric probabilistic model

Date:
01/07/03
Author (S):
S. CAMBIER, C.DESCELIERS Key
:
V5.06.001-A Page:
4/8

3 Modeling
With

3.1
Characteristics of modeling

Modeling: DKT

The average model with the finite elements of the plate consists of a regular rectangular grid whose step is constant and is worth 0.01m in the directions X1 and X2. There are thus 41 nodes in width and 51 nodes in the length. Consequently, all the finite elements are identical and each one is an element plates with 4 nodes. This average model finite elements comprises 2000 elements stop and m=6009 degrees of freedom, by counting only the translations in Z and rotations according to X1 and X2).

Eigen frequencies of the dynamic system linearized (the plate without the thrusts of shock but with the concentrated masses and stiffnesses) are f1=1.94, f2=10.28, f3=15.47,…, f8=53.5, f9=66,1, f10=68.9,…, f30=198.3, f31=206.0, f32=208.9,…, f50=330.9, f51=336.3,…, f100=670.8, f120=817.6Hz.

Modeling: DIS_T

The concentrated masses and the concentrated stiffness are modelled by elements DIST_T.

Damping

The matrix of damping [D] of the model average finite element is defined as being one linear combination of the average matrices finite elements of mass [M] and stiffness [K]. One thus

has
[D] =a [M] + B [K] with

2maxmin
2
has =
and
B =
,
max + min
max + min

where =0.04, min=4 rad/s and min=200 rad/s.

Small-scale model and ddl observed

For this case test, the model finite elements is projected on the first 5 elastic modes of structure linearized, which constitutes the data of the model reduces average. It should be noted that 5 first modes are not enough to obtain convergence compared to the number of modes (cf paragraph Comments of the Results of modelings).

The degree of freedom observed is the D.D.L jstop corresponding to displacement in translation according to Z of node or are the elastic thrusts. It is the node of co-ordinates (0.31, 0, 0). The spectrum of response standardized for this D.D.L is built for a band of frequential analysis J=2 [1, 100] rad/s and of which the frequential resolution is of 0.5Hz.

Achievements of the random matrices of the parametric nonparametric probabilistic model

The matrices of masses, stiffnesses and dissipation of the model reduces average are replaced by achievements of the random matrices of mass, stiffnesses and of dissipation according to the model nonparametric probabilist. For that, we use the generator of random matrices GENE_MATR_ALEA. At the time of the first call to this generator, key word INIT must take the value "YES" in order to initialize the generator of random variable of uniform law of Python. Thereafter, INIT will be able to take its default value (INIT= `NON'). The initialization of the generator of random variable of Python is to be done only one and only once by study, in theory, except if the user wishes explicitly to re-use the same random pseudo sequence.

The level of dispersion of the random matrices of the nonparametric probabilistic model is controlled by a parameter of dispersion fixed at 20% (=0.2). The key word DELTA thus takes value 0.2.

Lastly, for each pulling of the random matrices of mass, stiffness and dissipation, it is necessary to inform the corresponding average matrix of the model reduces average via the key word MATR_MOYEN.

The stiffness of shock is it also made random due to uncertainties. To build a realization stiffness of shock following a law gamma, we use random generator GENE_VARI_ALEA with key word TYPE= `GAMMA'. We suppose that the possible whole of the values for achievements of the random stiffness of shock is the interval [0, + [, that the average value of the unit achievements of the stiffnesses of shock corresponds to the stiffness of shock of the average model finite elements.
The level of dispersion of the achievements of the stiffness of shock is controlled by a parameter 'fixed at 1% (=0.01). The key word DELTA thus takes value 0.01.

Resolution of the probabilistic nonlinear dynamic system.

Operator DYNA_TRAN_MODAL is used to build the transitory response of the dynamic system nonlinear for each realization of the random stiffness of random shock and the matrices of mass, of stiffness and dissipation. It should be noted that we carry out for this case test only ns=5 achievements of each random variable (stiffness of shock + matrices) what corresponds to 5 iteration of method of digital simulation of Monte Carlo (cf paragraph Comments of the Results of modelings).

The temporal interval of the study is T= [0,4] S, with a step of 5. 105 S. the diagram of integration temporal selected is EULER.

Construction of the statistical estimates.

After each call to DYNA_TRAN_MODAL, we have a realization of the process stochastic of generalized displacements. It is thus possible to build acceleration with the node of shock following the D.D.L jstop by operator RECU_FONCTION. The spectrum of answer standardized is then built by operator CALC_FONCTION.

These two operations are classically carried out at the time of deterministic studies and give us here a realization of the stochastic process of the spectrum of answer standardized. It is then about to build statistical estimates of the NS achievements of this last. Estimates considered in this case test are the envelopes min and max as well as the average and the moment of order two of standardized spectra of answer. With each pulling (iteration of Monte Carlo) we build these estimates with the assistance only of operator CALC_FONCTION and the key words WRAPS, POWER and COMB. At the end of the NS iterations of Monte Carlo, we have the estimates required statistics relating to the stochastic process of the spectrum of answers standardized. Finally L2 of the average normalizes is calculated by the key word NORMALIZES of operator CALC_FONCTION. Interest to evaluate such a standard is to allow studies of convergence according to the number of modes of model reduces average random and according to the iteration count of the numerical method of Goes up Carlo. This standard is calculated here to check that the functionality goes, but convergence is not not reached to save time CPU.

3.2
Characteristics of the grid

A number of degrees of freedom: 6009
A number of finite elements: 2000 QUA4 and 2 DIS_T

3.3 Functionalities
tested

Orders
Key word
factor

GENE_MATR_ALEA

GENE_VARI_ALEA

CALC_FONCTION POWER

CALC_FONCTION NORMALIZES

4
Results of modeling A

4.1
Values of reference Aster

The initial validity of the case test was established by comparison with the bibliographical reference given in
[§3.2].
One tests the following values in nonregression (cf comments):

Statistics on the values of the spectrum of response to 50Hz with the ddl observed (cf modeling)
Identification References

Aster %
Difference
Estimate of the envelope
4.4433958494950E+02 4.4433958494950E+02
0
max
Estimate of the envelope
1.2534278720661E+02 1.2534278720661E+02
0
min
Estimate of the average
3.2330416710925E+02
3.2330416710925E+02
0
Estimate of the moment
1.2260792008492E+02 1.2260792008492E+02
0
of order 2
Estimate of the L2 Standard
2.0657959602609E+03 2.0657959602609E+03
0
average

4.2 Comments

The various statistical estimates are not converged here. Only 5 simulations of Monte Carlo were made. One would have needed 700 at least of them. Moreover, it is necessary to increase the number of modes with 50 to obtain the convergence of the model projected in the frequency band considered. Calculations being then too long for a case test, we preferred to voluntarily degenerate them two convergences after validation of those on a complete study. After convergence, them statistical estimates calculated starting from Aster correspond very exactly to the results given by the standard commodity.

---

5 Modeling B

5.1 Characteristics of modeling

Only the modeling of damping changes compared to modeling A.

Damping

The matrix of damping [D] of the model average finite element is defined as correspondent with one straight line modal reduced depreciation of 4%.

5.2 Characteristics of the grid

A number of degrees of freedom: 6009
A number of finite elements: 2000 QUA4 and 2 DIS_T

5.3 Functionalities tested

Orders
Key word
factor

GENE_MATR_ALEA

GENE_VARI_ALEA

CALC_FONCTION POWER

CALC_FONCTION NORMALIZES

COMB_MATR_ASSE CALC_AMOR_GENE

6
Results of modeling B

6.1
Values of reference Aster

One tests the following values in nonregression, with 50Hz:

Statistics on the values of the spectrum of response to 50Hz with the ddl observed (cf modeling)
Identification References Aster %
Difference
Estimate of the envelope
2.7570639015302E+02 2.7570639015302E+02
0
max
Estimate of the envelope
9.3629561795277E+01 9.3629561795277E+01
0
min
Estimate of the average
1.9641139264813E+02
1.9641139264813E+02
0
Estimate of the moment
4.3869049613023E+04 4.3869049613023E+04
0
of order 2
Estimate of the L2 Standard
1.2384277999571E+03
1.2384277999571E+03

0
average

6.2 Comments

Same comments as for modeling A.

7
Summary of the results

The results obtained are completely in conformity with those of the bibliographical reference [§2.2] obtained
entirely in Matlab.

30/01/98
Author (S):
PH. BONNIERES
Key:
V6.01.001-A Page:
1/6
Organization (S): EDF/IMA/MMN
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.001

SSNA01 - Infinite cylinder under pressure:
viscoelasticity of Lemaître

Summary:
This test of nonlinear quasi-static mechanics consists in modelling an infinite cylinder subjected to a pressure
intern depend on time. One thus validates the relation of nonlinear behavior of viscoelasticity of Lemaître into axisymmetric, and on a complete grid. This test is drawn from guide VPCS of the SFM.
The cylinder is modelled by axisymmetric elements 2D (QUAD8).
The results obtained by Code_Aster are very close to the reference solution.

1 Problem of reference

1.1 Geometry

Z
C
D
p
. E
1
With
B
R
20
20

1.2 Material properties

E = 210.000 MPa
= 0.3
Viscoelastic relation of behavior of Lemaître
1
-
1
NR = 11
= 328410 4
.
(*K* =
)
3045
= 017857
.
(*m* = 5.)

6
K
m
1.3
Boundary conditions and loadings
On AB: uz = 0
On CD = uz uniform
Loading below: uniform pressure p following along AD.
p
100 MPa
T
60 S
100 H
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HI-75/96/042 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SSNA01 Rolls infinite under pressure: viscoelasticity of Lemaître
Date:
30/01/98
Author (S):
PH. BONNIERES
Key:
V6.01.001-A Page:
3/6
2
Reference solution
2.1
Method of calculation used for the reference solution
Calculation carried out with various codes of finite elements using various explicit algorithms, semi-implicit or implicit.
2.2
Results of reference
3 -

3
v
and
at moment 60 S at the point E located at a distance *D* =

interior surface of
rr
vzz
6
roll.

2.3
Uncertainty on the solution

Uncertainty lower than 0.01%.

2.4 References
bibliographical

[1]
Card-index SSNA01/89 of Commission VPCS.

---

3 Modeling
With

3.1
Characteristics of modeling

Z
C
D
has
B
N1
GROUP_MA: AH
E
H
G
F

E
R
47 elements
GROUP_NO: NOEHGFE
The loading and the boundary conditions are modelled by:
DDL_IMPO: (GROUP_NO: NOEHGFE, DY: 0.)
LIAISON_DDL: (NODE: (N1 NXXX), DDL: (“DY”, “DY”), COEF_MULT: (1, -1),
COEF_IMPO: 0.)
for all the nodes belonging to edge AD (uz uniform on AD)
PRES_REP: (GROUP_MA: AH, NEAR: p (T))
or p (T) is the higher definite positive function [§1.3].

3.2
Characteristics of the grid

A number of nodes:
381
A number of meshs and types:
94 elements QUAD8

3.3 Functionalities
tested
Orders
Key

AFFE_MODELE
AFFE
MODELING
AXIS
[U4.22.01]
DEFI_MATERIAU
LEMAITRE
NR
[U4.23.01]
N_SUR_K
UN_SUR_M
AFFE_CHAR_MECA
PRES_REP
GROUP_MA
[U4.25.01]
STAT_NON_LINE
COMP_INCR
RELATION
LEMAITRE
[U4.32.01]
CALC_ELEM
OPTION

EPSI_ELNO_DEPL
[U4.61.01]
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HI-75/96/042 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SSNA01 Rolls infinite under pressure: viscoelasticity of Lemaître
Date:
30/01/98
Author (S):
PH. BONNIERES
Key:
V6.01.001-A Page:
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4
Results of modeling A

4.1 Values
tested

Identification	**Reference**	**Aster**	**% difference**
v at the point E with T = 60 S *rr*	1.08 104	1.077 104	-0.262%
v at the point E with T = 60 S *zz*	1.84 105	1.843 105	-0.314%

4.2 Remarks
One stopped with T = 60 S not to have time too long calculation.

4.3 Parameters
of execution
Version: 3.04.02
Machine: CRAY C90
Obstruction memory: 8

MW
Time CPU To use: 116.57
seconds

---

5 Summary of the results

The precision necessary for this test was fixed at 0.5% instead of 0.1% not not to lengthen time too much of calculation. However, one checks that by refining the discretization in time, the error made compared to
the reference solution tends towards zero.

Organization (S): EDF/AMA, AUSY France

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
V6.01.100 document

SSNA100 - Tube of Bree: Method Zarka-Rack (ZAC)

Summary:

This test of nonlinear quasi-static mechanics consists in modelling an infinite cylinder subjected to a pressure
intern and a variation in temperature in the thickness depending recurringly on time (tube of BREE).
behavior is elastoplastic with a criterion of Von Mises and a linear kinematic work hardening. One
validate the simplified method thus Zarka-Rack (ZAC) into axisymmetric for a radial loading in a case
of adaptation (T=30°C) then in a case of accommodation (T=120°C). This method is a postprocessing
realized by order POST_ZAC [U4.83.21]. For more details one will refer to the document [R7.06.01].
Two modelings make it possible to test the method in 2D and 3D:

· in modeling a: the cylinder is modelled by axisymmetric elements 2D (QUAD8),
· in modeling b: the cylinder is modelled in 3D (meshs HEXA20).

The results obtained by Code_Aster are very close to the reference solution.

1
Problem of reference

1.1 Geometry

Z
D
+ E
E
a=0.2
p
B
With
- E
C
F
R
R=10.
d=0.12

1.2
Material properties

E = 200.000 MPa

= 0.3

= 1.e-4 °C1

Tréf = 0.

Elastoplastic relation between behavior and criterion of Von Mises and kinematic work hardening linear:

T
E =
.
18181 MPa

y =
.
200 MPa

1.3
Boundary conditions and loadings

On AB: uz = 0

Loading:

· constant uniform pressure p = 2. MPa on CD.
· linear temperature in the thickness and varying according to time:

(
2 R - R)
T

(R) = -
(T) with (T) = (
) F (T)
D
E
E
2

E
T/2
T

0
1
3
5
7
9
11
13 ...
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/02/001/A

2
Reference solution

2.1
Method of calculation used for the reference solution

Elastoplastic calculation carried out with the Code Aster on twenty cycles in the case of adaptation (T = 30°C).
Analytical solution in the case of accommodation with T = 120°C ([bib1]).

2.2
Results of reference

p
moy
p

p

p

and
in the case of adaptation (
,
,
,
,
,
in the case
zz
zz
zz
zz
zz
zz
lim
zzlim
moy
moy
inf
inf
zz
sup
sup
of accommodation) statements at the points C (skin interns), E (average surface) and F (external skin).

2.3 References bibliographical

[1]
Contract EDF SEPTEN NC 4158. Study relating to the behavior of the components of nuclear engines. Laboratory of mechanics of the solids. Polytechnic school, Palaiseau, June 1985.
[2]
S.TAHERI: "Method ZAC". Note EDF/DER HI-71/6139 of June 14, 1989.

---

3 Modeling
With

3.1
Characteristics of modeling

It is about an axisymmetric modeling.

Z
N17
N33
N2
M1
M2
M3
M4
M5
M6
N26
N3
N18
N32
N4

N19
R
6 elements

The loading and the boundary conditions are modelled by:

DDL_IMPO: (NODE: (N26 N3), DY: 0.)
TEMP_CALCULEE: temple

where temple is the higher definite positive function for the moments t=1 and 3 [§1.3]

PRES_REP: (GROUP_MA: L4, NEAR: 2.)

Two preliminary calculations are carried out:

· an elastic design for the loadings min. and max. on a cycle (tmin = 1 and T
= 3)

max
· an optional elastoplastic calculation until the maximum loading before discharge (your = 3)

3.2
Characteristics of the grid

A number of nodes:
33
A number of meshs and type:
6 elements QUAD8

3.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
MODELING
AXIS

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI

SY
AFFE_CHAR_MECA
PRES_REP
GROUP_MA

TEMP_CALCULEE
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE

MECA_STATIQUE
OPTION
SIEF_ELGA_DEPL

POST_ZAC
EVOL_ELAS

EVOL_NOLI

4
Results of modeling A

4.1 Values
tested

· T = 30°C, case of adaptation.
The results of reference come from an elastoplastic calculation Aster on 20 cycles.

-
without elastoplastic semi-cycle given (0=0)

Identification Reference
ZAC - Aster %
difference
p

with the N32 node (skin interns)
zz
1.7898 10-3 2.7142
10-3
+51.65%
lim
moy

with the N32 node (skin interns)
86.55 72.27 -16.50%
zzlim

p

with the node N4 (external skin)
zz
3.1031 10-3 3.8715
10-3
+24.76%
lim
moy with the node N4 (external skin)
114.03 128.35 +12.56%
zzlim

-
with elastoplastic semi-cycle given (0_0)

Identification Reference
ZAC - Aster %
difference
p

with the N32 node (skin interns)
zz
1.7898 10-3 1.7872
10-3
-0.14 %
lim
moy

with the N32 node (skin interns)
86.55 89.09 +2.93%
zzlim

p with the node N4 (external skin)
zz
3.1031 10-3 3.1053
10-3
+0.07%
lim
moy with the node N4 (external skin)
114.03 114.31 +0.24
%
zzlim

· T = 120°C, case of accommodation.
The results of reference come from an analytical solution given in [bib1]

-
without elastoplastic semi-cycle given (0=0)

Identification Reference
ZAC - Aster %
difference
p with the N32 node (skin interns)
zz
4.141 10-3
4.424 10-3
+6.83%
moy

with the N32 node (skin interns)
zzmoy

91.82 87.52 -4.68%

p with the node N4 (external skin)
zz
9.59 10-3 9.75
10-3
+1.64%
moy

with the node N4 (external skin)
zzmoy

191.90 195.17 +1.70%
p with the node N18 (surf.moyenne)
zz
5.96 10-3 6.20
10-3
+4.06%
moy

with the node N18 (surf.moyenne)
zzmoy

319.18 320.45 +0.39%
p with the N32 node (skin interns)
zz
3.6363 10-3 3.6574
10-3
+0.58%
inf

with the N32 node (skin interns)
zzinf

472.72 474.66 +0.41%
p with the node N4 (external skin)
zz
3.6328 10-3 3.6098
10-3
-0.63%
inf

with the node N4 (external skin)
zzinf

472.72 473.97 +0.26%

p with the N32 node (skin interns)
zz
3.6363 10-3
3.6604 10-3
+0.66%
sup

with the N32 node (skin interns)
zzsup

472.72 473.31 +0.12%
p with the node N4 (external skin)
zz
3.6328 10-3 3.6097
10-3
-0.63%
sup

with the node N4 (external skin)
zzsup

472.72 473.18 +0.09%
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-
with elastoplastic semi-cycle given (0_0)

Identification Reference
ZAC - Aster %
difference
p with the N32 node (skin interns)
zz
4.141 10-3 4.177
10-3
+0.89%
moy

with the N32 node (skin interns)
zzmoy

91.82 83.43 -9.13%
p with the node N4 (external skin)
zz
9.59 10-3 9.51
10-3
-0.87%
moy

with the node N4 (external skin)
zzmoy

191.90 190.39 -0.79%
p with the node N18 (surf.moyenne)

zz
5.959 10-3 5.963
10-3
+0.08%
moy

with the node N18 (surf.moyenne)
zzmoy

319.18 313.5
-1.78%
p with the N32 node (skin interns)
zz
3.6363 10-3
3.6574 10-3
+0.58%
inf

with the N32 node (skin interns)
zzinf

472.72 474.66 +0.41%
p

with the node N4 (external skin)
zz
3.6328 10-3 3.6098
10-3
-0.63%
inf

with the node N4 (external skin)
zzinf

472.72 473.97 +0.26%
p with the N32 node (skin interns)
zz
3.6363 10-3
3.6604 10-3
+0.66%
sup

with the N32 node (skin interns)
zzsup

472.72 473.31 +0.12%
p with the node N4 (external skin)
zz
3.6328 10-3 3.6097
10-3
-0.63%
sup

with the node N4 (external skin)
zzsup

472.72 473.18 +0.09%

4.2 Remarks

In the case of accommodation (T=120°C), the M1 meshs, m2, M5 and M6 form a zone adapted whereas the central zone (meshs m2 and m3) remains adapted.

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling 3D

Angle nets: 5°

Z
y
X

The loading and the boundary conditions are modelled by:

DDL_IMPO: (GROUP_NO: facemoy,
DZ: 0.)
face0
DY: 0)
FACE_IMPO: (GROUP_MA: face10
DNOR: 0)
TEMP_CALCULEE: temple

where temple is the higher definite positive function for the moments t=1 and 3 [§1.3]

PRES_REP: (GROUP_MA: facepres, NEAR: 2.)

Two preliminary calculations are carried out:

· an elastic design for the loadings min. and max. on a cycle (tmin = 1 and T
= 3)

max
· an optional elastoplastic calculation until the maximum loading before discharge (your = 3)

5.2
Characteristics of the grid

A number of nodes:
793
A number of meshs and type:
120 elements HEXA20

5.3 Functionalities
tested

Orders

AFFE_MODELE
AFFE
MODELING
AXIS

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI

SY
AFFE_CHAR_MECA
PRES_REP
GROUP_MA

TEMP_CALCULEE
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE

MECA_STATIQUE
OPTION
SIEF_ELGA_DEPL

POST_ZAC
EVOL_ELAS

EVOL_NOLI

6
Results of modeling B

6.1 Values
tested

· T = 30°C, case of adaptation.
The results of reference come from an elastoplastic calculation Aster on 20 cycles.

-
without elastoplastic semi-cycle given (0=0)

Identification Reference
ZAC - Aster %
difference
p

at the point C (skin interns)
zz
1.7898 10-3 2.7151
10-3
51.700
lim
p

at the point F (external skin)
zz
3.1031 10-3 3.8794
10-3
25.014
lim

-
with elastoplastic semi-cycle given (0_0)

Identification Reference
ZAC - Aster %
difference
p

at the point C (skin interns)
zz
1.7898 10-3 1.7911
10-3
0.075
lim
p at the point F (external skin)
zz
3.1031 10-3 3.1133
10-3
0.327
lim

· T = 120°C, case of accommodation.
The results of reference come from an analytical solution given in [bib1]

-
without elastoplastic semi-cycle given (0=0)

Identification Reference
ZAC - Aster %
difference
p at the point C (skin interns)
zz
4.141 10-3 4.4393
10-3
7.203
moy

at the point C (skin interns)
zzmoy

91.82 8.782E+01
-4.345
p at the point F (external skin)
zz
9.59 10-3 9.766
10-3
1.803
moy

at the point F (external skin)
zzmoy

191.90 1.9537E+02
1.803
p at the point C (skin interns)
zz
3.6363 10-3 3.6299
10-3
-0.176
inf

at the point C (skin interns)
zzinf

472.72 4.7328E+02
0.117
p at the point F (external skin)
zz
3.6328 10-3 3.6401
10-3
0.202
inf

at the point F (external skin)
zzinf

472.72 4.7367E+02
0.200
p at the point C (skin interns)
zz
3.6363 10-3 3.632
10-3
-0.119
sup

at the point C (skin interns)
zzsup

472.72 4.7205E+02
-0.142
p at the point F (external skin)
zz
3.6328 10-3 3.6405
10-3
0.212
sup

at the point F (external skin)
zzsup

472.72 4.7323E+02
0.106

-
with elastoplastic semi-cycle given (0_0)

Identification Reference
ZAC - Aster %
difference
p at the point C (skin interns)
zz
4.141 10-3 4.1905
10-3
1.195
moy

at the point C (skin interns)
zzmoy

9.182 10+1 8.305
10+1

-9.552
p at the point F (external skin)
zz
9.59 10-3 9.5225
10-3
-0.741
moy

at the point F (external skin)
zzmoy

1.9190 10+2 1.9031
10+2
-0.832
p

at the point C (skin interns)
zz
3.6363 10-3 3.6299
10-3
-0.176
inf

at the point C (skin interns)
zzinf

4.7272 10+2 4.732810+2
0.117
p

at the point F (external skin)
zz
3.6328 10-3 3.64041
10-3
0.202
inf
at the point F (external skin)
zzinf

4.7272 10+2 4.7367
10+2
0.200
p at the point C (skin interns)
zz

3.6363 10-3 3.632
10-3
-0.119
sup

at the point C (skin interns)
zzsup

4.7272 10+2 4.720510+2
-0.142
p at the point F (external skin)
zz
3.6328 10-3 3.6405
10-3
0.212
sup

at the point F (external skin)
zzsup

4.7272 10+2 4.7323
10+2
0.106

6.2 Remarks

In the case of accommodation (T=120°C), the M1 meshs, m2, M5 and M6 form a zone adapted whereas the central zone (meshs m2 and m3) remains adapted.

7
Summary of the results

It appears at the end of this test that the results obtained are in concord with the solutions of reference. However, in the case of the adaptation (T=30°C) projection starting from an initial state corresponding to the preliminary calculation of an elastoplastic semi-cycle is necessary to approach accurately solutions. Contrary, the case of accommodation (T=120°C) has already results correctly approximate starting from an initial state no one.

One will find in [bib1] and [bib2] of other results relating to this test like incremental calculation realized with COCAINE or numerical solutions obtained with programmed method ZAC in the INCA code.

Titrate:
SSNA102 - Contact multicorps elastic

Date:
15/10/01

Author (S):
NR. TARDIEU *Key*

Organization (S): EDF/MTI/MMN

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.102

SSNA102 - Contact multicorps elastic

Summary:

This problem of nonlinear statics of an axisymmetric structure makes it possible to test the two alternatives of
the algorithm of contact in great displacements.
Calculation consists of the modeling of a structure made up of several elastic bodies in contact unilateral without friction. This calculation already was object IPSI-Phi2AS the case-test describes in the note
HI-75/97/034/0. The reference solution comes from calculations carried out with codes ABAQUS, SYSTUS and
The SAMCEF software.

Titrate:
SSNA102 - Contact multicorps elastic

Date:
15/10/01
Author (S):

1
Problem of reference

1.1 Geometry

Model: Axisymmetric
Units: mm

LCD1

10.

2.

PA1

PP2
Z

5.

PM2
R

PP3

10.

4.

LBC4

PA4

20.

1.2
Properties of material

Linear elastic material of characteristics: E = 200000. MPa

= 0.3

1.3
Boundary conditions and loadings

.
DR. and DZ blocked on LBC4
.
DZ imposed -2.0 mm on LCD1
.
Connections between degrees of freedom:
DZ (PA1) = DZ (PP2)
DZ (PM2) = DZ (PP3)
.
Conditions of unilateral contact between each face of the solids in opposite, is 3 couples of paired surfaces

---

2
Reference solution

2.1
Method of calculation used for the reference solution

Average of the results obtained by various computer codes in mechanics, ABAQUS, SYSTUS,
The SAMCEF software, within the framework of a case test IPSI-2AS [bib1].

2.2
Results of reference

Vertical displacement of point PA4:
ABAQUS: - 0.83 mm

SYSTUS: - 0.82 mm is - 0 8
. 1mm
The SAMCEF software: - 0.78 mm

Vertical component of the reaction to embedding LBC4:
ABAQUS: 110270 NR

SYSTUS: 109500 NR is 108257 NR
The SAMCEF software: 105000 NR

NB:

The efforts calculated by Aster into axisymmetric are it by radian. The value to be aimed is thus
108257/2 = 17229 58
. NR/rd

2.3
Uncertainties on the solution

Dispersion around the average value of vertical displacement in PA4 is 4%. Dispersion around the vertical reaction to embedding is 3%.

2.4 References
bibliographical

[1]
I. VAUTIER: "Example of use of the functionalities of contact in great displacements in Code_Aster", HI-75/97/034/0 notes.
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HI-75/01/010/A

---

3 Modeling
With

3.1
Characteristics of modeling

One uses the algorithm algoco.f i.e here the algorithm by defect of the key word CONTACT. It is one algorithm of active constraints where one activates/decontaminates the connections until reaching

one by one one
state of contact satisfying the conditions kinematics, before turning over towards an iteration of Newton.

3.2
Characteristics of the grid

Nodes: 4620 nodes

Meshs: 1348 QUAD8, 114 TRI6, 2213 SEG3

GIBI FECIT

3.3 Functionalities
tested

Orders Key word
factor
Key word
AFFE_CHAR_MECA CONTACT
METHOD
CONSTRAINT
STAT_NON_LINE

5/8

4 Results of modeling A

4.1 Values tested

Identification	Moments	Reference	Aster	% difference
DY not PA4	1.	-0.81	-0.83844	3.5
FY Bord LBC4	1.	17229.58	17443.16	1.2

4.2 Remarks

Calculation converges in a step of loading.

4.3 Parameters of execution

Version: 5.04

Machine: SGI-Origin2000-R12000

Obstruction memory: 50 Mo
Time CPU To use: 91.11 seconds

5 Modeling B

5.1 Characteristics of modeling

One uses the algorithm algocp.f i.e here the algorithm given by METHOD: "LAGRANGIAN" of the key word
CONTACT. One activates/decontaminates the connections per package without seeking to reach a state of contact
satisfying the conditions kinematics before turning over towards an iteration of Newton.

5.2 Characteristics of the grid

Nodes: 4620 nodes

Meshs: 1348 QUAD8, 114 TRI6, 2213 SEG3

GIBI FECIT

5.3 Functionalities tested

Orders Key word factor
Key word

AFFE_CHAR_MECA CONTACT
METHOD
LAGRANGIAN
STAT_NON_LINE

6
Results of modeling B

6.1 Values
tested

Identification Moments Reference
Aster *%*
difference
DY not PA4
1.
-0.81
-0.84110
3.84
FY Bord LBC4
1.
17229.58

17491.52
1.52

6.2 Remarks

Calculation converges in two steps of loading (difference with modeling A due to nature of the algorithm).

6.3 Parameters of execution

Version: 5.04

Machine: SGI-Origin2000-R12000

Obstruction memory: 50 Mo
Time CPU To use: 210.29 seconds

---

7 Summary of the results

The results are satisfactory taking into account the diversity of the origin of the reference solution. Although the two algorithms of contact give identical results in displacement and in force, returned effective surfaces of contact differ slightly. Sights respective natures

of the two algorithms, that is completely comprehensible. To obtain the same ones exactly results, it is necessary to make calculations in 10 steps of time.
Lastly, the difference in time CPU between the two algorithms is explained by the more significant number
iterations of Newton carried out by the algorithm algocp.f (METHOD: “LAGRANGIAN”).

Author (S):
R. MASSON, W. LEFEVRE, G. Key BARBER
:

Organization (S): EDF/RNE/MTC

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.103

SSNA103 - Chock of the parameters of the model of Weibull

Summary:

This test validates order RECA_WEIBULL allowing the identification of the parameters m and the model of
U
Weibull.

The identification is carried out using a data base made up of 45 tests, all carried out on cylindrical test-tubes smooth at three different temperatures, -150°C, -100°C and 50°C. This base of data is obtained by random pulling of a sample representative of the statistical law of Weibull correspondent with values of m and U arbitrarily fixed.
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-26/01/046/A

---

1 Problem of reference

1.1 Geometry

Each test is carried out on a smooth cylindrical test-tube. For obvious reasons of

symmetries, an axisymmetric modeling 2D of the quarter of the structure is sufficient.

1.2
Properties of material

One describes the behavior of material studied by an elastoplastic law of Von Mises with linear isotropic work hardening, “VMIS_ISOT_LINE”. Deformations used in the relation of behavior are the linearized deformations.

And
Y
E

The Poisson's ratio does not depend on the temperature, = 0,3.

The values of the Young modulus E, the tangent module And and the elastic limit are given in the following table:

Temperature [°C]
-150
-100
-50

E [MPa]
200000 200000
200000
And [MPa]
2000 2000
2000
Y [MPa]
750 700
650

1.3
Boundary conditions and loadings

By referring to the figure §1.1 the boundary conditions and loadings are as follows:

On segment BC (Y=L0), imposed displacement following direction OY:

T [°C]
Displacement (l-l0) with the rupture for a reference length l0 of 203.5 mm
[mm]
The results for each temperature are classified by ascending order
-50
10,68 28,78 30,31 31,66 32,53
33,90
34,38
35,82
36,69
37,09
37,37 37,49 38,45
39,77
44,39
-100
20,57 21,68 23,32 24,37 24,66
25,59
25,84
27,51
28,44
29,30
29,68 30,16 30,18
30,20
30,95
-150

11,33 14,70 14,79 14,90 18,62
18,87
19,00
19,37
19,61
20,07
21,19 22,79 23,28
24,17
24,41

On segment OA (Y=0) displacements blocked according to direction OY.
On segment OB (X=0) displacements blocked according to direction OX.

1.4 Conditions
initial

Null constraints and deformations.

2
Reference solution

2.1
Method of calculation

No calculation is necessary to obtain the reference solution. The values m and (M and
U
SIGM_REFE in option WEIBULL of DEFI_MATERIAU) which one seeks to identify with Code_Aster are known and make it possible to generate the base of the experimental data. Thus, them elongations with rupture are in the following way given:

For each couple m and U associated with a temperature with test, a sample of 15 values of forced of Weibull to the rupture were determined by random pulling taking into account the law following statistics:

m

P
(
) = 1 - exp-
W

F
W

U

The constraint of Weibull is defined by:

m V
= m (I
I

W
I)
V
I
0
The summation relates to volumes of matter V plasticized, I indicating the principal constraint
I
I
maximum in each one of these volumes (volume V0 (VOLU_REFE in option WEIBULL of DEFI_MATERIAU) is equal to (50 µ m) 3).

In the case of a request in simple traction with the assumption of the small deformations, *forced of Weibull, W, according to the elongation with the rupture (l-l0) /l0 is expressed, according to:*

L - L
E
V

0
T
= E
1
m

W
T
+
-
Y
l0
E
V

0

One thus deduces from this expression and preceding random pulling the values of lengthenings with rupture deferred in the table of [§1.3].

2.2
Sizes and results of reference

The reference variables of m and used to create the bases of experimental tests are
U
the following ones:

Temperature [°C]
-50
-100
-150
m
24 24
24
U [MPa]
2800 2700
2600

2.3
Uncertainties on the solution

Uncertainty on the solution cannot be given in a precise way. It can be rather high.
Indeed, the values of reference can be found only if populations are considered
experimental made up of an infinite number of samples.

---

3 Modeling
With

3.1
Characteristics of the grid

GROUP_MA: CB
GROUP_MA: BO
GROUP_MA: OA

A number of nodes: 149
A number of meshs and types: 40 elements QUAD8

3.2 Functionalities
tested

Orders

DEFI_MATERIAU WEIBULL
M

VOLU_REFE
SIGM_REFE
STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_LINE
DEFORMATION
SMALL
RECA_WEIBULL LIST_PARA SIGM_REFE

M

RESU
EVOL_NOLI

TEMPLE

COEF_MULT
METHOD
MAXI_VRAI
CORR_PLAST
NOT
OPTION
SIGM_ELMOY

6/6

3.3
Sizes tested and results

Identification of a m common to the three experimental bases and of one per base.
U

Temperature [°C]
Reference
Code_Aster

m
[MPa]
m
[MPa]
U
U
-50 24 2800
26,7
2536
-100 24 2700 26,7 2428
-150 24 2600 26,7 2372

3.4 Remarks

Although the variation enters the values of (m,) obtained with RECA_WEIBULL and their values of
U
reference remains considerable, it is in conformity with the result sought taking into account the number
relatively weak of samples used for retiming (15 per temperature). To obtain them
values of reference it would be necessary considerably to increase the number of samples per temperature
(N>1000). The noted variation remains however reasonable (about 10%). In addition,
growth of according to the temperature is respected
U

3.5 Parameters
of execution

Version: 5.4

Machine: SGI - ORIGIN 20 00 - R12000

Obstruction memory: 16 Mo
Time CPU To use: 23s

4
Summary of the results

The results obtained by Code_Aster show that the automatic procedure of chock of parameters of the models of Weibull functions and gives coherent results with the results theoretical waited.
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-26/01/046/A

Code_Aster ®
Version
8.1

Titrate:
SSNA104 - Hollow roll subjected to a pressure, linear viscoelasticity
Date:
02/11/05
Author (S):
PH. BONNIERES, S. LECLERCQ, L. SALMONA Key
:
V6.01.104-B Page:
1/6

Organization (S): EDF-R & D /AMA, EDF-R & D /MMC, CS IF

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.104

SSNA104 - Hollow roll subjected to a pressure, linear viscoelasticity

Summary:

This case-test makes it possible to validate the laws of LEMAITRE and LEMA_SEUIL established in Code_Aster in the case
of linear viscoelastic behavior. The found results are compared with an analytical solution.
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/05/005/A

1
Problem of reference

1.1 Geometry

Dimensions of the cylinder:
R0
1 m
R1
2 m
Appear 1.1-a: Cut hollow roll and loading

1.2
Properties of materials

Young modulus: E= 1 MPa
Poisson's ratio: =0.3

Law of LEMAITRE:
N

1
1
1
G (, T) =
with
= ,
1

= ,
0 N = 1

K 1
K
m
m

Law LEMA_SEUIL:

G (, T)
2
3
= A
with A =
, = 1

on all the grid
3
2
10
S 10
=

Being given the value of the various parameters materials, the two laws are absolutely identical and can thus be compared with the same analytical solution.

1.3
Boundary conditions and loading

Boundary conditions:
The cylinder is blocked out of DY on the sides [AB] and [CD].

Loading:
The cylinder is subjected to an internal pressure on [DA] P0 =1.E-3 MPa

2
Reference solutions

2.1
Method of calculation used for the reference solutions

The whole of this demonstration can be read with more details in the document [bib1].

In the case of a linear viscoelastic isotropic material, one can describe the behavior with the course time using two functions I (T) and K (T) so that strains and stresses can be written:

D (T)
D (Tr ((T))
*(T) = (I + K) **
*- K **
I
3

D

D
where I indicates the matrix identity of row 3
3
T
*and * the product of convolution: (F * G T*
) () = F T (-) G () D

0
1

1
I T is found
( ) =
+ kt, K T () =
+ kt
E
E
2

One imposes the P0 pressure on the moment t=0, the internal pressure is worth
0 if T - < 0
p (T) = H (T) P where H (T) =
with in this case = 0
0

1 if T - 0

One uses the transform of Laplace Carson
+
F (N) = L (F (T)) = N
-
F (T) E NT dt
0
From where +
p = P
0
The solution of the elastic problem are equivalent is:

R 2

1 - 1
0
0

2
R

2

2
+

P R
=

R
0
1+ 1
0 where
0 0
=

2
R

2
2
R - R

1
0
+

0
0
Z

One determines +
by the condition on +
data by the boundary conditions:
Z
Z

+
+

+
= 0 = (I + K +
+
)
- K (
2 + +
+
) = I +
+
- 2K
Z
Z
Z
Z

+

(2 -) 1p
From where = 1
.
Z

+

p + Ek

-
One finds by the transform of opposite Laplace
(T) = (1 - (1 -
2) Eht
E
Z
), in the same way in
applying the transform of Laplace reverses on and, one finds
R

R 2

1 - 1
0
0

2
R

2

+
=

R
0
1+ 1
0

2
R

0

0
(1- (1-
2) - Eht
E
)

One deduces some:
3 1-
2
R 2

- Ekt
K
E
- 1
0
0

2
2
3
R

2

3
1

& =
- 2
R
- Ekt
0
K

E
- 1
0

V

2
2
3
R

0
0
- K (1 -
2) - Ekt
E
)

and while integrating with ()
0 = 0 ;
V
3 1 - 2
R 2

- Ekt

E
- K 1 T
0
0

2

2
3rd
R

2

=
3 1 - 2
R

- Ekt
0

E
- K 1 T
0
.
V

2

2
3rd
R

(1- 2)

0
0
-
(1 - - Ekt
E
)

E

One deduces radial displacement from it

1

R 2

1 - 2

2

3

W (R, T) =

1

Ekt

R

R (1+)

+

(3 (1 - 2) - E)

+

2

K 1 T

2

E

R

2

2 R

2.2
Results of reference

Displacement DX on the node B and constraints SIXX, SIYY and SIZZ out of B

2.3
Uncertainty on the solution

0%: analytical solution

2.4 References
bibliographical

[1]
PH. BONNIERES: Two analytical solutions of axisymmetric problems in

linear viscoelasticity and with unilateral contact, Note HI-71/8301
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/05/005/A

---

3 Modeling With

3.1 Characteristics of modeling

The problem is modelled in axisymetry.

3.2 Characteristics of the grid

1000 meshs QUAD4

3.3 Functionalities tested

Orders

DEFI_MATERIAU LEMAITRE

STAT_NON_LINE COMP_INCR

LEMAITRE

4
Results of modeling A

4.1 Values tested

Identification Moments Reference
Aster Variation
%
DX (B) 0.9
2.14498
E3
2.14493496E03
0.002 %

SIXX (B)
0.9
0.0
4.8168 E6
4.8168 E6
SIYY (B)
0.9
2.7912 E4
2.759 E4
1.5 %
SIZZ (B) 0.9 6.66 E4
6.635 E4
0.5 %

---

5 Modeling B

5.1 Characteristics of modeling

The problem is modelled in axisymetry

5.2 Characteristics of the grid

1000 meshs QUAD4

5.3 Functionalities tested

Orders

DEFI_MATERIAU LEMA_SEUIL

STAT_NON_LINE COMP_INCR
LEMA_SEUIL

6 Results of modeling B

6.1 Values tested

Identification Moments Reference

Aster Variation
%
DX (B) 0.9
2.14498
E3
2.14493496E03
0.002 %

SIXX (B)
0.9
0.0
4.81687 E6
4.8168 E6
SIYY (B)
0.9
2.7912 E4
2.759 E4
1.5 %
SIZZ (B) 0.9 6.66 E4
6.635 E4
0.5 %

7
Summary of the results

The results calculated by Code_Aster are in agreement with the analytical solutions but very strongly depend on the refinement of the grid.

Organization (S): EDF/AMA, CS IF

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
V6.01.105 document

SSNA105 - Hollow roll subjected to a pressure, linear viscoelasticity, contact

Summary:

This case-test makes it possible to in the case of validate the law of LEMAITRE established in Code_Aster behavior
viscoelastic linear. The found results are compared with an analytical solution.
This test takes again same modeling as the case-test SSNA104A to which one adds a cylinder (pastille) and one
draft the contact.

---

1 Problem of reference

1.1 Geometry

The diagram is not on the scale, the difference between the two cylinders was amplified for the best visibility.

R1
0.82
R2
0.92
R3
1.
R4
2.

1.2 Properties of materials

The pastille is made up of an elastic material, the sheath consists of a viscoelastic material.
The elastic data coincide for two materials.
Young modulus: E= 1 MPa
Poisson's ratio: =0.3

Law of LEMAITRE:
N

1

1
1
G (, T) =
with
= ,
1
= ,
0 N = 1

K 1
K
m
m

1.3
Boundary conditions and loading

Boundary conditions:
The cylinder is blocked out of DY on the sides [AP, BP], [AG, BG] and [CP, PD] [CG, PG].

Loading:
The cylinder is subjected to an internal pressure on [DP, AP], this pressure is calculated of such kind that at the moment t=0, the sheath has the same behavior as the cylinder modelled in the test ssna104a.

R
E R
R
3
(22 - 21)

-1
if -1 T 0
p (T)
R
R

1
=

2
2 21 (1-)

[
WITH B (R R C D Ge Ekt HT
K
if
T
3 - 2 +
(+ - +) +]
0 < 5

with
2
R
R
E
3
P R
2 -
2
With =
1
, B =
,
0 3

C =
with P
2 2
R
R 1
(+)
2
2
R - R
0 =1.E-3 MPa, pressure of the test ssna104a.
1 (1 -)
2
4
3

1
2
(1 - 2) 2

2
3 R
2
P R

2
R
D =
(+) r4 + 3
1
, G = -
,
4
H = K
, K =
0 2
1- 2 + 1
2
(1-
2)

E
2
2

2

R
2
2nd
2
2 R
R
R
R
2 -
3

3
1
2

One treats the contact between the two cylinders.

2
Reference solutions

2.1
Method of calculation used for the reference solutions

The whole of this demonstration can be read with more details in the document [bib1].

Phase without contact

One wants to find the value of p (T) to apply to the internal wall of the pastille for which the contact
1
place has.
For the pastille, one finds:

2
R

1 - 2
0
0

2
R

2

2

R
p (T) R
0
1
2
0
=
+
where
1
1
=

2
R

2
2
R - R

2
1

0
0

2

(1+)
R 2
W
=
1 - + 2
2
= .
E

R 2
R

(21+)
The condition of being written contact: (
W R) - (
W R) = 0, one has R
R
R

3 - 2 = 2
(1-)
3
2
E
R

E

From where
3
=
-1

R
(
2 1 -) 2
2
R
E R - R
3
(2 2
2
1)
p lim =
-1
.
1

2
R
R
-
2
2
1
1 (
) 2

Phase with contact

It is wanted that as from the moment t=0, the sheath has same behaviour as in the test ssna104a.
When there is contact, one a:
W (R) = W (R) + R - R,
P
2
G

3
3
2
thus by recovering the value of displacements in the test ssna104, one must obtain:
p R 3
1
1 2
3
0 3

R 24
-

2
W (R
4
)
1
3 1 2
.
P
2
= r3 - r2 +
Ekt
R
2
2
(+)
-

+
2
(- (-) E)

+ K
T
2

R
2
2

4 - r3

E
r3

r3

The stress field of the pastille is given by

R 2

R 2

1 - 2
1
- 1
2
0
- 2
0
0

2
R
R

2
2

R

R
0
1
2
1
2
0
=

1
+
-
2
0
+

2
R
R

0
0
Z

2
p R
2
p R
with
1 1
=
and
0 1
=
.
1
2
2
R - R
0
2
2
R - R
2
1
2
1
1+

Like

, one finds: Z = 2 (
-
1

0) .
Z =
Z -
((2 - + Z =
1
0)
) 0
E
E

1+

1+
R 2
R 2
W
One thus has =
- (+ + =
1- 2

1 -
0 +
2
1
-
1
2
0
2 =
R
Z)
(
)(
)
E
E
E
R
R
R

1+

2
R
W (R)
R 2 1
1 2
, one finds a little more p (T) given by the formula
P
2
=
2 (-
)

1 -
-
+ 1
0
2

E

1

r2
high.

2.2
Results of reference

Displacement DX on the node B

2.3
Uncertainty on the solution

0%: analytical solution

2.4 References
bibliographical

[1]
PH. BONNIERES, two analytical solutions of axisymmetric problems in linear viscoelasticity and with unilateral contact, Note HI-71/8301 Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/02/001/A

---

3 Modeling With

3.1 Characteristics of modeling

The problem is modelled in axisymetry

3.2 Characteristics of the grid

750 meshs QUAD4

3.3 Functionalities tested

Orders

DEFI_MATERIAU
ELAS
LEMAITRE
AFFE_CHAR_MECA
CONTACT
STAT_NON_LINE
COMP_INCR
LEMAITRE
COMP_ELAS
ELAS

4
Results of modeling A

4.1 Values
tested

Identification Moments
Reference
Aster
Variation (%)
DX (B)
0.9
2.14 E3
2.14 E3
-0.953
SIXX (B)
0.9
0.0
4.8168 E6
4.8168 E6
SIYY (B)
0.9
2.7912 E4
2.759 E4
1.5
SIZZ (B) 0.9 6.66 E4 6.635
E4
0.5

5
Summary of the results

The results calculated by Code_Aster are in agreement with the analytical solutions but depend very strongly of the refinement of the grid.

Code_Aster *®*
Version
6.0

Titrate:
SSNA106 - Hollow roll subjected to a behavior thermoviscoelastic Date:
19/08/02
Author (S):
PH. *Key* ***BONNIERES****, D. NUNEZ*
:
V6.01.106-A Page:
1/6

Organization (S): EDF/AMA, CS IF

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
V6.01.106 document

SSNA106 - Subjected hollow roll with a behavior thermoviscoelastic

Summary:

This case-test makes it possible to in the case of validate the law of LEMAITRE established in Code_Aster behavior
thermoviscoelastic linear. The found results are compared with an analytical solution.

1
Problem of reference

1.1 Geometry

D
C

T (R, T)

With
B

R0

R

1

R0
1 m
R1
2 m

1.2
Properties of materials

Young modulus: E= 1 MPa
Poisson's ratio: =0.3
Dilation coefficient: =0.7

Law of LEMAITRE:
N

1
1
1
G (, T) =
with
= ,
1
= ,
0 N = 1

K 1
K
m
m

1.3
Boundary conditions and loading

Boundary conditions:
The cylinder is blocked out of DY on the sides [AB] and [CD].

Loading:

The cylinder is subjected to a field of temperature
2
T (R, T) = tr

2
Reference solutions

2.1
Method of calculation used for the reference solutions

The whole of this demonstration can be read with more details in the document [bib1].

In the case of a linear viscoelastic isotropic material, one can describe the behavior with the course time using two functions I (T) and K (T) so that strains and stresses
can be written:

D (T)
D (Tr ((T))
*(T) = (I + K) **
*- K **
I + T
(R, T) I
3
3
D
D
where I indicates the matrix identity of row 3

3
T
*and * the product of convolution: (F * G T*
) () = F T (-) G () D
0

The thermoelastic problem are equivalent, while passing by the transform of Laplace is:

R
2
+
= +
(I + +
+
K
)
- +
+
K Tr
(
) I
I
3 +
3

p

+
D
1
+
'=
R

R
= (+ - +r)

Dr.
R
+

0

Z =
(+
R) = +
R
By eliminating the sign “+”:

1
'

0
R +
(R -) =

R

R 2
(I + K)
(
)
0
Z - K
R +
+ Z +
=

p

R 2
2

R
R (I + K) - K (

(
)

R +
+ Z) +

= I + K R - K (R +
+ Z) +

p
p
maybe,

1
'
(
) 0
R +
R -

=

R

K
R 2

(
)

Z =
R +
-

I
pi

(I + K) K
R 2

2

I K K
I K
R

R (I + K) -
(
(
)

R +
)
(+)
+

= I + K R -
(R +) (+)
+

I
p
I
I
p

(I + K) K
+
2
(I + K
)
+ R (I + K

)

-
(
I
K
R
+ +
= (I + K

)

R
) (
)

R
I
I
p

According to the equilibrium equation, one has = R

'
+, one obtains:
R
R

(I + K)
2
K
I + K
R

(I + K) '

,
R +r (I + K) (R

'
R +
)

R
-
(2 R + R 'R) (
)
+
= 0

I
I
p

R

(
2

2

,
R + R
'
R) +
= 0
p (I - K)

2
R
2 +

R '= A +
what while integrating compared to R gives:
R
R
p (K - I)

2
With

B
R
= +
+

,
R
2
2
R
4 p (K - I)
boundary conditions (R)
give:
R
=
(R)
R
= 0
0
1

With = -
(2
2
R + R)
2 p (K - I) 0
1

2 2
R
R
0 1
B = 4p (K - I)
One thus has by taking again the initial notations:

2 2

R R
+
R =
(2
R
R

R
0 +
2
1 -
2 - 0 1)
+
+
2

4 p (I - K)
R

2 2

R R
+
=
(2
R
R
R

0 +
2
1 - 3 2 + 0 1)

+
4 p (I - +
K)
2
R

+
2
2
+

K (R
R
0 + 1)
Z =
(
- 2

R)

+
p (I - +
+
K) I
2
Maybe, by taking the opposite transform,

2
2
R R

-
1
(
LT
E) 2
2
2
0 1
R
R
R
0
0

-
0 + 1 -
-

2

2k
R

2
2

R R
- LT
2
2
2
0 1

=
0
1
(- E

) R
R
R
0 + 1 - 3
+ 2
0
2k
R

2
2
-
R
R
LT
2
2
2
0 +
0

0
1
(- E) (
Ekt
R
R
R
E
0 + 1 - 2
)

1
-

+
1
(-
)
2

K
R

One deduces some and W:
V
1 - 2

2 2
LT
R R

2
2
2 2
-
Ekt
(R
R)
3Ekt
R R
2

2
0 1
-
- 0 +

(
W R, T) =
R
(1 - E) R R
1 E
R

0 + 1 -
2
+ (-
)

1
+
0 1 + 2
2

Ek

R

4

(41- 2)

R

Handbook of Validation
V6.02 booklet: Nonlinear statics into axisymmetric
HT-66/02/001/A

Code_Aster ®
Version
6.0

2.2
Results of reference

Displacement DX on the node B

2.3
Uncertainty on the solution

0%: analytical solution

2.4 References
bibliographical

[1]
PH. BONNIERES, two analytical solutions of axisymmetric problems in linear viscoelasticity and with unilateral contact, Note HI-71/8301

Titrate:
SSNA106 - Hollow roll subjected to a behavior thermoviscoelastic Date:
19/08/02
Author (S):
PH. Key BONNIERES, D. NUNEZ
:
V6.01.106-A Page:
6/6

3 Modeling
With

3.1
Characteristics of modeling

The problem is modelled in axisymetry

3.2
Characteristics of the grid

120 meshs QUAD4

3.3 Functionalities
tested

Orders

DEFI_MATERIAU
LEMAITRE
STAT_NON_LINE
COMP_INCR
LEMAITRE

4
Results of modeling A

4.1 Values
tested

Identification Moments Reference
Aster
Variation %
DX (B) 0.24
1.110
1.1106
0.05%

5
Summary of the results

The results calculated by Code_Aster are in agreement with the analytical solutions but depend very strongly of the refinement of the grid.

V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.108

SSNA108 - Models of Weibull and Rice and Tracey

Summary:

This test of nonlinear quasi-static mechanics makes it possible to validate the models of Weibull and Rice -
Tracey in 2D (order POST_ELEM) in the case of a notched axisymmetric test-tube subjected to one simple tensile test.

The modeling of the test-tube is carried out with elements 2D (QUA8).

1
Problem of reference

1.1 Geometry

A notched cylindrical test-tube is considered:

· diameter of the test-tube: 18 mm,
· ray of the notch: 5 Misters.

1.2
Properties of material

One adopts an elastoplastic law of behavior of Von Mises with isotropic work hardening "TRACTION" whose traction diagram is given point by point:

0.0027 0.005 0.01 0.015 0.02 0.025 0.03 0.04 0.05 0.075 0.1

(MPa)
555 589 631 657 676 691 704 725 741 772 794

0.125
0.15 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
812 827 851 887 912 933 950 965 978 990

The deformations used in the relation of behavior are the linearized deformations. Young modulus E amounts to 200 GPa while the Poisson's ratio is worth 0,3.

The coefficients of the model of Weibull used are as follows:

m = 8,
V = 100 m
μ,
0
= 2630MPa.
U

1.3
Boundary conditions and loadings

While referring to the figure [§3.1] boundary conditions are as follows:

· BC: following imposed displacement (Y),
· OA: displacements blocked according to (Y),
· OB: displacements blocked according to (X).

1.4 Conditions initial

Null constraints and deformations.

---

2 Reference solution

2.1 Method of calculation

Numerical solution calculated by CASTEM2000 and Zébulon.

2.2 Sizes and results of reference

The constraint of Weibull (WEIBULL) as well as the rate of triaxiality (RICE_TRACEY) on different meshs were calculated at various moments.

2.3 Uncertainties on the solution

Precision of the codes.

3 Modeling
With

3.1
Characteristics of the grid

10 mm

B

C

30 mm

O In R=2 mm
Y

X

5 m m

3.2
Characteristics of the grid

A number of nodes: 1219
A number of meshs and types: 320 (QUA8).

3.3 Functionalities
tested

Orders

DEFI_MATERIAU
WEIBULL
M
VOLU_REFE
SIGM_REFE
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_ISOT_TRAC
DEFORMATION
SMALL
CALC_ELEM
OPTION
EPSG_ELGA_DEPL
POST_ELEM
WEIBULL
COEF_MULT

OPTION
SIGM_ELGA
POST_ELEM
RICE_TRACEY
COEF_MULT
ROOM
YES
OPTION
SIGM_ELMOY

3.4
Sizes tested and results

The variation noted with the reference solution remains lower than 1%.

4
Summary of the results

The results obtained by Code_Aster are close to the reference solution since the variation with reference solution is lower than 1%.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.111

SSNA111 - Indentation of a solid mass by a punch

Summary:

This test relates to the study of a conical punch deforming an elastoplastic massive structure.

The unit is modelled with elements axisymmetric and subjected to a displacement imposed and on contact.

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/03/008/A

Code_Aster ®
Version
7.1

Titrate:
SSNA111 - Indentation of a solid mass by a punch
Date
:

1
Problem of reference

1.1 Geometry

2,7

1

With

Y

X

5

10

The problem is axisymmetric (of axis Y). The punch consists of only one triangular element. It is in initial contact with the solid mass at point A.

1.2
Material properties

Elastoplastic material with linear isotropic work hardening:

E = 2.0x105 MPa; =0.3
Y = 300MPa; AND = 5000

1.3
Boundary conditions and loadings

The base of the solid mass is embedded and its with dimensions left is imposed on DX=0. The vertical displacement of
punch is imposed on 0.4 and horizontal displacement is imposed on 0.

Loadings

Vertical displacement of the punch: uy = 4 NR

2
Reference solution

2.1
Results of reference

Displacements and rotations of node A (DEPL).
The results calculated in this case test result from a former execution of Aster. It is a case test
of nonregression.

---

3 Modeling
With

3.1
Characteristics of modeling

· Modélisation AXIS

3.2
Characteristics of the grid

The grid is obtained by GMSH.

A number of nodes: 1803
A number of meshs: 1852

3.3 Functionalities
tested

Orders Options

AFFE_CHAR_MECA DDL_IMPO

CONTACT "MAIT_ESCL"

4
Results of modeling A

4.1 Values
tested

Loading Value
tested Aster
Vertical displacement in A
Displacement of A Dy
-0,25

Force reaction of A Dx
-17,2144

Force reaction of A Dy
-16,3087

Displacement of A Dy
-0,392

Force reaction of A Dx
-18,6982

Force reaction of A Dy
-13,7081

4.2 Remarks

The force of nodal reaction is in N/rad since the problem is axisymmetric.

5
Summary of the results

This example of nonregression shows a non-linear calculation with contact.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.112

SSNA112 axisymmetric Test of wrenching (Borderie & Pijaudier- Pooch) for the study of steel-concrete connection: law JOINT_BA

Summary:

In this case test of mechanics one modelled the test of wrenching carried out by Borderie & Pijaudier-Pooch [bib1] of which the goal was to study the influence of the state of stress in the matrix on the properties
mechanics of the interface. The geometrical data and the characteristics materials result from their report/ratio, and the numerical results will be compared with the experimental results.

For axisymmetric modeling, one uses elements QUAD4 for the concrete and steel, in combination with elements joint for the interface (see Doc. [R3.06.09]). The concrete and steel are considered elastic so
to test only nonthe linearity of the law of behavior of connection steel concrete, JOINT_BA (see document [R7.01.21]). One carries out a monotonous calculation with the displacements imposed at the end of the bar
of steel.

1
Problem of reference

1.1
Geometry and boundary conditions

80
U = 6 mm
10
45
80

Appear 1.1-a: Geometry and boundary conditions

1.2
Properties of material

Steel*: rubber band*
E = 2.1x10+5 MPa,
= 0.3

Concrete*: rubber band*
E = 1.55x10+4 MPa,
= 0.17

Element of joint*:*

.
law of behavior ELAS with the following parameters:
E = 1.55x10+4 MPa,
= 0.17

.
law of behavior JOINT_BA with the following parameters:

- Initial Parameters:

coefficient of penetration:
Hpen = 0.64 mm
(key word: HPEN)

modulate rigidity:
G
(key word: GTT)
bound
= 6.65x10+3 MPa

Handbook of Validation

- Parameters of tangential damage:

threshold of elastic strain:
0

(key word:

= 5x10-4
GAMD0)

coefficient of damage area 1:
AD
= 1.0
(key word: AD1)
1

coefficient of damage area 1:

Data base
= 0.5
(key word: BD1)
1

threshold of the great slips:
2

(key word:

= 9.6x10-1
GAMD2)

coefficient of damage area 2:
AD
= 4x10-5 MPa-1
(key word: AD2)
2

coefficient of damage area 2:
Data base
= 1.0
(key word: BD2)
2

- Parameters for the friction of the cracks and containment:

coefficient material by friction:

= 10.0 MPa
(key word: VIFROT)

coefficient by kinematic work hardening:

= 4x10-1 MPa-1
(key word: F)

C

coefficient of containment:

= 1.0
(key word: FC)

- Parameters of normal damage:

normal deformation criticizes (opening):
0

= 9x10-1
(key word: EPSTR0)
NR

coefficient of normal damage:
AD
(key word: ADN)
NR
= 1x10-9 MPa-1

coefficient of normal damage:
Data base
(key word: BDN)
NR
= 1.5

1.3
Boundary conditions and loadings

Null displacements imposed (embedding) on the side face of the elements of the concrete.
The axis of rotation is fixed in the middle of the steel bar.
The mechanical loading into monotonous is applied in the form of displacements imposed to the end of the steel bar in two stages:

.
20 increments of 0.005 mm, for U = {0 to 0.1 mm}

.
118 increments of 0.05 mm, for U = {0.1 to 6 mm}

2

Reference solution

It is about a numerical comparison - experimental. The work of Borderie & Pijaudier-Pooch [bib1] consisted in a trial run of wrenchings carried out on fibres and reinforcements for reinforced concrete. The object of these tests was to study the influence of the state of stress in the matrix on the mechanical properties of the interface.

Each specimen was a cube of 80x80x80 mm whose concrete paste was Grade C30/37 (gravel of 16 mm) with a resistance to the moment of the test (three days after the casting and with a treatment 4 hours thermics) of 14.5 MPa, a Young modulus of 15.500 MPa and a Poisson's ratio from 0,17. For the reinforcements, they used deformed bars 8 mms in diameter, with a length of steel-concrete contact of 45 mm, plus 10 mm free at the edge of the concrete, which allowed to eliminate the singularities in the field from the concrete stresses in the embedded surface of the cube. The test was carried out with controlled displacements (u& = 8.3 X 10th-3 mm/s) and four levels of containment: 0, 5, 10 and 15 MPa, constant during each experiment.

3 Bibliography

[1]
BORDERIE C. & PIJAUDIER-CABOT G. - experimental Study of the behavior of reinforced materials: Experimental determination of the laws of behavior of the interface matrix fibre. Laboratory of Mechanics and Technology (LMT) ; ENS Cachan/CNRS/Université Paris 6; Contract I 70/1F 3146 with Electricity of France, 1994

---

4 Modeling
With

4.1
Characteristics of modeling

It is about an axisymmetric modeling 2D, where one can identify 2 groups of elements:

Axisymmetric modeling (key word AXIS) for the elements of the concrete and steel.
Modeling fissures axisymmetric (key word AXIS_JOINT) for the element of joint.

The concrete and steel are modelled with elements QUAD4.
The interface is modelled with degenerated elements QUAD4 (confused nodes).

Interface
Embedding
Center
of
rotation

Appear 4.1-a: Modeling of the test into axisymmetric

4.2
Characteristics of the grid

A number of nodes: 94 (with 20 confused nodes)
A number of meshs and type: 11 QUAD4 for steel
+ 9 QUAD4 for the interface
+ 54 QUAD4 for the concrete.

Handbook of Validation
V6.01 booklet: Non-linear statics into axisymmetric
HT-66/05/005/A

4.3 Functionalities tested

The law of behavior JOINT_BA local version in 2D.

Orders
Options

DEFI_MATERIAU JOINT_BA
HPEN

GTT

GAMD0

AD1

BD1

GAMD2

AD2

BD2

VIFROT

F

FC

EPSTR0

ADN

BDN

STAT_NON_LINE COMP_INCR
RELATION
JOINT_BA

5
Results of modeling A

5.1 Values
tested

One tests the components xy element which correspond to the tangential components of the law
local of behavior in the interface, starting from the stress field SIEF_ELGA. Values
are tested at the point of Gauss 2 of the element joint, with 4 steps of different times: at the beginning of
loading, during the phase of growth of the damage, in the peak of resistance
maximum and after the peak of the resistance of the connection.

Component field SIEF_ELGA SITX

Identification Reference
Code_Aster *%*
difference
For an imposed displacement
U TT = 0.2 mm
-7.20 E+00
-7.39825 E+00
2.753
For an imposed displacement
U TT = 0.8 mm
-1.14 E+01
-1.17820 E+01
-3.351
For an imposed displacement
U TT = 1.0 mm
-1.26 E+01

-1.21161 E+01
-3.841
For an imposed displacement
U TT = 1.6 mm
-1.22 E+01
-1.19952 E+01
-1.679

5.2
Evolution of the damage

To observe the coherence of the evolution of the damage in the various elements of connection, one builds the graphics of the variable of damage compared to displacement imposed.

6
Summary of the results

With lower deviations than 5.0% compared to the experimental results obtained by Borderie & Pijaudier-pooch [bib1], one considers that the axisymmetric simulation of the test of wrenching is satisfactory. However, in order to test the stability of the law of behavior in combination with other laws (law MAZARS for the concrete, for example), it will be necessary to decrease the size of the steps of time by considering that the other laws are made normally for formulations into small deformations.

Organization (S): EDF-R & D /AMA, MMC

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.113

SSNA113 Notched sample in viscoplasticity

Summary:

This test models a notched sample into axisymmetric. The law of behavior used is the law VISC_ISOT_TRAC. Two loading rates are simulated:

· slow:
-
T = 1000s
that is to say
3
1
& = 10
-
S

· fast:
T = 0.001s
that is to say

3
1
& 10 -
=
S

The results (effort resulting and contraction from the ligament) are compared with the calculations carried out with the model
of viscous Rousselier (ROUSS_VISC) degenerated so that the evolution of porosity is negligible.

1
Problem of reference

1.1 Geometry

Ud
U
P8
P9
30
P2
4.8
P0

P1
3
5.4

The test-tube is axisymmetric, and only half of the test-tube is represented. Dimensions are given in millimetres.

1.2
Properties of material

Isotropic elasticity
Young modulus: E =
MPa

215000

Poisson's ratio: = 0.3
Traction diagram
Traction diagram
1100
1000
900
has

)
P
M
800
T
E
(
700
T
R
has
in
N
C
O
600
500
400
0
0,2
0,4
0,6
0,8
1
deformation

Coefficient for viscous law

MPa

6176
0 =

VISC_SINH
13
0 =
10

483
3.31131121

m = 6.76

9
-
Coefficients of the model of Rousselier
f0 = 510
used to obtain the solution of
D = 0.0001
reference

MPa

1575
1 =

1.3 Boundary conditions and loadings

Because of symmetry, vertical displacements are blocked for side P0P1 is DY=0.
Side P8P9 is subjected to a displacement imposed Ud = 1 Misters.
The loading is imposed using 500 steps of time in T=1000s for the slow case and T=0.001s for the fast case.

2 Reference solution

2.1 Results of reference

The reference solution is obtained by carrying out same calculation with the model of Rousselier in viscous version (COMP_INCR = "ROUSS_VISC", DEFORMATION = "PETIT_REAC") of which them
parameters were selected in order to return the effect of negligible porosity.
One compares the contraction of the ligament, i.e. displacement following X of the P1 node like resulting effort (REAC_NODA) on face P8P9. One is interested in 3 values of Ud displacement: 0.05mm, 0.5mm and 1mm.

3 Modeling
With

3.1
Characteristics of modeling

.
Modeling AXIS_SI

3.2
Characteristics of the grid

The grid is obtained by GIBI.

A number of nodes: 1440
A number of meshs: 445 QUAD8

3.3 Functionalities
tested

Orders

AFFE_MODELE AFFE
MODELING
AXIS_SI
DEFI_MATERIAU TRACTION

VISC_SINH

STAT_NON_LINE COMP_INCR
VMIS_ISOT_TRAC_V
DEFORMATION
SIMO_MIEHE

4
Results of modeling A

Fast speed

Identification displacement
Reference
Aster
% difference
U =0.05 mm
REAC_NODA on P8P9
3.43132 103
3.42727 103
-0.12

Uy in P1
-8.0411 10-3
-8.09476 10-3
0.67
U =0.5 mm
REAC_NODA on P8P9
3.93495 103
3.92628 103
-0.22

Uy in P1
-4.06758 10-1
-4.06649 10-1
-0.03
U =1 mm
REAC_NODA on P8P9
3.17328 103
3.16438 103
-0.28

Uy in P1
-8.89457 10-1
-8.89189 10-1
-0.03

Slow speed

Identification displacement
Reference
Aster
% difference
U =0.05 mm
REAC_NODA on P8P9
2.86423 103
2.86076 103
-0.12

Uy in P1
-1.52635 10-2
-1.52998 10-2
0.24
U =0.5 mm
REAC_NODA on P8P9
3.36223 103
3.35580 103
-0.19

Uy in P1
-4.19637 10-1
-4.19497 10-1
-0.03
U =1 mm
REAC_NODA on P8P9
2.73903 103
2.73204 103
-0.26

Uy in P1
-9.14404 10-1
-9.14069 10-1
-0.04
Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/04/005/A

5
Summary of the results

One obtains a good agreement of the results between the 2 models with lower deviations than 1%.
At the total level, one notes that to the maximum 4 iterations are necessary to obtain convergence.
On the level of the integration of the law of behavior, less than 10 iterations are necessary for
to obtain an accuracy of 10-9.

6/6

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Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-66/04/005/A

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.115

SSNA115 Wrenching of a rigid reinforcement with elements with discontinuity

Summary:

This case test has as an aim the numerical study of the wrenching of a rigid reinforcement embedded in a cylinder
hollow. Decoherence is modelled starting from elements with internal discontinuity with a cohesive law CZM_EXP
(see documentation [R7.02.12]) by using modeling AXIS_ELDI. To validate the results us
will support on the analytical solution developed in [bib3]. The interested reader will also be able y
to defer for a thorough study of this case test.

1
Problem of reference

1.1 Geometry
and
loading

Either a hollow roll length L, interior ray RF and external ray R. Or one
brace rigid circular section of ray RF embedded in its center. One notes I and E them
surfaces interior and external of the hollow roll (see [Figure 1.1-a]). The loading consists with
to apply, at the top of the rigid reinforcement, a displacement I
U.E.
I
Z *(U > 0) as well as a displacement*
no one on the external edge E.

=

U
With
R
0

I
U *= U.E.*

Z

L

I
E

E

Z

ur = 0
E

With
R

R F

R

Appear 1.1-a: Diagram of the field and loading

The assumption of an axisymmetric solution is made what enables us to restrict our study has one rectangular field 2D. Dimensions of the field are as follows
:
RF = 0.5mm, R = 5.5mm, L = 10mm. The loading on the rigid reinforcement will be taken into account by applying displacement imposed I
U ***ez*** *on all side I of the field 2D like one*
null displacement on the side E to take into account the embedding of the cylinder. Finally one imposes a radial displacement no one on the faces lower and higher of the field in order to avoid a singularity dependent on a change of boundary condition at points A and A (see [Figure 1.1-a]). These conditions in extreme cases will lead to a anti-plane solution (independent of Z) what makes it possible to obtain more
simply an analytical solution.

1.2 Parameters
Material

Values of the Young modulus, the Poisson's ratio, the critical stress and the tenacity of material are taken in the following way:

-1
E = 1.5 MPa, = 0, C = 1.1 Mpa, C
G = 0.9 N.mm

(They are of course values "tests" which does not correspond to any material in particular.)

2
Reference solution

The reference solution is an analytical solution draw from [bib3], it even inspired from a study unidimensional proposed in [bib1] and in a more general way being based on the approach energetics of the rupture suggested per G.A. Francfort and J.J. Marigo [bib2]. We will not return in the details of the calculation of this solution, we will present just the analytical value of the answer total of the structure: displacement imposed U according to the corresponding force F:

( )
F L

U F =
+ sign (F)
1
F
-

éq
2-1
2 R µ

F L
2 R

F L

where µ indicates the coefficient of Lamé (µ = E 2 here), the density of energy of cracking (see documentation [R7.02.12]) and where L = RF ln (R RF) is a length structural feature decisive for the brutal or progressive evolution of decoherence.

3 Modeling With

3.1 Characteristics of modeling

Simulation is carried out into axisymmetric. The elements with internal discontinuity allow to represent the crack along I. The latter have as a modeling AXIS_ELDI and one cohesive behavior CZM_EXP. The other elements of the grid are QUAD4 with one elastic behavior ELAS in modeling AXIS.

3.2 Characteristics of the grid

One carries out a grid structured in quadrangles of the field with 76 meshs in the height and 28 meshs in the radial direction. One lays out a layer of elements with discontinuity interns length of I using order CREA_MAILLAGE and key word CREA_FISS (see documentation [U4.23.02]). The orientation of the elements with discontinuity is carried out so that the direction normal is directed according to - ***er*** *(the tangential direction is thus according to -* ***ez****). The remainder of the field is divided into linear meshs QUAD4 (see [Figure 3.2-a]).*

ez

I
E
E

R

Elements with discontinuity

QUAD4

Appear 3.2-a: Grid of the field

3.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
CZM_EXP
AFFE_MODELE MODELING AXIS_ELDI
DEFI_MATERIAU RUPT_FRAG
SIGM_C

SAUT_C

CREA_MAILLAGE CREA_FISS

3.4 Sizes tested and results

The tangential constraint T along the crack (i.e in the elements with discontinuity) corresponds to opposite of the force F divided by the surface of decoherence: 2 R F L. Moreover while resting on form density of energy of surface defined in [R7.02.12] and according to [éq 2-1] one deduces following relation:
( )
L

T
= -
+ sign () C
G
U

T
T
ln
T
µ

éq

3.4-1

C
C

The latter will enable us to carry out tests summarized in the table below.

Size tested
Theory
Code_Aster
Difference (%)
Tangential constraint: VI7
7.69747E-01
7.6974726277784E-01
3.41E-05
PG1 of mesh MJ38
Moment: 6.00070E+00
Tangential constraint: VI7
4.34935E-01
4.3493490987033E-01
-2.07E-05
PG1 of mesh MJ38
Moment: 1.20004E+01
Tangential constraint: VI7
1.28483E-01
1.2848319446210E-01
1.51E-04
PG1 of mesh MJ38
Moment: 1.93334E+01
Displacement DY
1.57674E+00
1.5767415306566E+00
9.71E-05
N5 node
Moment: 1.20004E+01

4
Summary of the results

It is noted that the element with discontinuity allows a good prediction of decoherence, indeed this last develops in an identical way on all the height of the cylinder moreover the results *numerical are very close to the analytical solution. In addition modeling suggested allows to correctly reproduce the brutal or progressive evolution of cracking according to lengths characteristic L of the structure and C G C of the behavior. This last point is not highlighted here but the interested reader will be able to refer to [bib3] for more details.*

---

5 Bibliography

[1]
CHARLOTTE Mr., FRANKFURT G.A., MARIGO J.J. and TRUSKINOVSKY L.: Revisiting brittle fracture have year energy minimization problem: comparison of Griffith and Barenblatt surface energy models. Proceedings of the Symposium one "Continuous Ramming and Fracture " The dated science library, Elsevier, edited by A. BENALLAL, Paris, pp. 7-18, (2000).
[2]
FRANKFURT G.A. and MARIGO J.J.: Revisiting brittle fracture have year energy minimization problem. J. Mech. Phys. Solids, 46 (8), pp. 1319-1342 (1998).
[3]
LAVERNE J.: Energy formulation of the rupture by models of cohesive forces: numerical considerations theoretical and establishments, Thesis of Doctorate of the University Paris November 13, 2004.

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Code_Aster ®
Version
8.1

Titrate:
SSNA116 - Triaxial compression test with the model of Hoek-Brown modified
Date:
15/02/06
Author (S):
C. CHAVANT, V. GERVAIS
Key:
V6.01.116-A Page:
1/10

Organization (S): EDF-R & D /AMA, CS-SI

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.116

SSNA116 - Triaxial compression test with the model of Hoek-Brown modified into axisymmetric

Summary

This test makes it possible to validate the elastoplastic law of behavior of Hoek-Brown modified in

mechanics of
rocks. It is about a triaxial compression test for which calculations are carried out only on the solid part of the ground in
pure mechanics.
Two levels of containment are applied: 5 MPa and 12 MPa. The parameters end
, rup
and LMBO
are taken
equal (what returns to a constant voluminal plastic deformation): one can in this case calculate one analytical solution with the problem and thus to compare the results obtained with Code_Aster with this solution of
reference.
For reasons of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test.
modeling is axisymmetric.

Contents

1
Problem of reference

1.1 Geometry

One considers here a cube of dimension 1m × 1m × 1m.

y

1 m

.

D

· C

1 m

With
B
.
.

X

Z
1 m

Co-ordinates of the points (in m):

WITH B C
D
X 0 1 0.5
1
y 0 0 0.5
1
Z 0 0 0.5
1

1.2
Properties of material

Parameters of the elastic law of behavior:
E = 4500 MPa

= 0.3

Parameters of the law of Hoek-Brown modified:
rup
= 0.005
LMBO
= 0.017
2 end
(S) = 225 MPa2
C
2 rup
(S) = 482.5675 MPa2
C
end
(m) = 13.5 MPa
C
rup
(m) = 83.75 MPa
C
= 3 MPa
end
= 15°
rup
= 15°
LMBO
= 15°
= 3.3

4/10

1.3 Conditions
initial,
with the limits and loading

The test breaks up into two phases:

1) Initially, one brings the sample in a homogeneous state 0
0
0
= =. For
xx
yy
zz
that, the corresponding confining pressure is imposed on the front faces (Z = 1),
side right-hand side (X = 1) and higher (y = 1), while displacements are taken null on
the faces postpones (U
= 0), side left (U
= 0) and the lower (U
= 0).
Z z=0
X x=0
y y=0
2) Once the homogeneous state obtained, displacements are maintained blocked on the faces
back, side left and lower and the confining pressure are always imposed on
front faces and side right-hand side. A displacement is imposed on the higher face (U (T))
y
in order to obtain a deformation equalizes to 25% starting from the beginning of the second phase,
yy
by constant increments of deformation
= - 5
.
2nd - 4.
yy

2
Reference solution

2.1
Calculation of the reference solution

One places here in the case of a triaxial compression test for which the constraints of containment are applied in directions X and Z and for which the direction of imposed deformation is the direction y. One supposes moreover than the parameter is independent of the parameter of work hardening, i.e. end
rup
LMBO

=
=: it is then possible to calculate an analytical solution with the problem.
The criterion of plasticity and flow are written:

2

(
-) -

S

( ) -
m

(
)
- B
() 1
3
-
= 0
3
1
C
C
3

data base

3

p

-1
& = &
(-)
1 =

1

&
+1

p
p
1

2 +1
& = =
+
=
3
&
&
(
)

2
2

&
(
2 +)
1
p

3
& =
3 & =

&
+1

An increasing situation of loading is considered for which the preceding equations can *to be written in a nonincremental way:*

p
-1
p
p

2 +1
p

=

,
= =

3

,
=

1
+1
3
2

(
2 +)
1
+1

The relations of elasticity give:

p
1

0
2
- = (-) -
(
0
-)
1

1
1
1
3
3
E
E

p
1-

- =
(
0
-) - (
0
-)
3
3
3
3
1
1
E
E

---

i.e.: -1 1

0
2
-
= (-) -
(
0
-)
1
+1
1
1
3
3
E
E

2 +1
1-

-
=
(
0
-) - (
0
-)
3
2(+)
1
3
3
1
1
E
E
with
0
and 0
values of and at the beginning of the loading. It thus remains to calculate in
3
1
1

3
1
function of by using the criterion of plasticity to obtain, and
.
1
3

1st case:
rup

While noting
2
S () = A + A
and m () = B + B
where
B are given in
C
1
2
C
1
2
1
With,
2
With, 1
B and 2
reference material of the law of behavior, is solution of the polynomial of degree 2:
2
-1

- A - B
WITH - B
2
1
-

2
2
3
2

2
1
3 1

+

+ -
= 0 ,
+1
1

+1
2
1
2

E

E

with

in interval
[, 0 rup

].

2nd case: rup
LMBO

By taking again the notations of the reference material of the law of Hoek-Brown modified for A, D, C and data base

, is solution of the polynomial of degree 2:
3
2 rup
rup
has

-

-

3
2
1
D

(S
3
c)
(m
3
c)
C

1-

+ -
+ 1 -
+ +
+ 1
3
-
= 0

data base

+

data base
1

data base
E

1 E

E
E

3

3

3

with

in interval [rup LMBO

,
]

3rd case: LMBO
In this case, is constant:
1

= -
2 LMBO
(S) -
LMBO
(m) - LMBO
B
3
1

1
3
C
3
C

- data base

3

0
-
and
1
1
=
- .
1
E

2.2
Results of reference

Constraints (), () and () at point D.
xx
3
yy
1
zz
3
Displacements () and () at point D.
xx
3
yy
1

---

3 Modeling With

3.1 Characteristics of modeling

Axisymmetric modeling 2D

y

D

Z
X

Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = - MPa

5

(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0

3.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

3.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR
RELATION
"HOEK_BROWN"

4
Results of modeling A

4.1 Values tested

Localization Number Forced
Code_Aster
Solution of
Relative variation
of order
(MPa)
reference
Not D
12

-5 -5
0
xx
70

-5 -5
0
xx
12

-5 -5
0
zz
70

-5 -5
0
zz
12

-18.50 -18.50 0
yy
16

-22.5676 -22.5675778 0
yy
32

-30.8798 -30.8797526 0
yy
41

-34.9342 -34.9342281 0
yy
42

-32.9137 -32.9136722 0
yy
46

-26.8215 -26.8215156 0
yy
52

-22.7560 -22.7560224 0
yy
70

-20.7512 -20.721512 0
yy

Localization Number Deformation
Code_Aster
Solution of
Relative variation
of order
reference
Not D
12

0.9 E-3
0.9 E-3
0
xx

16
1.24644 E-3
1.24644 E-3
0
xx
32
3.48682 E-3
3.48682 E-3
0
xx
41
4.81373 E-3
4.81373 E-3
0
xx
42
5.22653 E-3
5.22653 E-3
0
xx
46
6.66403 E-3
6.66403 E-3
0
xx
52
8.27551 E-3
8.27551 E-3
0
xx
70
12.0186 E-3
12.01865 E-3
0
xx
12
-0.003 -0.003 0
yy
70
-0.0175 -0.0175 0
yy

Handbook of Validation

5 Modeling B

5.1 Characteristics of modeling

Axisymmetric modeling 2D

y

D

Z
X

Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0

= = = - MPa

12
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0

5.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

5.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR
RELATION
"HOEK_BROWN"

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HT-62/06/005/A

Code_Aster ®
Version
8.1

Titrate:

6 Results of modeling B

6.1 Values tested

Localization Number Forced
Code_Aster
Solution of
Relative variation
of order
(MPa)
reference
Not D
16

-12 -12 0
xx
80

-12 -12 0
xx
16

-12 -12 0
zz
80

-12 -12 0
zz
16

-30 -30 0
yy

20

-33.4287 -33.4287301 0
yy
36

-43.5095 -43.5095082 0
yy
49

-50.4230 -50.4230084 0
yy
52

-48.4776 -48.4775526 0
yy
56

-46.4936 -46.4935733 0
yy
60

-45.0479 -45.0479008 0
yy
70

-43.1175 -43.1174944 0
yy
80

-42.8023 -42.8023313 0
yy

Localization Number Deformation
Code_Aster
Solution of
Relative variation
of order
reference
Not D
16

1.2 E-3
1.2 E-3

0
xx
20
1.61504 E-3
1.61504 E-3
0
xx
36
3.66549 E-3
3.66549 E-3
0
xx
49
5.46863 E-3
5.46863 E-3
0
xx
52
6.265 E-3
6.265 E-3
0
xx
56
7.26131 E-3
7.26131 E-3
0
xx
60
8.19982 E-3
8.19982 E-3
0
xx
70
10.3653 E-3
10.36527 E-3
0
xx
80
12.3573 E-3
12.35726E-3
0
xx
16

-0.004 -0.004
0
yy
80
-0.02 -0.02 0
yy

7
Summary of the results

The results obtained make it possible to validate the model of Hoek-Brown modified integrated in Code_Aster in the particular case of a constant voluminal plastic deformation.

16/11/98
Author (S):
***J.M. PROIX**, L. LAMMERANT, J.P.DELSEMME*
Key: V6.01.301-A Page: 1/14

Organization (S): EDF/IMA/MMN, SAMTECH SA

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
V6.01.301 document

SSNA301 - Melts of pressurized thick tank

Summary:

This test consists in analyzing until the ruin, the spherotoric bottom of a thick tank subjected to a pressure
intern by taking of account the elastoplastic behavior of material and the nonlinear behavior of the structure.

Modeling is made with axisymmetric elements of type MEAXQU8.

One will test the taking into account here or not nongeometrical linearities and the use of one or two assumptions material.

1
Problem of reference

1.1 Geometry

With
L = 50 ''
B

1.2
Material properties

Elastoplastic material without work hardening

E = 3.E+07 MPa
= 0.3
y = 3.E+04 MPa

1.3
Boundary conditions and loadings

Not a: ux =0
Not b: uy =0.

The setting charges some (= pressure interns) following is applied:

p = 1.737 p0 (vicinity of the ruin) with p0 = 658.257 MPa (fine of the linear mode)

The load p is applied in 50 identical increments.

2
Reference solution

2.1
Method of calculation used for the reference solution

Calculation finite element with the SAMCEF software Version 7.0 (Mecanl).

2.2
Reference solution

Variation of the tensions on the skins along the meridian section for an internal pressure p0 [bib2]

Variation of the tensions on the skins along the meridian section in the vicinity of the ruin for a pressure pmax interns [bib2]

Version
5.0

Titrate:
SSNA301 Melts of pressurized thick tank

Date:
16/11/98
Author (S):
J.M. PROIX, L. LAMMERANT, J.P.DELSEMME
Key: V6.01.301-A Page: 4/14

Variation of the azimuth constraint on the higher skin along the meridian section
in the vicinity of the ruin for a pressure pmax interns. Geometrical linear calculation.

30

p
20
10
0
0,0
, 9
, 9
, 8
, 3
, 7
5,0
-10
12
25
38
51
63
10
-20
-30
-40
Meridian length

Variation of the azimuth constraint on the lower skin along the meridian section
in the vicinity of the ruin for a pressure pmax interns. Geometrical linear calculation.

30

p
20
10
0
0
8
0,
,
7
,
4
,
1
,
3
,
6
12
25
38
49
60
1,
10
-10
-20
Meridian length

Handbook of Validation
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Code_Aster ®
Version
5.0

Titrate:

SSNA301 Melts of pressurized thick tank

Variation of the azimuth constraint on the skin higher along the meridian section than vicinity of the ruin for a pressure interns pmax. Geometrical nonlinear calculation.

30

p
20
10
0
0
, 9
, 9
, 8
, 3
, 7
0,
12
25
38
51
63
4,9
-10
10
-20
-30 node 1
node 73
node 137
Meridian length

Variation of the azimuth constraint on the lower skin along the meridian section in the vicinity of the ruin for a pressure pmax interns. Geometrical nonlinear calculation.

30

p
20
10
0
0
8
0,
, 7
, 4
, 1
, 3
, 6
12
25
38
49
60
1,
10
-10
-20
node 1
node 27
node 57
node 87
node 137
Meridian length

Z
Meridian length
higher skin
Node
Position 1
There are 68 elements
(with nodes mediums)
and 137 nodes along
skin
skin
lower
Node
Position 137

Discretization used for the reference solution. Definition of the axes

Geometrical nonlinear calculation: pressure = pmax

Skin Length
meridian
Position node

(inch)
p
0.0 1
26.223
Higher 46.298

73 -26.688
137.9 137
24.103
0.0 1
25.231
16.491 27
27.909
Lower 35.518
57 -12.711
52.707 87
-8.1652
134.76 137
25.103

Geometrical linear calculation: pressure = pmax

Skin Length
meridian
Position node

(inch)
p
0.0 1
26.2
Higher 45.1
71 -30.7

138 137
24.0
0.0 1
25.231
22.833
37
29.899
Lower 32.981
53 -16.127
52.707
87
-13.756
134.76 137
25.008

Field of displacement (not A, lower skin)

Calculation… geometrical meridian Length Position
Pressure Displacement
UZ
(inch)
node
(inch)
Linear 0.0
1
0.5
pmax
0.100945
0.0
1
pmax
0.370468
Nonlinear
0.0
1
0.5 pmax
0.0990524
0.0
1
pmax
0.244347

2.3
Uncertainty on the solution

Uncertainty lower than 2% (linear mode), lower than 5% (elastoplastic mode).

2.4 References
bibliographical

[1]
LARSEN, P.K., POPOV, E.P., Elastic-plastic analysis of thick-walled presses vessels with sharp discontinuities, Trans. ASME Applied Mechanics, pp 1016-1019, 1971
[2]
NYSSEN, C., Modeling by finite elements of the nonlinear behavior of structures aerospace, thése of doctorate, University of Liege, 1979
Handbook of Validation
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HI-75/01/010/A

---

3 Modeling
With

3.1
Characteristics of modeling A

Nonlinear material + linear geometrical

3.2
Characteristics of the grid

A number of nodes:
2197
A number of meshs and types: 544 MEAXQU8 (diagram of integration 3 X 3) + 68 SEG3 (68 meshs on the length (30 on the part with a radius of 100 '', 20 on the part with
a radius of 20 '' and 18 on the right part) and 8 on the thickness)

3.3 Functionalities
tested

Orders

Keys
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI

[U4.23.01]

SY

STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_LINE
[U4.32.01]

DEFORMATION
SMALL

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HI-75/01/010/A

Code_Aster ®
Version
5.0

Titrate:
SSNA301 Melts of pressurized thick tank

Date:
16/11/98
Author (S):
***J.M. PROIX**, L. LAMMERANT, J.P.DELSEMME*

Key: V6.01.301-A Page: 9/14

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster
% difference

Long SIZZ/p Skin sup. Merid=0. p=pmax
26.2
26.218
0.071
Long SIZZ/p Skin sup. Merid=45.1 p=pmax
-30.7
-30.531
-0.553
Long SIZZ/p Skin sup. Merid=138 p=pmax
24.0
24.011
-0.553
Long SIZZ/p Skin inf. Merid=0. p=pmax
25.231
25.229
-0.553
Long SIZZ/p Skin inf. Merid=22.833
29.899 29.957 -0.553
p=pmax
Long SIZZ/p Skin inf. Merid=32.981
-16.127 -16.294 -0.553
p=pmax
Long SIZZ/p Skin inf. Merid=52.707
-13.756 -13.699 -0.553
p=pmax
Long SIZZ/p Skin inf. Merid=134.76
25.008 25.012 -0.553
p=pmax

DY node 2313 with p=0.5 pmax
0.100945
0.100946
0.002
DY node 2313 with pmax
0.370468
0.370470
0.001

4.2 Parameters of execution

Version: 3.09

Machine: CRAY

System:

Obstruction memory:
16 Megawords
Time CPU To use:
360.52 seconds

5 Modeling

B

5.1
Characteristics of modeling B

Nonlinear material + nonlinear geometrical

5.2
Characteristics of the grid

A number of nodes:
2197
A number of meshs and types: 544 MEAXQU8 (diagram of integration 3 X 3) + 68 SEG3 (68 meshs on the length (30 on the part with a radius of 100 '', 20 on the part with
a radius of 20 '' and 18 on the right part) and 8 on the thickness)

5.3 Functionalities
tested

Orders

Keys
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI

[U4.23.01]

SY

STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_LINE
[U4.32.01]

DEFORMATION
PETIT_REAC

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster
% difference

Long SIZZ/p Skin sup. Merid=0. p=pmax
26.223
26.299
0.025
Long SIZZ/p Skin sup. Merid=45.298
-26.688 -27.156
1.756
p=pmax
Long SIZZ/p Skin sup. Merid=137.9 p=pmax
24.103
24.018
-0.352
Long SIZZ/p Skin inf. Merid=0. p=pmax
25.231
25.236
0.021
Long SIZZ/p Skin inf. Merid=16.491
27.909 28.086 0.638

p=pmax
Long SIZZ/p Skin inf. Merid=35.518
-12.711 -13.095
3.026
p=pmax
Long SIZZ/p Skin inf. Merid=52.707
-8.1652 -8.426
3.196
p=pmax
Long SIZZ/p Skin inf. Merid=134.76
25.103 25.018 -0.337
p=pmax
DY node 2313 with p=0.5 pmax
0.099052
0.099191
0.141
DY node 2313 with pmax
0.244347
0.246979
1.077

6.2 Parameters
of execution

Version: 3.09

Machine: CRAY

System:

Obstruction memory:
16 megawords
Time CPU To use:
456.41secondes

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
HI-75/01/010/A

Code_Aster ®
Version
5.0

7 Modeling C

7.1 Characteristics of modeling C

All the meshs have a nonlinear behavior material, except the 8x5 meshs of the part lower of the structure (this part does not plasticize) which has a linear behavior material.

A geometrical linear analysis is carried out.

7.2 Characteristics of the grid

A number of nodes:
2197
A number of meshs and types: 544 MEAXQU8 (diagram of integration 3 X 3) + 68 SEG3 (68 meshs on the length (30 on the part with a radius of 100 '', 20 on the part with a radius of 20 '' and 18 on the right part) and 8 on the thickness)

7.3 Functionalities tested

Orders

Keys
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI

[U4.23.01]

SY

STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_LINE
[U4.32.01]

DEFORMATION
SMALL

8 *Results of modeling C*

8.1 Values *tested*

Identification Reference
Aster
% difference

Long SIZZ/p Skin sup. Merid=0. p=pmax

26.2
26.218
0.071
Long SIZZ/p Skin sup. Merid=45.1 p=pmax
-30.7
-30.531
-0.553
Long SIZZ/p Skin sup. Merid=138 p=pmax
24.0
24.011
-0.553
Long SIZZ/p Skin inf. Merid=0. p=pmax
25.231
25.229
-0.553
Long SIZZ/p Skin inf. Merid=22.833
29.899 29.957 -0.553
p=pmax
Long SIZZ/p Skin inf. Merid=32.981
-16.127 -16.294 -0.553
p=pmax
Long SIZZ/p Skin inf. Merid=52.707
-13.756 -13.699 -0.553
p=pmax
Long SIZZ/p Skin inf. Merid=134.76
25.008 25.012 -0.553
p=pmax
DY node 2313 with p=0.5 pmax
0.100945
0.100946
0.002
DY node 2313 with pmax
0.370468
0.370470
0.001

8.2 Parameters of execution

Version: 3.09

Machine: CRAY

System:

Obstruction memory: 16 megawords
Time CPU To use:
196.02 seconds

9
Summary of the results

The results provided by Aster concerning modelings A and C are close to the reference (variation < 0.6%). Moreover, one finds well the same results for modelings A and C; what is normal because the lower part remains elastic.

For modeling B, variations of results between Code_Aster and reference (the SAMCEF software) 3.3% reach and come owing to the fact that nonthe geometrical linearities are treated in manner different in Code_Aster (by order "PETIT_REAC") and in the SAMCEF software.

Titrate:
SSNA302 - Plate circular subjected to pressure

Date:
03/01/00
Author (S):
***E. LORENTZ**, L. LAMMERANT, J.P.DELSEMME*
Key: V6.01.302-A Page: 1/10

Organization (S): EDF/IMA/MMN, SAMTECH SA

Handbook of Validation
V6.01 booklet: Nonlinear statics into axisymmetric
Document: V6.01.302

SSNA302 - Plate circular simply supported
subjected to pressure

Summary:

This test consists in applying a transverse pressure to a circular, simply supported plate and composed of an elastic material. It is intended to study the taking into account of nonthe geometrical linearities
particularly in the absence of initial curve when the transverse stiffness is only due to the effect of plate.

Modeling is made with voluminal elements of type HEXA20 and PENTA15 and elements surface of type QUAD8 and TRIA6 for the application of the pressure.

The reference is software the SAMCEF software. One has for information the results resulting from the theory of the hulls thin.

Order COMP_ELAS with option "GREEN" is compared with COMP_INCR with option "PETIT_REAC".

Handbook of Validation
V6.04 booklet: Nonlinear statics into axisymmetric
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNA302 - Plate circular subjected to pressure

Date:
03/01/00
Author (S):
***E. LORENTZ**, L. LAMMERANT, J.P.DELSEMME*
Key: V6.01.302-A Page: 2/10

1
Problem of reference

1.1 Geometry

thickness H
pressure p
With
B
ray R
center
symmetry

1.2
Material properties

Isotropic elastic material:

E = 200000 Mpa
= 0.3

1.3
Boundary conditions and loadings

Not b:
ux =0

uy =0.

One applies a transverse pressure p to the plate: p = 222.72 N/mm2. This pressure corresponds with an arrow w0 of 1.5 Misters.

Ray R = 10 mm
Thickness H = 1 mm

The problem is axisymmetric.
Handbook of Validation
V6.04 booklet: Nonlinear statics into axisymmetric
HT-66/02/001/A

2
Reference solution

2.1
Reference solution

The reference is software the SAMCEF software. , For information, in the paragraph [§2.2], they are presented
theoretical results related to an assumption of thin the hull type. Then, the results are presented obtained with the SAMCEF software according to whether one chooses an assumption of thick the hull type or type
volume. It is the latter which is taken into account for the evaluation of Code_Aster.

2.2
Analytical solution and results of reference

The following formula gives the arrow w0 to the center of the plate:

W
W3

LP R 4
0

+ A
0
H

H = E H with A = 1.852 and B = 0.696

The constraints with mid thickness are worth:

2
=
w0
rr
R E r2 2

w0
= T E r2

The constraints in lower skin are worth

W H
, =
0
rr
R E r2
W H
,
0
= T E r2

The coefficients are worth:

In the center of the plate:

=
R
T = 0.905
=
R

T = 1.778

At the edge of the plate:

R = 0.610
T = 0.183
R = 0
T = 0.755

For a pressure of 222.72 MPa, the arrow w0 is worth 1.5 mm and one obtains the following constraints:

Position
rr (MPa)
(MPa)
rr `(MPa)
`(MPa)
Center
4072.5 4072.5 5334.0 5334.0

These results correspond to an assumption of thin hull.

The following table shows the results obtained by the SAMCEF software for a modeling of the hull type
thick and of volume type.

Identification Hull

thick
Volume

Arrow w0 (mm)
1.43041 E3
1.441838 E3
SIXX (MPa) center, miepaissor
3899.88
3850.88
SIYY (MPa) center, miepaissor
3899.53
3850.91
SIXX (MPa) center, skin inf
8085.81
8133.60
SIYY (MPa) center, skin inf
8083.32
8133.65
SIXX (MPa) R =R/2, miepaissor
3596.91
3512.79
SIYY (MPa) R =R/2, miepaissor
3056.37
2947.55
SIXX (MPa) R =R/2, skin inf
7798.18
7815.73
SIYY (MPa) R =R/2, skin inf
7264.69
7307.04

The values of the constraints are values by element extrapolated with the nodes.

The results obtained with the SAMCEF software are close one to the other.

Variations of results between the mean theory hull and calculation finite element using the assumption hull thick are important.

One chooses to take as reference the voluminal calculation obtained by the SAMCEF software.

2.3 References

bibliographical

[1]
Theory of Plates and Shells, Timoshenko S.P., 2nd edition, p 412

---

3 Modeling
With

3.1
Characteristics of modeling A

Face 1:
Fixing on X

Appear 3.1-A: Face 2: Fixing on y

Only one quarter of plate is modelled. One introduces conditions of symmetry on the two faces shown above.

Moreover one fixes according to X, y, Z all the nodes of the edge located at semi thickness.

In order to most accurately represent the assumptions of thin hull, constraints are introduced linear on the degrees of freedom of the nodes of the edge. Those Ci are written:

for two nodes I and J located on both sides of the average layer:

ui + uj = 0
VI + vj = 0

where U and v indicate displacements along axes X and Y.

The syntax used in the data file of Code_Aster is as follows:

LIAISON_DDL (Node: Nor Nj), DDL: ("DX", "DX"), COEF_MULT: (1, 1), COEF_IMPO: 0

One applies the pressure linearly by using 6 increments.

3.2
Characteristics of the grid

A number of nodes:
2091
A number of meshs and types:
368 HEXA20, 28 PENTA15

92 QUAD8, 7 TRIA6

3.3 Functionalities
tested

Orders
Keys
DEFI_MATERIAU ELAS

[U4.23.01]
STAT_NON_LINE COMP_ELAS RELATION ELAS
[U4.32.01]

DEFORMATION

EXCIT
TYPE_CHARGE
“SUIV”

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster
% difference

Arrow w0 (mm)
1.441838E3
1.43823E3
-0.250
SIXX (MPa) center, miepaissor
3850.9
3901.8

1.322
SIYY (MPa) center, miepaissor
3850.9
3901.8
1.323
SIXX (MPa) center, skin inf
8133.6
8341.0
2.550
SIYY (MPa) center, skin inf
8133.6
8341.1
2.549
SIXX (MPa) R =R/2, miepaissor
3512.8
3513.1
0.010
SIYY (MPa) R =R/2, miepaissor
2947.5
3016.6
2.344
SIXX (MPa) R =R/2, skin inf
7815.7
7885.4
0.892
SIYY (MPa) R =R/2, skin inf
7307.0
7439.5
1.813

4.2 Remarks

One obtains the same precision on the results by using only one increment of loading. Time CPU is then 736.19 seconds.

4.3 Parameters of execution

Version: 5.02

Machine: SGI ORIGIN 2000 - R12000

Obstruction memory: 64 megawords
Time CPU To use:
475 seconds

5 Modeling
B

5.1
Characteristics of modeling B

Idem modeling A, but by treating nonthe geometrical linearities by order COMP_INCR
option PETIT_REAC.

5.2
Characteristics of the grid

A number of nodes:
2091
A number of meshs and types: 368 HEXA20, 28 PENTA15

92 QUAD8, 7 TRIA6

5.3 Functionalities

tested

Orders
Keys
DEFI_MATERIAU ELAS

[U4.23.01]
STAT_NON_LINE COMP_INCR RELATION ELAS
[U4.32.01]

DEFORMATION
“PETIT_REAC”

EXCIT
TYPE_CHARGE
“SUIV”

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster
% difference

Arrow w0 (mm)
1.441838E3
1.3692E3
-5.036
SIXX (MPa) center, miepaissor
3850.9
4219.3
9.568
SIYY (MPa) center, miepaissor
3850.9
4219.4
9.569

SIXX (MPa) center, skin inf
8133.6
7950.5
-2.251
SIYY (MPa) center, skin inf
8133.6
7950.5
-2.252
SIXX (MPa) R =R/2, miepaissor
3512.8
3838.4
9.268
SIYY (MPa) R =R/2, miepaissor
2947.5
3314.2
12.440
SIXX (MPa) R =R/2, skin inf
7815.7
7593.9
-2.839
SIYY (MPa) R =R/2, skin inf
7307.0
7123.7
-2.509

6.2 Remarks

One notes an important difference between the reference solution and the solution provided by Code_Aster.
It is checked that this variation tends towards 0 when one increases the number of increments.

6.3 Parameters of execution

Version: 5.02

Machine: SGI ORIGIN 2000 - R12000

Obstruction memory: 64 megawords
Time CPU To use: 924 seconds

---

7 Modeling C

7.1 Characteristics of modeling C

Z
With
B
R

- *axisymmetric modeling*
- *boundary conditions:*

B:
DX = 0
DY = 0

As for modeling A (3D), of the linear constraints are introduced for better representing a kinematics of hull. They relate to the nodes of the edge external of the disc. If I and J indicate 2 nodes on both sides of the average layer, they are written:

U + U = 0
where U
I
J
indicate radial displacement

7.2
Characteristics of the grid

A number of nodes:
149
A number of meshs and types: 40 QUAD8, 10 SEG3

7.3 Functionalities
tested

Orders
Keys
DEFI_MATERIAU ELAS

[U4.23.01]
STAT_NON_LINE COMP_ELAS RELATION ELAS
[U4.32.01]

DEFORMATION
"GREEN"

EXCIT
TYPE_CHARGE
"SUIV"

8
Results of modeling C

8.1 Values
tested

Identification	*Reference*	*Aster*	*% difference*
Arrow w0 (mm)	*-1.430*	*-1.438*	*0.5*
SIXX (MPa) center, miepaissor	*3900*	*3909*	*0.2*
SIZZ (MPa) center, miepaissor	*3900*	*3896*	*0.1*

8.2 Remarks

In the absence of an axisymmetric calculation of reference the SAMCEF software, one bases oneself on calculation in hull thick (always the SAMCEF software) and one compares only the arrow and the constraints with the center with mid-thickness.

8.3 Parameters

of execution

Version: 5.02

Machine: SGI ORIGIN 2000 - R12000

Obstruction memory: 64 megawords
Time CPU To use: 12 seconds
Handbook of Validation
V6.04 booklet: Nonlinear statics into axisymmetric
HT-66/02/001/A

9
Summary of the results

The performances in time calculation and precision of the results are satisfactory while using order COMP_ELAS option "GREEN". On the other hand, treatment of nonthe geometrical linearities
by order COMP_INCR option "PETIT_REAC" provides results rather far away from reference solution by adopting a discretization in 6 steps of time which leads to costs in already important times calculation.

The following table recapitulates the performances (computing time and iteration count) between Code_Aster and the SAMCEF software. The number of imposed increments is identical in both cases (6 increments).

GREEN

PETIT_REAC
(A)
(B)
Iteration count Code_Aster 27 67
Time CPU Code_Aster (in S)
470
5108
Iteration count the SAMCEF software
26
-
Time CPU the SAMCEF software (in S)
403
-

Document: V6.02.100
SSNL100 - Pose of a canton of line with two
equal ranges
Summary:
This test simulates the operation of installation of a cable with two ranges. The cable is fixed at the one of its ends, passes
on a fast pulley towards the other end and rests in its medium on a pulley placed at the bottom of a suspension
mobile. One adjusts the arrow of the ranges in "giving" more or less cable to the level of the fast

pulley.
Interest: to test the elements of cable and cable-pulley and their operation in the operator STAT_NON_LINE [U4.32.01].
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/96/064 - Ind A

---

1 Problem of reference

1.1 Geometry

0
P1
P2
R2
C
X
0.
100.
200.
220.
100.
Z
0.
0.
0.
0.
10.
Co-ordinates of the points (in m)

Names and position of the nodes (medium of front range poses):

· range of left: N6 and X = 48.50 m

· range of right-hand side: N19 and X = 160.50 m

1.2 Material properties

Linear weight of the cable: 30N/m

Axial rigidity of the cable (produced Young modulus by the surface of the cross-section): 5 X 107N

1.3 Boundary conditions and loadings

The points O, C and P2 are fixed.

The cable, fixed out of O, is pressed on two pulleys. First is attached at the lower end P1 of suspension fixed out of C. second is fixed at P2.
The cable is subjected to its weight and one gives him arrow by moving his right end of 10 m of R2 with R'2.
The position of the points Q1, R1 and Q2 is not imposed, but one must make so that with the course pose the P1 pulley remains on the length of cable Q1 R1.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The arrow of reference relates to an inextensible cable of 105 m on a range of 100 Mr. It is obtained by the solution of a transcendent equation [bib2].

2.2 Results of reference

The arrow of reference is 13.93 m, equal for each range.

2.3 Uncertainty on the solution

Semi-analytical solution.

2.4 References bibliographical

[1] Mr. AUFAURE, “a finite element of cable-pulley”, Document R3.08.05 (1996).
[2] H. MAX IRVINE, “Cable Structures”, The MIT Press (1981).

---

3 Modeling With

3.1 Characteristics of modeling

· 10 elements of cable
MECABL2 between O and Q1, carried by meshs SEG2;
· 1 element
MEPOULI passing by the pulley P1 and carried by mesh SEG3
Q1 P1 R1;
· 9 elements
MECABL2 between R1 and Q2;
· 1 element
MEPOULI on Q2 P2 R2;
· 1 element
MECABL2 on suspension P1C.

3.2 Characteristics of the grid

A number of nodes: 25
A number of meshs and types: 20 meshs SEG2 and 2 meshs SEG3

3.3 Functionalities tested

Orders
Keys
STAT_NON_LINE
COMP_ELAS
DEFORMATION
"GREEN"
[U4.32.01]
EXCIT
TYPE_CHARGE
"SUIV"

3.4 Remarks

On the basis of a horizontal rectilinear cable in weightlessness, one applies gravity while increasing length of the cable between O and P2 of 10m by the displacement of R2 in R'2 (R2 R'2 = 10 m). Like not tended right cables do not have rigidity for the transverse loads, one cannot apply
from the start the loading case preceding bus one would lead to a singular system of equations.
Calculation is thus done in 2 stages:

· one puts the cables in prevoltage by applying a tension to the cable itself in R2 and to the suspension in P1 (one suggests taking tensions of 10.000 NR);

· one makes a continuation on the preceding situation of balance by applying gravity and it displacement R2 R'2. The load of gravity will be declared of type “SUIV”, because of elements MEPOULI of which the 2 parts are variable length.

4

Results of modeling A

4.1 Values

tested	**Results**		
	Reference	**Aster**	**% difference**
Arrow of the range of N6 left	13.93 m	13.96 m	0.23
Arrow of the range of N19 right-hand side	13.93 m	13.89 m	+0.25

4.2 Parameters of execution

Version: NEW 3.06.11
Machine: CRAY C90
System: UNICOS 8.0
Obstruction memory: 8 megawords
Time CPU To use: 22 seconds

5
Summary of the results

This test makes it possible to make sure that the evolutions of Aster do not generate regressions for elements of cable and cable-pulley, like for the following loads of the order STAT_NON_LINE.

Organization (S): EDF/EP/AMV

Handbook of Validation

V6.02 booklet: Nonlinear statics of the linear structures

Document: V6.02.101

SSNL101 - Non-linear behavior of an element
of conductor arrangement

Summary:

One considers in this test, 1 discrete element with 2 nodes subjected to a transverse effort in static analysis not
linear.
The element has a behavior governed by a nonlinear relation expressed in effort and displacement one-way in transverse and local direction *Y*.
The interest of the test is to simulate in an exhaustive way the ways of possible loading, in load and discharge, in each field of the relation of behavior: rubber band, plastic and ultimate.
The reduced dimension of the problem with 1 unknown factor (the transverse displacement of the end) makes it possible to have
as solution the result d'1 algebraical expression found exactly by Aster.

---

1 Problem of reference

1.1 Geometry

1 discrete element of null size to 2 nodes.
Locate local = total reference mark.
1 matrix of rigidity “K_TR_D_L” affected by defect:
1.6 N/m in translation, 1.9 N/m in rotation.
The characteristics of rigidity according to the local direction *y* (here with the total axis Y equalizes) are modified by

a relation of behavior of the type “ARMS” in effort-displacement introduced by a material characteristic.

1.2

Material properties

Dependent on an incremental behavior “ARMS” with 5 parameters: *of* (key word “DLE”) = 0.048 m, *dl* (“DLP”) = 0.7 m, *Kel* (“KYE”) = 1.67 E4 N/m, *Kpl* (“KYP”) = 2.9 E3 N/m, *KG* (“KYG”) = 1 E6 N/m.
“*of*” displacement elastic range limits,
“*dl*” displacement limits plastic range,
“*Kel*” slope of the elastic range,
“*K pl*” slope of the plastic range,
“*KG*” ultimate slope,
Behavior of an arm of armament in longitudinal request
F
KG
Fm
K
L
pl
E
Kel
of
D
dl
D
of = 0.048 m, *dl* = 0.7 m, *It* = 800 NR, *Fm* = 2800 NR
One-way behavior in force-displacement with 1 internal variable: *D* - *D*
p
E defined by
5 parameters: *of*, *dl*, *Kel*, *Kpl* and *KG*.
Affected with a discrete element with 2 nodes.

1.3

Boundary conditions and loadings

Embedding in one of the 2 nodes.
Force imposed in the local direction *y* (= total *Y*) on the second node, by increments of charge. A unit increment being worth 500 NR.

1.4 Conditions

initial

Internal displacements, efforts and variables null.

2 Reference solution

2.1 Method of calculation used for the reference solution

One reproduces on an element a course of loading in each of the 3 fields (rubber band, plastic, limits) of an one-way relation of behavior (local direction *y*). Parameters are described on joined figure 1.

The way of load comprises 12 stages thus definite:

10
Fy
9
4
11
3
2
8
12
5
7
1
6
D = Uy

2.2 Results of reference

Direct calculations on the curve limits relation of behavior:

F
= *K U*
if *U*

< *D*
y
el

y
y
E
F
= *K D* + *K*
-
if

y
el
E
pl (*U*
D
y
E)
Uy [*D*, *D*
E
L]
Vari = *U* - *D*
y
E
Varimax = *D* - *D*
L
E
F
= *K D* + *K*
-
+
-
if Vari =
y
el
E
pl (*D*
D
L
E)
kg (*U*
D
y
L)
Varimax
2.3

Uncertainty on the solution
Exact solution: Imposed *Fy* and *Uy* deduce directly from the relations in [§2.2].

2.4 References
bibliographical

[1]
Note HM-77/94/368, G. DEVESA. “Dynamic Study of rupture of driver and discharge of white frost on an experimental line with Medium Average ".

---

3 Modeling
With

3.1
Characteristics of modeling

An element DIS_TR_L with 2 nodes of null size (idem [§1.1]).
A node N2: all is blocked.
A N3 node: one imposes *Fy* by step of 500 NR with the chart of time:

T	0.	4.	6.	10.	12.
F (T)	0.	4.	2.	6.	4.

3.2

Characteristics of the grid
1 SEG2.
2 nodes.
3.3 Functionalities
tested
Orders
Key word factor
Key word
Key
DEFI_MATERIAU
ARM
KYE, DLE, DYP,
[U4.23.01]
DLP, KYG
STAT_NON_LINE
COMP_INCR
RELATION:
[U4.32.01]
“WEAPON”

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference

Uy displacement: N3 node, Order 2 (*F* =
y
)
1000
1.1641 101
idem
0
Uy displacement: N3 node, Order 8 (*F* =
y
)
2000
4.6124 101
idem
0
Uy displacement: N3 node, Order 10 (*F* =
y
)
3000
7.0030 101
idem
0
Variable interns 1: Order 2 (*F* =
y
)
1000
6.8414 102
idem
0
Variable interns 1: Order 8 (*F* =
y
)
2000
4.13241 101
idem
0
Variable interns 1: Order 10 (*F* =
y
)
3000
0.52 101
idem
0

4.2 Remarks

General:
The behavior “WEAPON” is usable also in non-linear dynamic Analysis but is not tested.

4.3 Parameters of execution

Version: 3.03.07
Machine: CRAY C90
Obstruction memory: 8 MW
Time CPU To use: 9.1 seconds

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/96/041 - Ind A

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5 Summary of the results

The reduced dimension of the problem makes it possible to have only one unknown factor, transverse displacement *Uy*
dependent on the internal variable, calculable exact solution by an algebraical expression and found by Aster
with the identical one.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.102

SSNL102 - Non-linear behavior of one
assembly of angles

Summary:

One considers in this test a discrete element with 2 nodes subjected to a two-dimensional loading of traction and
from moment requesting the degrees of freedom in translation and rotation.

The analysis is static with a nonlinear relation of behavior incrémentable expressed by one adimensional internal variable combining the two-dimensional efforts and generalized displacements.

The relation of behavior includes/understands 2 mechanisms respectively associated with 2 curves being connected
between them by a concavity.

The interest of the test is to simulate in an exhaustive way the possible ways of loading in load and discharge and in particular the transition between mechanisms.

The results correspond to the numerical solution in displacements of the problem with 1 unknown factor (the variable of
mechanism running) obtained by the inversion of the curve of the relation of behavior in each one of 2 mechanisms compared to an imposed force.

1
Problem of reference

1.1 Geometry

1 discrete element of null size to 2 nodes.

Locate local = total reference mark.

1 matrix of rigidity "K_TR_D_L" affected by defect (partner with 1 element DIS_TR_L)

1.6 N/mm in translation, 1.9 N/mm in rotation.

The characteristics of rigidity according to local directions' X and rotation around are modified there by a relation of behavior of the type "ASSE_CORN" introduced by a characteristic material.

1.2
Material properties

Dependent on an incremental behavior "ASSE_CORN" including/understanding 2 mechanisms requiring each one
5 characteristic parameters (see [1.2-a] and [1.2-b]):

N1 = 10.050 NR, M1 = 150.000 N.mm, U1 = 1 mm, 1 = 6,7 10-2, C1 = 0,95

N2 = 50.000 NR, m2 = 750.000 N.mm, U2 = 10 mm, 2 = 0,01, C2 = 0,95

Normal effort
Moment/y
SLU

SLU
mechanism 1
mechanism 2
mechanism 1
mechanism 2
SLF
SLF
U
butted
butted
1
Displacement

Rotation
1
0
0
0
U
0
2
2
Appear 1.2-a: Mechanisms of assembly in normal effort and moment

(
R p) =
N2 + m2
N
U&
p& =
(
R p)
R

m
&r

N
m
N = Nx/NR
1
m = My/M
N m
Ur = U/U
R =/
criterion
kinematics
Ur
1

R

Appear 1.2-b: Relation of behaviour of assembly

&p =
&
U2 + &2
R
R

- C p 2
1

p = R-1 (p)
'
'

=

(HP) '=

c2 1 - p'

1.3
Boundary conditions and loadings

Embedding in one of the 2 nodes.

Force imposed in direction X per unit of 1.000 NR and Moment imposed around axis Z by unit of 3.000 NR. the whole on the second node, by increments of load.

1.4 Conditions
initial

Internal displacements, efforts and variables null.

2
Reference solution

2.1
Method of calculation used for the reference solution

One reproduces on an element a course of loading (growing and in discharge) in each one of

2 mechanisms of assembly of the bidirectional relation of behavior (effort according to the direction X and moment around the axis y). This one expresses the displacements reduced compared to the efforts
reduced. The mechanisms and the law of behaviour of assembly are described on the figures [Figure 1.2-a] and [Figure 1.2-b].

The way of load expressed in (p, (
R p
1
1) comprises 12 stages thus definite:

R (p
1)
4
8
3
7
5
2
1
9
6
Mechanism 1
Mechanism 2
p1 = 1
10
p 1
11
12

2.2
Results of reference

To find the correspondence variable-criterion of the curve limits relation of behavior.

2.3
Uncertainty on the solution

Numerical solution of the inversion of a non-linear relation. There is an unknown factor at the same

time: the variable
intern of the mechanism. The other values result some. Calculation is direct for the 1st mechanism, incremental for the second (discussion in the synthesis in [§5]).

2.4 References
bibliographical

[1]
P. PENSERINI: "Modeling of the assemblies bolted in the webmasts". Note
HM-77/93/287
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/05/005/A

---

3 Modeling
With

3.1
Characteristics of modeling

An element DIS_TR_L with 2 nodes of null size (idem 1.1).

A node N2: all is blocked.
A N3 node: one imposes Fx by steps of 1.000 NR and My by steps of 3.000 N.mm with the chart of time:

T 0. 1. 2. 3. 4. 6. 8. 10.
11. 12.
0. 6. 7 17. 40. 20. 42 0. -6

.
-17.

3.2
Characteristics of the grid

1 SEG2.

2 nodes.

3.3 Functionalities
tested

Orders Key word
factor
Key word

DEFI_MATERIAU ASSE_CORN

STAT_NON_LINE COMP_INCR
RELATION
=
ASSE_CORN

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
Displacement UX, N3 Node, Order 2
9.468 10-2 9.468 10-2
(Direct Calculation and
Displacement DRY, N3 Node, Order 2
1.275 10-3 1.275 10-3
exact)
Displacement UX, N3 Node, Order 8
3.7366
3.7366
Incremental calculation
Displacement DRY, N3 Node, Order 8
1.3754 10-2 1.3754 10-2
exact
Displacement UX, N3 Node, Order 12
2.6799
2.6799
Incremental calculation
Displacement DRY, N3 Node, Order 12
5.3598 10-4 5.3598 10-4
exact
Variable interns 1, Noeud N3, Ordre 2
9.6574 10-2
9.6574 102 exact direct Calculation
Variable interns 1, Noeud N3, Ordre 3
1.07417
1.07417
Incremental calculation
exact
Variable interns 1, Noeud N3, Ordre 11
9.6574 10-2
9.6574 102 incremental Calculation
exact
Variable interns 1, Noeud N3, Ordre 12

1.07417
1.07417
Incremental calculation
exact

4.2 Notice

The reference solution is the numerical solution of a problem to an unknown factor determined by Code_Aster.

5
Summary of the results

The interest of the test is to represent the exhaustiveness of the possible ways of loadings with multiple factors of change of incline: load-discharge, transition from mechanism.

On the other hand, the dimension of the problem makes it possible to have only one unknown factor (the internal variable
current), solution of the inversion of the curve of the law of behavior: direct solution for 1st mechanism and incremental for the second.

The reduction of the problem makes it possible (if one converges) to trust Aster like "slide rule" and to regard the result as a numerical solution "exact".

V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.103
SSNL103 - Beam Cantilever in great rotations
subjected to one moment

Summary:
Calculation of the static deformation of a beam fixed at an end and subjected to one bending moment with
the other end.
The beam is modelled by 5 elements MECA_POU_D_T_GD.
Interest:
To test the element of beam MECA_POU_D_T_GD and the algorithm of great displacements established in
STAT_NON_LINE.
Note:
The algorithm is particularly powerful for this problem, since the deformation of a beam
right-hand side in closed traverse registers in a circle (reference solution) is obtained in 2 iterations.

1
Problem of reference
1.1 Geometry
deformation
Beam at rest
Z
M = 4
With
y
X
N2

N3
N4
N5
N6
B
1
Beam right AB, of section unit, length L = 1, embedded of A and subjected out of B to one moment bending concentrate Mr.
1.2
Material properties
Elastic behavior:
E = 1.
The Poisson's ratio does not intervene in pure inflection.
Inertias of a section:
Iy = Iz = 2.
Ix = 4. (does not intervene)
Ay = Az = 0.25 (does not intervene)
1.3
Boundary conditions and loadings
Embedding in A. One seeks forms it of balance under the loading made up of the moment:
M = 4
concentrate out of B.

2
Reference solution
2.1
Method of calculation used for the reference solution
The curve of a beam in great rotation subjected to the bending moment M is:

1
M
=
R
I.E.(internal excitation)

As the moment is constant along the beam, the deformation is circular and its ray has for value, taking into account the data:

L
R
= 2 .

In other words, the deformation is a complete circle.

2.2
Results of reference

NODE	N3	N4	N6
DX	0.30645	0.69355	1

2.3 References bibliographical

[1]
J.C. SIMO and L. CONSIDERING QUOC, A three-dimensional finite strain rod model. Leaves II : computational aspects. Comput. Meth. Appl. Mech. Engrg. 58, 79-116 (1986).

Code_Aster ®
Version
4.0
Titrate:
SSNL103 Beam Cantilever in great rotations subjected to one moment
Date:
30/01/98
Author (S):
Mr. AUFAURE
Key:
V6.02.103-A Page:
4/4

3 Modeling
With

3.1
Characteristics of modeling

The beam is modelled by 5 linear elements MECA_POU_D_T_GD pressed on meshs SEG2:
who remain right. The deformation is thus a pentagon.

3.2 Functionalities
tested

· The static algorithm of great displacements of STAT_NON_LINE.
· Element MECA_POU_D_T_GD.

4
Results of modeling A

4.1 Values
tested

Identification	**Reference**	**Aster**	**% difference**
DX (N3)	0.30645	0.29999	2.1%
DX (N4)	0.69355	0.69999	0.93%
DX (N6)	1.00000	1.00003	0%

4.2 Remarks

For this problem, convergence is exceptionally fast: 2 iterations. For the problems of great rotations, static balance is in general reached in an iteration count of about 10.

4.3 Parameters of execution

Version: NEW3
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
4,4 seconds

5
Summary of the results

The deformation of the modelled beam is a CLOSED PENTAGON. But nodes, in situation deformation, are apart from the circle of reference because the elements of beam MECA_POU_D_T_GD preserve their length but remain right instead of becoming deformed in arcs of ring.

Author (S):
J.M. PROIX, J.L. FLEJOU

Organization (S): EDF/IMA/MMN, ERMEL/PEL

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.105

SSNL105 - Tally stayed

Summary:

Test of mechanics of the structures in static nonlinear elasticity.
The framework is made of pin jointed struts. The stays consist of two cables. Only one modeling is built.
This test makes it possible to check the behavior in traction and compression of the elements of cable (traction possible,

null compression) and the elastic behavior of the bars.

---

1 Problem of reference

1.1 Geometry

Tally square plan provided with two stays (cables) on the two diagonals.

2
3
bars
cables
1
1
4
1

Co-ordinates of the points:

1 0. 0.
2 0. 1.
3 1. 1.
4 1. 0.

The cables are not connected in their mediums.

1.2 Material properties

E = 2.1 1011 Pa
= 0.3

1.3 Boundary conditions and loadings

DZ = 0.

nodes 1, 2, 3, 4
DY = 0.
nodes 1, 4
DX = 0.
node 1
FX = 1000. NR
node 3
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/96/041 - Ind A

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The solution is obtained by elementary statics.

In cable 1 - 3
NR
= 1000 2 *NR*
1414 2
. *NR*

In bar 3 - 4
NR
= -1000 *NR*

NR = 0 everywhere else (and in particular in cable 2-4).

2.2 Uncertainty on the solution

The reference solution is exact.

2.3 References bibliographical

Simple problem imagined to put in contrast the behavior of two cables: one with traction, the other with compression.

---

3 Modeling With

3.1 Characteristics of modeling

2
3
1
4

Bars 1-2, 2-3, 3-4 and 4-1 are modelled each one by 1 element BARS.
The cables are modelled each one by an element CABLE.

3.2 Characteristics of the grid

There are thus 4 elements BARS and 2 elements CABLE.

3.3 Functionalities tested

Order
Key word fact.
Key word
Argument
Keys
DEFI_MATERIAU
CABLE
EC_SUR_E
[U4.23.01]
AFFE_MODELE
AFFE

MODELING
“BAR”
[U4.22.01]
STAT_NON_LINE
COMP_ELAS
RELATION
“CABLE”
[U4.32.01]
and
“ELAS” with bars
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/96/041 - Ind A

4
Results of modeling A

4.1
Values tested: constraints in the elements

Net	**Reference**	**Aster**	**difference %**
3-4	1000.0	999.77	1.7 E2
1-3 (cable)	1414.2	1413.9	2.3 E2
1-2			

0
2.73 E26
0
2-3
0
9.09 E13
0
4-1
0
5.39 E12
0
4-2 (cable)
0
0
0

4.2 Remarks

These results are obtained with a criterion of convergence of 106 (convergence in 3 iterations).

4.3 Parameters
of execution

Version: NEW 3.05.28
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
6.5 seconds

5
Summary of the results

The results show that the behavior of the cables is in conformity so that one expects some: not compression, rubber band in traction.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/96/041 - Ind A

Code_Aster ®
Version
7.3

Titrate:
SSNL106 - Elastoplastic beam in traction and pure inflection
Date:
25/10/04
Author (S):
***J.M. PROIX**, J.L. FLEJOU*
Key: V6.02.106-C Page: 1/16

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
V6.02.106 document

SSNL106 - Elastoplastic beam in traction and pure inflection

Summary:

This test validates elastoplasticity in a right beam in traction and inflection, for a behavior elastoplastic perfect or with linear work hardening.

.

Analyze static

.

Elastoplastic behavior of beam: VMIS_POUTRE or of PIPE

.

3 sections: rectangular, circular full, hollow circular

.

3 types of work hardening: no one, linear (ECRO_LINE), nonlinear (ECRO_FLEJOU)

8 modelings make it possible to test elements POU_D_TG, POU_D_E, POU_D_T, PIPE (3 and 4 nodes)
COQUE_3D, POU_D_EM and POU_D_T_GM.

The test makes it possible to validate the operation of the integration of these laws of behavior and of the algorithm of
resolution until complete plasticization of the beam.

One also tests plasticization in alternating bending. Moreover, the two methods of resolution are tested
for modelings of beams with total plasticity (POU_D_TG, POU_D_E, POU_D_T): implicit integration or
by Runge-Kutta of order 4.

The ninth modeling makes it possible to test the operation of DYNA_NON_LINE on a calculation quasi-static of traction of a beam modelled in POU_D_TG.

1
Problem of reference

1.1 Geometry

Right beam length L = 1, direction X.

y
L
O
X
O
B
L = 1
Z

One calculates simultaneously 2 types of section:

y
1 rectangular section
2 v = 0.2
Z
B = 0.1
1 circular section
R
R = 0.1

R = 0.1
E
For modeling D, one calculates 1 section of thin tube:
E = 0.001

1.2
Material properties

E = 2. 1011 Pa
= 0.3

ECRO_LINE:
ECRO_FLEJOU:

SY = y = 150.106 Pa
EP = 2.E10
H = D_SIGM_EPSI = 2.109 Pa or 0
SY = 150.E6

KNOWN = 160.E6

PUISS = 1

VMIS_POUTRE: rectangular section:

normal effort limits NP
= 3. 106 NR
elastic moment MEZ
= 105 Nm
limiting moment MPZ
= 1.5.105 Nm
coefficient AZ
= 0.84
coefficient BZ =
0.0013
MEY, MPY, MT, AY, BY
= without object

VMIS_POUTRE: circular section:

normal effort limits NP
= 4.712389 106 NR
MEZ = MEY
= 117809.72 Nm
MPZ = MPY
= 200.000 Nm
MT =
without
object
AY = AZ
= 0.84
BY = BZ
= 0.0012

1.3
Boundary conditions and loadings

Embedding out of O

Displacement imposed out of B

L.
DX E
y
=
= 0.75 10 3 m
E

DX vari
DX E
E of
with 3DX E

Rotation imposed out of B

DRZ E = 0.75 10 2 m

DRZ varies
D
RZ E to 20 × DRZ E then décroit until - 2 × DRZ E

Note:

In pure inflection, MZ and DRZ do not depend on X. Curve
D (DRZ)

=
= DRZ
dx
L

like L = 1
= DRZ ()
B

2
Reference solution

2.1
Method of calculation used for the reference solution

2.1.1 Pure inflection - linear Work hardening

Analytical solution:

y
v
v
xx
U
xx
0
X
0
X
U
v
v
xx=. y: curve

Calculation of the moment by:

M (U) = xx (y). y ds
S
= E for 0 y U
xx

xx

= + H
y
xx
y
xx -

E
for U < y v

One obtains:

for the rectangular section:

M

H 3 1 2
H
E
=

1 -

M

E
-
2 2 + E
E
E

M
I
y
E
.
front

EC.
=
M
Z
E
=
I.E.(internal excitation)
E
v

for the circular section:

R3 y
H 4
3/2
M (μ) =

+ (E - H) (1 - μ2)
E
4 μ
3
E - H

+
sin μ - μ 1 - 2μ 2 1 - μ 2

2μ (Arc
(
)
)
U
y
E
front
μ
EC. =
=
=
R
ER

In discharge, after having reached the limiting load charges some, one obtains a limiting load of sign opposite.

---

for the tubular section:
(assumption of beam of Navier-Bernoulli)

The limiting load (H = 0) is worth:

M
4
=
Me

The complete solution for a thin tube is [bib1]:

M (µ)

(
2 1 -)
=
+
arcsin µ + µ 1 - µ 2
µ
µ (
)
Me

E
H
T

with =
=
E
E + H

2.1.2 Traction - linear Work hardening

H
HS
Analytical solution: there is immediately NR = S
1 ***-***
. DX
y

.
E + L

2.1.3 Traction - nonlinear Work hardening

The analytical solution is obtained here for a particular case: the model of work hardening (ECRO_FLEJOU) is written into uniaxial:

-
with = U
y
U
p
p
E. p
E
= +
y
1

p

E.H

p
1+

and
E =

E H
U
-

If = 1, one finds according to while solving:

(

p
-
p
p
y)

1 +
= E.

U

What leads to the equation of the 2nd degree in:

2 - (E (+ U) + U) + E (+
y U
U) = 0
Then:
= (E (+
p
U) - U) 2 + 4th. E. 2u

and
1
= (E (+ U) + ±
U
)
2

The solution corresponding to the beginning of plasticization (growing starting from y) is that corresponding to the sign -.

Thus the normal effort in the beam is:

2

S (
U B)

(
U B)

2
NR =
E
+

E

+ 4th E p

L
U
U

+
-
+
L
U
U
U

-

2

2.2 References bibliographical

[1]
J.H. LAU and T.T. LAU: Newspaper of Pressure Vessel Technology vol. 106 p188-195 - May 1984.

3 Modeling With

3.1 Characteristics of modeling

2 elements POU_D_TG by type of section. There are thus 2 groups of elements comprising each one 2 elements.

Group GR1:
rectangular section

GC1:
circular section
Simple traction:
on GR1 (ECRO_FLEJOU) and GC1 (ECRO_LINE)
Pure inflection:
on GR1 and GC1 without work hardening

3.2 Characteristics of the grid

2 X 2 elements POU_D_TG

3.3 Functionalities

tested

Orders

STAT_NON_LINE COMP_INCR RELATION
:
“VMIS_POUTRE”
DEFI_MATERIAU VMIS_POUTRE

ECRO_LINE

ECRO_FLEJOU

STAT_NON_LINE CONVERGENCE
RESO_INTE
:
“RUNGE_KUTTA_4”

4
Results of modeling A

4.1 Values
tested

Traction

DX (B)
N°ordre
GROUP_MA
Identification Reference Aster Difference
DX E
(%)
2 11
GR1 NR
3.123 106 3.123
106
0
3 21

GR1 NR
3.1529 106 3.1532
106
0.01
2 21
GC1 NR
4.75951 106 4.75951
106
0
3 31
GC1 NR
4.80664 106 4.80664
106
0

Inflection

DRZ (B)
N°ordre
GROUP_MA
Identification Reference Aster Difference
DRZ E
(%)
1 1
GR1
MFZ
(Nm)
105 105
0
5 21
MFZ 1.48 105 1.477
105
-0.23
10 31
MFZ 1.495 105 1.489
105
-0.39
20 41
MFZ 1.499 105 1.495
105
-0.26
1 1
GC1 MFZ 1.1781 105

1.1781 105
0
5 21
MFZ 1.9602 105
1.955 105
-0.27
10 31
MFZ 1.99 105 1.98
105
-0.53
20 41
MFZ 1.998 105 1.99
105
-0.36
2 71 GR1 MFZ 1.5.105 1.499
105
-0.08
2 71 GC1 MFZ 2. 105 1.994
105
-0.32

---

5 Modeling B

5.1 Characteristics of modeling

2 elements POU_D_T by type of section. There are thus 2 groups of elements comprising each one 2 *elements.*

Group GR1:
rectangular section

GC1:
circular section
Simple traction:
on GR1 (ECRO_FLEJOU) and GC1 (ECRO_LINE)
Pure inflection:
on GR1 and GC1 without work hardening

5.2
Characteristics of the grid

2 X 2 elements POU_D_T

5.3 Functionalities
tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
:
"VMIS_POUTRE"

DEFI_MATERIAU VMIS_POUTRE

ECRO_LINE

ECRO_FLEJOU

STAT_NON_LINE CONVERGENCE
RESO_INTE
:
"IMPLICIT"

6
Results of modeling B

6.1 Values
tested

Traction

DX (B)
N°ordre
GROUP_MA
Identification Reference Aster Difference
DX E
(%)
2 11
GR1 NR
3.123 106 3.125
106
0.08
3 21
GR1 NR
3.1529 106 3.15
106
0.09
2 21
GC1 NR
4.75951 106 4.7596
106
0.004
3 31
GC1 NR
4.80664 106 4.8068
106
0.004

Inflection

DRZ (B)
N°ordre
GROUP_MA
Identification Reference Aster Difference
DRZ E
(%)
1 1

GR1
MFZ
(Nm)
105 105
0
5 21
MFZ
1.48 105 1.477
105
-0.20
10 31
MFZ
1.495 105 1.489
105
-0.37
20 41
MFZ
1.499 105 1.495
105
-0.24
2 71 GR1 MFZ
-1.5 105 -1.496
105
-0.23
2 71 GC1 MFZ
-2 105 -1.993
105
-0.33
1 1
GC1 MFZ
1.1781 105 1.1781
105
0
5 21
MFZ
1.9602 105 1.955
105
-0.24
10 31
MFZ
1.99 105 1.98
105
-0.50

20 41
MFZ
1.998 105 1.99
105
-0.33

---

7 Modeling
C

7.1
Characteristics of modeling

2 elements POU_D_E by type of section. There are thus 2 groups of elements comprising each one 2 elements.

Group GR1:
rectangular section

GC1:
circular section
Simple traction:
on GR1 (ECRO_FLEJOU) and GC1 (ECRO_LINE)
Pure inflection:
on GR1 and GC1 without work hardening

7.2
Characteristics of the grid

2 X 2 elements POU_D_E

7.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR RELATION
:
“VMIS_POUTRE”

DEFI_MATERIAU VMIS_POUTRE

ECRO_LINE

ECRO_FLEJOU

STAT_NON_LINE CONVERGENCE
RESO_INTE
“IMPLICIT”

“RUNGE_KUTTA_4”

8 Results of modeling C

8.1 Values tested

Traction

DX (B)
N°ordre
GROUP_MA
Identification Reference Aster Difference
DX E
(%)

2 11
GR1 NR
3.123 106 3.123
106
0
3 21
GR1 NR
3.1529 106 3.1532
106
0.01
2 21
GC1 NR
4.75951 106 4.75951
106
0
3 31
GC1 NR
4.80664 106 4.80664
106
0

Inflection

DRZ (B)
N°ordre
GROUP_MA
Identification Reference Aster Difference
DRZ E
(%)
1 1
GR1
MFZ
(Nm)
105 105
0
5 21
MFZ
1.48 105 1.477
105
-0.23
10 31
MFZ
1.495 105 1.489

105
-0.39
20 41
MFZ
1.499 105 1.495
105
-0.26
2 71 GR1 MFZ
-1.5 105 -1.499
105
-0.08
2 71 GC1 MFZ
-2 105 -1.994
105
-0.32
1 1
GC1 MFZ
1.1781 105 1.1781
105
0
5 21
MFZ
1.9602 105 1.955
105
-0.27
10 31
MFZ
1.99 105 1.98
105
-0.53
20 41
MFZ
1.998 105 1.99
105
-0.36

---

9 Modeling D

9.1 Characteristics of modeling

2 elements PIPE for the tubular section.

Simple traction:
(ECRO_LINE)
Pure inflection:
without work hardening

Moreover, one blocks the DDL which correspond to the mode 3d' ovalization: U03 V03 W03

9.2 Characteristics of the grid

2 elements PIPE (METUSEG3)

9.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
: "VMIS_ISOT_LINE"

TUYAU_NCOU
:
3

TUYAU_NSEC
:
16

AFFE_MODELE
MODELING
:
PIPE

AFFE_CHAR_MECA

DDL_IMPO
U03: 0.

V03: 0.
W03: 0.

10 Results of modeling D

10.1 Values tested

Traction

DX (B)
N°ordre Identification Reference Aster Difference
DX E
(%)
2 11
NR
9.47 104 9.47
104
0
3 21
NR
9.565 104
9.565 0

Inflection

DRZ (B)
N°ordre Identification Reference Aster Difference
DRZ E
(%)

1 1
MFZ
4.642 103 4.642
103
0
5 21
MFZ
5.9106 103 5.9365
103
0.4

---

11 Modeling E

11.1 Characteristics of modeling

2 elements PIPE with 4 nodes for the tubular section.

Simple traction:
(ECRO_LINE)
Pure inflection:
without work hardening

Moreover, one blocks the DDL which correspond to the mode 3d' ovalization: U03 V03 W03

11.2 Characteristics of the grid

2 elements PIPE (meshs SEG4)

11.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR RELATION : "VMIS_ISOT_LINE"

TUYAU_NCOU *: 3*

TUYAU_NSEC *: 16*

AFFE_MODELE MODELING : PIPE

AFFE_CHAR_MECA

DDL_IMPO
U03: 0.

V03: 0.
W03: 0.
MODI_MAILLAGE
OPTION
SEG3_4

12 Results of modeling E

12.1 Values tested

Traction

DX (B)
N°ordre Identification Reference
Aster Difference
DX E
(%)
2 11
NR
9.47 104 9.47
104
0
3 21
NR
9.565 104
9.565 0

Inflection

DRZ (B)
N°ordre Identification Reference
Aster Difference
DRZ E
(%)
1 1 MFZ 4.642 103 4.642
103
0
5 21 MFZ 5.9106 103 5.9365
103
0.4

---

13 Modeling
F

13.1 Characteristics of modeling

112 elements COQUE_3D for the tubular section, and 2 elements pipe to apply the conditions with the limits. The length of the grid hulls is of 0.98m. The length of each element pipe is of 0.01m.

A connection COQUE_TUYAU is applied at each end of the grid hulls, with an element pipe. Moreover, one blocks the DDL of the pipes which correspond to the mode 3d' ovalization: U03
V03
W03

Simple traction:
(ECRO_LINE)
Pure inflection:
without work hardening

13.2 Characteristics of the grid

112 meshs QUAD9 and 2 meshs SEG3.

13.3 Functionalities
tested

Orders

STAT_NON_LINE COMP_INCR RELATION
: "VMIS_ISOT_LINE"

COQUE_NCOU
:
1

AFFE_MODELE

MODELING:
COQUE_3D, TUYAU_3M

AFFE_CHAR_MECA
DDL_IMPO

Ui3: 0.

Vi3: 0.
Wi3: 0.
Uo3: 0.
Vo3: 0.
Wo3: 0.
AFFE_CHAR_MECA LIAISON_ELEM
OPTION
"COQ_TUYAU"

14 Results of modeling F

14.1 Values tested

Traction

DX (B)
N°ordre Identification Reference
Aster Difference
DX E
(%)
2 11
NR
9.47 104 9.473
104
0.02
3 21
NR
9.565 104
9.569 E+04
0.04

Inflection

DRZ (B)
N°ordre Identification Reference
Aster Difference
DRZ E
(%)
1 1 MFZ 4.642 103 4.6415

103
0.01
2.8 19
MFZ 5.7824 103 5.7836
103
0.02

---

15 Modeling G

15.1 Characteristics of modeling

2 elements POU_D_EM for the tubular section.
The section is with a grid in QUAD4: it is discretized by a mesh in the thickness, and 90 meshs on the circumference.

Simple traction:
(ECRO_LINE)
Pure inflection:
without work hardening

15.2 Characteristics of the grid

2 meshs SEG2 for the beam. 90 meshs QUAD4 for the section.

15.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
: “VMIS_ISOT_LINE”

AFFE_CARA_ELEM BEAM
SECTION
GENERAL

AFFE_SECT
GRID

AFFE_MODELE
MODELING
:
POU_D_EM

16 Results of modeling G

16.1 Values
tested

Traction

DX (B)
N°ordre Identification Reference
Aster Difference
DX E
(%)
2 11
NR
9.47 104 9.471
104
0.01
3 21
NR
9.565 104
9.5647 0.01

Inflection

DRZ (B)
N°ordre Identification Reference
Aster Difference
DRZ E
(%)
1 1 MFZ 4.642 103 4.641
103
0.01
5 21 MFZ 5.9106 103 5.90
103
0.02

---

17 Modeling
H

17.1 Characteristics of modeling

2 elements POU_D_TGM for the tubular section.
The section is with a grid in QUAD4: it is discretized by a mesh in the thickness, and 90 meshs on the circumference.

Simple traction:
(ECRO_LINE)
Pure inflection:
without work hardening

17.2 Characteristics of the grid

2 meshs SEG2 for the beam. 90 meshs QUAD4 for the section.

17.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
: "VMIS_ISOT_LINE"

AFFE_CARA_ELEM BEAM
SECTION
GENERAL

AFFE_SECT
GRID

AFFE_MODELE
MODELING
:
POU_D_TGM

18 Results of modeling H

18.1 Values tested

Traction

DX (B)
N°ordre Identification Reference
Aster Difference
DX E
(%)
2 11
NR
9.47 104 9.471
104
0.01
3 21

NR
9.565 104
9.5647 0.01

Inflection

DRZ (B)
N°ordre Identification Reference
Aster Difference
DRZ E
(%)
1 1 MFZ 4.642 103 4.641
103
0.01
5 21 MFZ 5.9106 103 5.90
103
0.02

---

19 Modeling I

19.1 Characteristics of modeling

2 elements POU_D_TG by type of section. There are thus 2 groups of elements comprising each one 2 elements.

Group GR1:
rectangular section

GC1:
circular section
Simple traction:
on GR1 (ECRO_FLEJOU) and GC1 (ECRO_LINE)
Pure inflection:
on GR1 and GC1 without work hardening

19.2 Characteristics of the grid

2 X 2 elements POU_D_TG

19.3 Functionalities tested

The characteristic of modeling I is to test the operation of DYNA_NON_LINE in calculation of quasi-static traction of a beam modelled in POU_D_TG. This type of modeling has for characteristic to reveal null pivots on the lines of the matrix of mass corresponding with the degrees of freedom of warping. In this case, the initialization of the diagram of NEWMARK fact more by inversion of the matrix of mass, which is singular, but by zero setting of acceleration initial.

Orders

DYNA_NON_LINE COMP_INCR
RELATION
:
“VMIS_POUTRE”
DEFI_MATERIAU VMIS_POUTRE

ECRO_LINE

ECRO_FLEJOU

STAT_NON_LINE CONVERGENCE RESO_INTE
:
“RUNGE_KUTTA_4”

20 Results of modeling I

20.1 Values
tested

Traction

DX (B)
N°ordre
GROUP_MA
Identification
Reference
Aster Difference
DX E
(%)
2 11 GR1 NR
3.123 106 3.123
106
0.009
3 21 GR1 NR
3.1529 106 3.153
106
0.012

2 21 GC1 NR
4.75951 106 4.760
106
0.0003
3 31 GC1 NR
4.80664 106 4.807
106
0.0003

20.2 Observations

It is noticed that the results in traction resulting from DYNA_NON_LINE are identical to those given by STAT_NON_LINE.

An alarm informs the user who the matrix of mass is singular, which should attract sound caution.
Indeed for the majority of the finite elements the matrix of mass is definite positive. A message invites it
thus to check the assignments of its model. In the framework of this modeling, the presence of degrees of freedom of warping naturally involves the singularity of the matrix of mass.

---

21 Summary of the results

The results obtained for a traction correspond exactly to the analytical solution. On the other hand in inflection, the difference reaches 0.5%. This is due to the criterion of plasticity chosen, whose form does not allow
not to find the analytical solution exactly. It is necessary to adjust as well as possible parameters AY, BY, AZ,

BZ.

With regard to modelings pipe and hull, the conclusions are the same ones, but this time the difference with the analytical solution comes from this solution which is valid for a beam of very mean tubular section, without effect of ovalization. This ovalization is blocked at the ends, it who allows to obtain a solution with less than 0.4% of the analytical solution.

Two modelings in multifibre beams provide a solution to less than 0.02% of analytical solution, for a very weak time calculation, compared to modeling pipe and hull, but without it being necessary to adjust parameters as for modelings of beam with total plasticity. The only approximation comes from the grid of the section.

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HT-66/04/005/A

Code_Aster ®
Version
6.0

Titrate:
SSNL107 - Plate embedded subjected to an inflection by beams
Date:
22/11/02
Author (S):
J.M. PROIX
Key: V6.02.107-C Page: 1/6

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.107

SSNL107 - Plate embedded subjected to an inflection
by beams in contact with the free edge

Summary:

This test validates the unilateral contact between elements of beam POU_D_E (right beam of Euler) and
elements of hull DKQ.

The principal characteristics are:

· linear behavior,
· analyzes elastic,
· unilateral contact,
· 2 modelings: elements POU_D_E and DKQ by using CONTACT in AFFE_CHAR_MECA and in AFFE_CHAR_MECA_F.

The reference solution is analytical and the results obtained are of good quality.

1
Problem of reference

1.1 Geometry
G
E
y
Z

With
H
D
B
H
F
X
B
C
L
Plate A B C D
of length
L = 10 mm
of width
B = 1 mm
of thickness
H = 0.1 mm
2 beams EF and GH
of length
L = 1 mm
of section
S
Circular sections
R
E
R = 2. 10-3 mm
E = 2. 10-4 mm

1.2
Material properties

Linear elasticity: E = 2.105 MPa, = 0.3
Identical for the plate and the two beams.

1.3
Boundary conditions and loadings

Embedding on AB: DX = DY = DZ = DRX = DRY = DRZ = 0
Displacement imposed in E and G: DZ = 0.2 mm
Unilateral contact between F and C and H and D

1.4 Conditions
initial

Without object.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical

The plate undergoes a pure bending. The solution is of the type `'beam '':

PL3
bh3
V = DZ (C) = DZ (D) =
with I =

3rd. I
y
y
12

The arrow V and the load P are unknown.

The two beams are in pure compression:

ES
- P = 2.
(V - U) with U = DZ (E)
L
= DZ (G)

One can thus find P and V starting from these two equations. One obtains:

6th S I U
P = 2SL3 + 3I ly

2SL3 U
V = 2SL3 + 3I ly

2.2
Results of reference

V = -019005
.
mm

P = -
-
9 5025
.
10 3 NR

2.3
Uncertainty on the solution

Null. Analytical solution.

---

3 Modeling B

3.1 Characteristics of modeling

20 elements of hull DKQ
2 elements of beam POU_D_E

There is a play (0.2 mm) between the points H and D in the grid.
One introduces a fictitious play (0.2 mm) between the points F and C by key word DIST_2 of CONTACT.
The contact is treated between meshs POI1 thanks to key word VECT_2_NORMALE of CONTACT.

3.2 Characteristics of the grid

A number of nodes: 46
A number of meshs and types: 20 QUAD4, 2 SEG2

3.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
DIST_2

CONTACT
VECT_2_NORMALE

STAT_NON_LINE COMP_ELAS

RELATION
:
“ELAS”

4
Results of modeling B

4.1 Values tested

Identification	Reference	Aster	% difference
C DZ N46	-0.19005	-0.18991	0.03
D DZ N45	-0.19005	-0.18991	0.03
EF NR M22	-4.75126 10-3	-4.7790 10-3	0.58
GH NR M21	-4.75126 10-3	-4.7790 10-3	0.58

---

5 Modeling C

5.1 Characteristics of modeling

20 elements of hull DKQ
2 elements of beam POU_D_E

There is a play (0.2 mm) between the points H and D in the grid.
One introduces a fictitious play between the points F and C by key word DIST_2 of CONTACT. This play is declared
like a function of time, of constant value equal to 0.2 Misters One thus uses the key word CONTACT of order AFFE_CHAR_MECA_F.

5.2 Characteristics of the grid

A number of nodes: 46
A number of meshs and types: 20 QUAD4, 2 SEG2

5.3 Functionalities tested

Orders

AFFE_CHAR_MECA_F CONTACT
DIST_2

COQUE_NCOU: 19

STAT_NON_LINE COMP_ELAS
Relation
:

"ELAS"

6
Results of modeling C

6.1 Values
tested

Identification Reference
Aster %
difference
C DZ N46
-0.19005
-0.18999
0.03
D DZ N45
-0.19005
-0.18999
0.03
EF NR M22
-4.75126 10-3 -4.7790
10-3 0.58
GH NR M21
-4.75126 10-3 -4.7790
10-3 0.58

7
Summary of the results

The results are very close to the analytical solution (0.58%). They are not exact because they depend on the smoothness of the grid of the plate.

The results show the correct operation of the unilateral contact between the beams and the plate.

Titrate:
SSNL108 - Connection tube-grid with friction of Coulomb

Date:
23/10/02
Author (S):
J.M. PROIX, B. QUINNEZ

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.108

SSNL108 - Connection tube-grid with friction of Coulomb

Summary:

This two-dimensional problem makes it possible to test the law of behavior used to model the connection roasts mix fuel pins of the fuel assemblies. This test of nonlinear statics has only one only modeling.

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

Imposed displacement
N4
y
N2
X
N1
N3

1.2
Material properties

Linear elastic rigidity of the connection (for the three directions of translation and rotation):
K
NR m
E = 103
/

Initial tension of the spring following direction X: R
NR
No = -102

Young modulus of the beam: E = 105

Poisson's ratio of the beam: = 0 3
.

Function of evolution of rigidity: F (T) 1

Coefficient of Coulomb: µ = 0 4
.

Modulate work hardening: KTT=0, then KTT=100N /m

1.3
Boundary conditions and loadings

Embedded N1 node: U = v = W = 0
X = y = Z = 0

Nodes N2, N3, N4 movement according to y
U = W = 0
X = y = Z = 0

Nodes N2, N3, N4 movement imposed according to y
v = 0 0
. 1 G (T)

G (T)
with
10.
0.
10.
20.
T

Two calculations are carried out: one without work hardening, with all the way above, the other with work hardening, for the first part of the way (0<t<10).

1.4 Conditions
initial

With T = 0, the spring of connection are compressed and the beam is in initial position.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is obtained analytically. Three nodes of the beam having the same one imposed displacement, the beam is thus indeformable.

The node N2 not having displacement according to X one a:

R = R
T
N
No

In addition one a: U = U = 0 0
. 1 G (T
T
Y
)

1st phase: R
= K U < μ R = μ R
, U
T
E
T
N
No
T increases.
In this phase, RT is strictly lower than μ RN and one thus does not have friction.

Limit T1 of this phase is defined by
: R = K U = μ R
T
E
T
No i.e. for
0 0
. 1 K G (T1) = μ R
E
No.
One finds T1 = 4.

Without work hardening:

2nd phase: R
= μ R = μ R
, U
T
N
No
T increases.
The tangential force reached the value of the threshold μ Rno and one thus has slip. This phase is delimited by the moments T = 4. and T
1
2 = 10. (moment when U T starts to decrease).

3rd phase: R
= K U < μ R = μ R
, U
T
E
T
N
No
T decreases.
In this phase, RT is lower than the value of the threshold μ RN and one is thus in a phase rubber band R = - K U + μ R
T
E
T
No.
The limits of this phase are T = 10. and T
2
3 defined by:

- 0 0
. 1k G (T) + μ R = - R
T
E
No
No
> 10
3
3
.
One finds T3 = 18.

4th phase: R
= μ R
, U
T
No
T decreases.
In this phase, one reached the threshold of slip again. One a: R = μ R
T
No This phase is
delimited by the moments T3 = 18. and t4 = 20.

With work hardening:

K
2nd phase:
Tt
R = μ R 1
+ K U
.
.
T
N
Tt
T

K

Te

The tangential force reached the value of the threshold μ Rno and one thus has slip. This phase is

delimited by the moments T = 4. and T
1
2 = 10. There is an effect of work hardening.

2.2
Results of reference

For the various remarkable moments, the value of RT is equal to:
Without work hardening:

T =.
4
RT =.
40
T =.
10
RT =.
40
T =.
18
RT = -.
40
T =
.
20
RT = -.
40

With work hardening:

T =.
4
T
R =
.
40
T =.
10
T
R =
.
46

2.3
Uncertainty on the solution

Analytical solution.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

N4
N1
N2
N3

Characteristics of the elements

BEAM:
POU_D_E for the meshs (N3 N2) and (N2 N4)
E = 105 Naked Pa = 0 3
.
DISCRETE:
K_TR_D_L for the mesh (N1 N2)
K = K = K = 103 NR/m
X
y
Z

K = K = K = 103 NR/m
X-ray
ry
rz

Characteristics agent the bonding (mesh (N1 N2)) :

Coefficient of Coulomb: COULOMB = 0.4
Initial tension of compression: EFFO_N_INIT: 100. NR
Function of evolution of rigidity: RIGI_N_FO: F (T) 1

Boundary conditions

DDL_IMPO: (NODE: N1
DX
:0.
DY
:0.
DZ
:0.
DRX: 0.
DRY: 0.
DRZ: 0.
)
DDL_IMPO: (NODE: (N2, N3, N4)
DX

:0.
DY
: 0.01
DZ
:0.
DRX: 0.
DRY: 0.
DRZ: 0.
)

3.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 3 SEG2

3.3 Functionalities
tested

Orders

AFFE_MODELE
MODELING
MECHANICS
POU_D_E

MODELING
MECHANICS
DIS_TR

AFFE_CARA_ELEM
BEAM
GROUP_MA
"RIGHT-ANGLED"

DISCRETE
GROUP_MA
"K_TR_D_L"

DEFI_MATERIAU
DIS_CONTACT

ELAS

AFFE_CHAR_MECA
DDL_IMPO
NODE

DEFI_FONCTION
NOM_PARA
“INST”

STAT_NON_LINE
EXCIT
FONC_MULT

COMP_ELAS
GROUP_MA
“ELAS”

COMP_INCR
GROUP_MA
“DIS_CONTACT”

4
Results of modeling A

4.1 Values tested

One tests component VY of field "SIEF_ELGA" at various moments:

With work hardening:

Identification Reference
Aster %
difference Tolerance
Sequence number
Moment
VY (NR)

1 4.
40.
39.9999
0.
0.01
2 10.
40.
40. 0.
0.01
3 18.
-40.
-39.9999
0.
0.01
4 20.
-40.
-39.9999
0.
0.01

Without work hardening:

Identification Reference
Aster %
difference Tolerance
Sequence number
Moment
VY (NR)

1 4.
40.
39.9999
0.
0.01
2 10.
46.
46. 0.
0.01

5
Summary of the results

The results are identical to the reference solution. This test validates the slip with friction of Coulomb introduced via a discrete element. This development allows in particular to model the connection between the grids and the fuel pins.

Author (S)
:
J.M. PROIX, B. QUINNEZ

Organization (S): EDF/IMA/MMN

Document: V6.02.110

SSNL110 - Nonlinear spring including of friction of Coulomb

Summary:

This two-dimensional problem makes it possible to test the law of behavior used to model the connection roasts
mix fuel pins of the fuel assemblies.
A reduction according to the time of the rigidity of the connection is taken into account in this test.
This test of nonlinear statics has only one modeling.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/98/040 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SSNL110 Arises nonlinear including friction of Coulomb
Date: 01/12/98
Author (S)
:
J.M. PROIX, B. QUINNEZ
Key:
V6.02.110-A Page:
2/6
1
Problem of reference
1.1 Geometry
(
H T) yo imposed Déplacement
y
Imposed displacement
G (T) X

O
N2
X
N1
1.2
Material properties
Linear elastic rigidity of the connection (for the three directions of translation and rotation):
K = 103 NR/m
E
2
Initial tension of the spring in translation according to direction X: R
= -10 NR
NR 0

Coefficient of Coulomb: μ = 0 4
.

T
Function of evolution of rigidity in translation according to X: F (T) = 1 -

10
1.3
Boundary conditions and loadings
N1 node:
embedding: U = v = W = 0
= = =
X
y
Z
0
Node N2:
U = G (T) X
v = H (T) y
with
X =
O
O
O
0 1
.
y =
O
0 0
. 1
Two cases are considered:
Case 1:
Case 2:
(
H T) 1
(
T
H T) =
T
10
G (T) = 10
T

G (T) = 10
1.4 Conditions
initial
For the node N2 there are following imposed displacements:
U = 0.
v = 0.

2
Reference solution
2.1
Method of calculation used for the reference solution
T
R
effort in the directio NR
NR
N
NR
R
effort in the directio T
T
N
1
2
U
displacement in the directio T
T
N
U

displacement in the directio NR
NR
N
One a:

T
T

R (T) = min F (T)
( )
( )
R
+ K

,
2
1

0

(U - U
NR
NO
E
NR
NR)

At every moment T, one calculates:
-
R
= R + K U

with
U

=
2
-
2

-
Te
T
E
T
T
(UT (T) UT (T T))
- (U 1 - 1 -
T (T)
U T (T
T))
If
R
< - μ R
Te
N (T)
then
+
R
= R
T
Te
If not
R
+
R
= - μ R
Te
T
N (T)
(there is slip)
RTe
2.1.1 Case
1
In case 1, as long as there is not slip, one a:
R
= K y =
Te
E O
10

T

T
R (T)
= F (T)
0 +
= 1-
N
[R
K G (T) X
NR
E
O]

100 1000
0 1
.
10 -
+
×
×

10

= -100 + T
20 - T 2
There will be slip when: R
= - μ R (T)
Te
N
I.e.: 10
0 4
. (100 20
2
= -
-
+ T - T)
T = 5 is root of this equation.
One thus has in short:
T < 5.
5. T 10.

R (T) = K y = 10
R (T) = -100 + 20t - T 2
T
E O
NR
R (T) = -100 + 20 T - T 2
R (T) = 0 4
. × 100 - 20 + 2
NR
T
(
T
T)
No slip
There is slip

2.1.2 Case
2
In case 2, as long as there is not slip, one a:
R (T) = K
H (T) y = T
Te
E
O
R (T) = F (T)
2
0 +
= -100 + 20 -

N
[R
K G (T) X
NR
E
O]
T
T
There will be slip when: R
(T) = - μ R (T)
Te
N
2
I.e.: T = -0 4
. × (- 100 + 20 T - T)
T = 6 096
.
is root of this equation.
One thus has in short:
T < 6 096
.
6 096
.
T 10.
R
=
= -100 + 20 - 2
T (T)
T
RN (T)
T
T
R
= -100 + 20 - 2
= 0 4
. × 100 - 20 + 2
NR (T)
T
T
RT (T)
(
T
T)

No slip
There is slip
2.2
Results of reference
For various moments, there are the following results:
Case 1
Moment
R
Slip
T
RN
0.5
10.
90.25
Not
4.5
10.
-25.
Not
5.5
8.1
20.25
Yes
9.5
0.1
0.25
Yes
Case 2
Moment
R
Slip
T
RN
0.5
0.5
90.25
Not
6.
6.
-16.
Not
6.5
4.9

12.25
Yes
9.5
0.1
0.25
Yes
2.3
Uncertainty on the solution
Analytical solution.

---

3 Modeling
With
3.1
Characteristics of modeling
N1
N2
Discrete element of rigidity DIS_T
Characteristics of the elements
DISCRETE:
Stamp rigidity K_T_D_L in total reference mark
Characteristics agent the bonding (N1 N2)
Coefficient of Coulomb: COULOMB = 0.4
Initial tension of compression: EFFO_N_INIT: 100.
Function of evolution of rigidity: RIGI_N_FO: F (T)
Boundary conditions
Embedding N1 node:
NODE: N1
DX: 0.

DY: 0.
DZ: 0.
Case 1:
Displacement imposed node N2
T
DX:
× .
0 1
DY: .
0 01
10
Case 2:
Displacement imposed node N2
T
T
DX:
× .
0 1
DY:
× .
0 01
10
10
3.2
Characteristics of the grid
A number of nodes: 2
A number of meshs and types: 1 SEG2
3.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
“MECHANICAL”
“DIS_T”
[U4.22.01]
AFFE_CARA_ELEM
DISCRETE
GROUP_MA
“K_T_D_L”
[U4.24.01]
DEFI_MATERIAU
DIS_CONTACT
[U4.23.01]

AFFE_CHAR_MECA
DDL_IMPO
[U4.25.01]
STAT_NON_LINE
EXCIT
CHARGE
FONC_MULT
[U4.32.01]
COMP_INCR
"DIS_CONTACT"
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/98/040 - Ind A

---

4 Results of modeling A

4.1 Values tested

One tests the components NR and VY of field SIEF_ELGA and the variable interns (field VARI_ELGA) who is worth 1 when there is slip (if not it is worth 0.).

Case 1:

Identification			**Reference**	**Aster**	**% difference**	**Tolerance**
Sequence number	**Moment**	**Variable**				
1	0.05	VY	10.	10.	0.	104
		VARI	0.	0.	0.	104 (absolute)
9	4.5	VY	10.			

10.
0.
104
VARI
0.
0.
0.
104 (absolute)
11
5.5
VY
8.1
8.1
0.
104
VARI
1.
1.
0.
104
19
9.5
VY
0.1
0.1
0.
104
VARI
1.
1.
0.
104
Case 2:
Identification
Reference
Aster
% difference
Tolerance
Sequence number
Moment
Variable
1.
0.05

VY
0.5
0.5
0.
104
NR
90.25
90.25
0.
104
VARI
0.
0.
0.
104 (absolute)
12.
6.
VY
6.
6.
0.
104
NR
-16.
-16.
0.
104
VARI
0.
0.
0.
104 (absolute)
13.
6.5
VY
4.9
4.9
0.
104
NR
12.25
12.25
0.

104
VARI
1.
1.
0.
104
19.
9.5
VY
0.1
0.1
0.
104
NR
0.25
0.25
0.
104
VARI
1.
1.
0.
104

4.2 Parameters of execution

Version: 4.2.24
Machine: CRAY C90
System: UNICOS 8.0
Obstruction memory: 8 megawords
Time CPU To use: 33 seconds

5 Summary of the results

The results coincide perfectly with the reference solution. This test thus validates the element of arises nonlinear allowing to model a contact with friction of Coulomb.

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/98/040 - Ind A

Code_Aster ®
Version
5.0

Titrate:

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
V6.02.111 document

SSNL111 - Three thermoelastoplastic bars
Perfect von Mises

Summary:

This quasi-static test enters within the framework of the validation of the relations of elastoplastic behavior.
Three perfect, parallel thermoelastoplastic bars, rotulées on a rigid support at an end and rotulées on a rigid bar with the other, undergo an external thermal loading.

This application, where all the fields are uniform in each bar makes it possible to validate 2 types of numerical modelings: massive finite elements (2D forced plane), plates and bars.

1
Problem of reference

1.1 Geometry

1
2
3
L
y
P
P
P
1
2
3
X
L
L
L
L

The three bars have the same length L = 1m, and are spaced of l= 1m.

1.2
Material properties

Law of standard perfect thermoelastoplastic behavior, with criterion of Von Mises.

plastic deformations are null in an initial state.

E = 200000 MPa
Y
= 0.3

E

Y = 200 MPa
= 0.00001

1.3
Boundary conditions and loadings

The three bars have a displacement blocked according to OY at the points higher ends, where they are articulated, and they are attached at the lower points P1, P2, P3, than one can represent by one rigid frame compels to move vertically, length 4l on which the three are articulated bars. The bars are free of mechanical effort.

The way of loading is described by the change of the temperature, uniform in each bar (T max = 330° C):

T empératures
350
300
250
Barre1
200
Barre2
°C *150*
Barre3
100
50
0
0
1
2
3
3,81
4
5
you mps

2
Reference solution

2.1
Method of calculation used for the reference solution

To refer to the document [bib1] which provides the thermoelastoplastic solution.

2.2
Results of reference

Modeling A
in P1, P2, P3.
yy

Modeling B
Normal effort NR constant on each bar (value identical to, because a section was taken
yy
equalize to 1).

2.3 References
bibliographical

[1]
S. ANDRIEUX: Thermoelastoplastic TD 1 Three bars perfect Von Mises. In "Initiation with

thermoplasticity in Code_Aster", HI-74/96/November 13, 1996 (manual of reference course).

3 Modeling
With

3.1
Characteristics of modeling

Elements 2D (QUAD4). Modeling C_PLAN.

y
R
Q R
Q R
Q
1
1
2
2
3
3
X
1
S
1
P S

P S
P
2
2
3
3

3.2
Characteristics of the grid

A number of nodes: 12.
A number of meshs and types: 3 QUAD4.

3.3
Functionalities tested

Orders

AFFE_MODELE
AFFE
MODELING: "C_PLAN"

DEFI_MATERIAU ECRO_LINE

D_SIGM_EPSI

SY

STAT_NON_LINE COMP_INCR
VMIS_ISOT_LINE

OPTION
ELNO

5.0

4
Results of modeling A

4.1 Values tested

Identification Moments Node
Reference
Aster Variation
%
yy
1 P1 200
-200.00000
0
yy
P2 100
100.00000
0
yy
P3 100
100.00000
0
yy
2 P1 200
-200.00036
1.8
E4
yy
P2 100
100.00017
1.7
E4
yy

P3 100
100.00017
1.7
E4
yy
3 P1 20
19.99978
-1.1
E3
yy
P2 120
-119.99989
-0.8
E4
yy
P3 100
100.00010
1
E4
yy
4 P1 200
200.00060
3
E4
yy
P2 100
-100.00008
0.8
E4
yy
P3 100
-100.00008
0.8
E4
yy
5 P1 200
200.00002
0.1
E4
yy
P2 100
-100.00011
1.1

E4
yy
P3 100
-100.00011
1.1
E4

---

5 Modeling
B

5.1
Characteristics of modeling

3 elements 1D (SEG2). Modeling BARS

5.2
Characteristics of the grid

6 nodes.
3 meshs SEG2

5.3
Functionalities tested

Orders

AFFE_MODELE
AFFE
MODELING: “BAR”

DEFI_MATERIAU ECRO_LINE

D_SIGM_EPSI

SY

STAT_NON_LINE COMP_INCR
VMIS_ISOT_LINE

OPTION
SIEF_ELNO_ELGA

6
Results of modeling B

6.1 Values
tested

Identification Instants Bars
No Reference
Aster Variation
%
normal effort NR
1
1
-200
-200
0
normal effort NR

2
100
100
0
normal effort NR

3

100
100
0
normal effort NR
2
1
-200
-200
0
normal effort NR

2
100
100
0
normal effort NR

3
100
100
0
normal effort NR
3
1
20
20
0
normal effort NR

2
-120
-120
0
normal effort NR

3
100
100
0
normal effort NR
4
1
200
200

0
normal effort NR

2
-100
-100
0
normal effort NR

3
-100
-100
0
normal effort NR
5
1
200
200
0
normal effort NR

2
-100
-100
0
normal effort NR

3
-100
-100
0

7
Summary of the results

The results provided by Code_Aster are in excellent agreement with the analytical solution.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNL112 - Bar subjected has a cyclic thermal loading
Date:
09/04/02
Author (S):
C. CHAVANT
Key: V6.02.112-A Page: 1/14

Organization (S): EDF/AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
V6.02.112 document

SSNL112 - Bar subjected has a loading cyclic thermics

Summary:

This case test enters within the framework of the validation of the relations of behavior in elastoplasticity of the elements bar for the quasi-static mechanics of the structures.
An embedded bar has these two ends undergoes a cyclic thermal loading inducing efforts of traction and compression.

Each modeling makes it possible to validate one of the relations of non-linear behavior introduced:

Linear isotropic work hardening with criterion of Von Mises (modeling A), linear kinematic work hardening
with criterion of Von Mises (modeling B), as well as a model known as of Pinto-Menegotto, representing it
cyclic behavior of the steel reinforcements in the reinforced concrete (modelings C and D).

1 Problem of reference

1.1 Geometry

N1
y
X
N2
Z

Length of the bar: 1 m
Section of the bar
: 5 cm2

1.2 Properties of materials

1.2.1 Linear work hardenings isotropic and kinematics

E

T
y
E

Young modulus:
E = 2. 1011 Pa
Slope D `work hardening:
And = 2.109 Pa
Elastic limit:
= 2.108 Pa
Poisson's ratio:
= 0,3
Thermal dilation coefficient:
= 1.10-5 K-1

1.2.2 Model of Pinto-Menegotto

U
0y
E

0y

H
U

Young modulus:
E
=
2. 1011 Pa
Elastic limit:
0
=
2.108 Pa
y
Poisson's ratio:

=
0,3
Thermal dilation coefficient:

=
1.10-5 K-1
Deformation of work hardening:
H
=
2.3 10-3
Ultimate constraint:
U
=
2.58 108 Pa
Ultimate deformation:
U
=
3.10-2
Coefficient defining the curve:
R0
=
20
Coefficient defining the curve:
A1
=
18.5
Coefficient defining the curve:
A2
=

0.15
Coefficient of buckling:
C
=
0.5
Coefficient of buckling:
With
=
0.008

1.3
Boundary conditions and loading

Boundary conditions:

The bar is embedded. Displacements are thus blocked in the three directions.
In N1 and N2: DX = DY = DZ = 0
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

Loading:

The way of loading is described by the change of the temperature, uniform in the bar:

T 0
1 2 3 4 5 6 7
T (°C)
50
-50
-300
-100 50 -150 -350 -200

Temperatures

0
1
2
3
4
5
6
7

50

0
-50

C) *-100*

-150

-200

-250

T (degrees *-300*

-350
-400

Time

The temperature of reference is taken with 0oC

2
Reference solutions

2.1
Method of calculation used for the reference solutions

2.1.1 Work hardenings
linear

Isotropic work hardening

For a uniaxial traction, the criterion of plasticity is written:

L - R (p) 0

where p is the cumulated plastic deformation
E E
R p
R p
y
() = + and R =
T

E - And
The criterion is written then:
- R p
- y
L
0

The tensor of the constraints is obtained by:
*= **A.** ((**U**) - p) - 3 (- ref.*
*K T T) **Id***

One thus deduces the expression from it from:
L
= E (- T) - E p
ref.
L
(T =) 0

In our case, = 0 thus:
= E - E p
with =
L
L
L
- T

Thus:

.

If L - R (p) < 0:

p=0 and = E
L
L

.
If L - R (p) = 0:
y
-
p =

R

= - p
E
E

L
L

Application to the way of loading

Moment 1:
= E = 200MPa and R p
R p
y
() = + = 100MPa bus p=0.
el
One has well - R (p) 0.

L

The criterion is not crossed, the evolution is elastic: = 100 MPa and NR = 100kN

L

Moment 2:

The criterion is reached:

11

E

2

=

(

10

R

+ y =

2 0

. 2.109 × 35

. -

10 3 + 2.108 = 205MPa

L

L

)

11

9 (

)

E + R

2 10 + 2 02

. 10

NR = 102 5

. kN

and p =

-

2.475 10 3

.

Moment 3:

One discharges elastically:

= - p

E

E

= 11

-3 -

-
2 10 15 10
2.475 10 3
(.
.
) = -195MPa
L
L

NR = -97. K
5 NR

Moment 4:
One plasticizes again:
The criterion is written: - RP - y = 0 with p = p + p where p
-3
= 2 475
.
10
1
2
1
One thus obtains:

y
-
p =
- p
2
R
1

= - E p
= - E (p - p

1
2)
R
E y

=
2nd p
= -207 9

. MPa

R + E
1

-
-

R

And thus NR = -103
K
95
.
NR

Moment 5:
One discharges elastically:
= - p
E
E
= 11 -3 -
-
2 10 2 10
10395 10 3
(
.
) = 192 1
. MPa
L
L

NR = 96. K
05 NR

Moments 6 and 7:
The reasoning is identical
One finds:
NR
=
.
10587kN
(inst.6)

NR
= - .
44
K
13 NR
(inst.7)
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNL112 - Bar subjected has a cyclic thermal loading
Date:
09/04/02
Author (S):
C. CHAVANT
Key: V6.02.112-A Page: 7/14

Kinematic work hardening

The method of calculation is identical, but in this case, the criterion of plasticity is written:

*(- **X**) - **y** 0*
eq
3
p
p
E E
with X
C ()
C
T
p
=
=
=

eq
eq

2
E - And
With the preceding notations, the criterion is written:
- p

- y
R
0
L
And = p ± y
R
(according to the direction of the flow).
L

Application to the way of loading

Moment 1:
The criterion is not crossed, the evolution is elastic: = 100 MPa and NR = 100kN
L

Moment 2:
The criterion is reached: - p - y
R
= 0
L
= p + y
R
=
9 ×
-
2 02 10
2.475 10 3 + 2 108
.
.
= 205MPa
L

Moment 3:
One discharges elastically:
= - p
E
E
= 11
-3 -

-
2 10 15 10
2.475 10 3
(.
.
) = -195MPa
L
L

NR = -97. K
5 NR

Moment 4:
One a:
- R
p - y = 0 with
p
-3
= 2 475
.
10

1
p = p - p
1
2
y
+
p = p -
2
1
R
= - E p
= - E (p - p
1
2)

y
+
= - E

198MPa

R

= -
NR = 99
- kN

Moment 5:
One discharges elastically:
= - p
E
E
= 11 -3 -
-
2 10 2 10
9 9 10 4
(
.
) = 202 MPa
L
L

NR =
K
101 NR

Moments 6 and 7:
The reasoning is identical
One finds:
NR
=
K
103 NR
(inst.6)

NR
= -47kN
(inst.7)

2.1.2 Model of Pinto-Menegotto

This model is described in the Handbook of Reference of Code_Aster [R5.03.09] [bib1]. The constitutive law
steels is made up of two distinct parts: the monotonous loading composed of three zones
successive (linear elasticity, plastic stage and work hardening) and the cyclic loading where the way
between two points of inversion (semi-cycle) is described by an analytical curve of expression of the type
= F ().
As previously the imposed deformations are thermal deformations: =
- T

2.1.2.1 Case without buckling

First loading

.
Linear elasticity: = E

Moment 1:
NR = E S = 11 × -3 × -

2 10
1 10
5 10 4 = 100kN

.
Plastic stage: = y
- 4
.
Polynomial of degree 4: = -
(
- 0) U

U

known

y -
U
H
Moment 2:
=
-3
> =
-
3510
2.310 3
.
.
, one uses the polynomial of degree 4:
H
= 209 416
.
MPa
and NR = 104 708
.
kN

Cycles

Semi-cycle 1:

0 are determined:
p
0 = 0 - 0
-3
-3
-3
= 351
. 0 - 1.10 = 2 51
. 0 bus 0 =
.
p
R
y
R
(inst.2)

Then 0:

0 = E 0
9
-3
= 210 × 2 5
. 10 = 5MPa
H
p

From where 1 = 0 sign (0
-) + 0

= -200 + 5 = -195MPa
y
y
p
.
One calculates then 1:
y
1 - 0
6

-
(- 195 - 209 416
.
) 10
1 = 0
y
R
3
-3
+
= 351
. 0 +
= 1477
.
10
y
R
E
11
2 0
. 10

One determines thus

= F (), defined by:

1 - B
E
B

=
+
H

,
1 R
with B =

(

1 + (R
))
E

- 0
=
R
1 - 0
y

R

- 0
=
R

1 - 0
y
R

0
With
0

p
0
1
p
1
p =
and R = R -

1 - 0
0
With
0
+
y
R
2
p

One obtains 0 = -12
. 3 and R1 = 35
. 1
p

One can then calculate the value of at moments 3 and 4:

Moment 3:

- 0
-3
-3

(inst.)
3
R
.
1510
- .
3510
=
=
= .
0 988
1 - 0
-3
-
.
1477 10
- .
35
3
y
R
10

1 - B

1 - 0 0
. 1

B

=
+
0 0
. 1 0 988
.
0 8
. 2
1 R
=
×
+
=

3 51
.
1/3 51
.
(

1 + (R
))
1
(+ (0 988
.
)
)

and =
(1 - 0) + 0 = .
0 82 × (-195 -
.
209
)
416 +
.
209 416 = -
y
R
R
122 MPa

from where NR = - K
61 NR

Moment 4:

One uses the same method, with = 0.
= 17
. 3
= 05
. 6

= -20MPa
NR = -10kN

Semi-cycle 2:

Moment 5 and 6:
The method of calculation is identical, one determines:
1, 2, 2, 1, R2, then
F (
=
) and
F (
=
)
p
y
y
p
(inst.)
5
(inst.)
5
(inst.6)
(inst.6)
and finally (inst.)
5 and (inst.6).

Semi-cycle 3:

Moment 7: Idem

2.1.2.2 Case with buckling

First loading

Identical to the preceding case.

Cycles

Semi-cycle 1 (compression):

The method of calculation is identical, but the value of the slope of the asymptote is modified: A new coefficient bc is calculated:

11
E

210

-3
B

.
0 01 .
1.477 10

8
8

B
has (.
5 0 L/D) E
y
=
-

-
×

= .
0 006 × *(.*
5 0 - *.*
5 9) E

2 10 - *.*
1

36 10
C
= ***-*** *.*
0 0057
It is necessary then, as in the model without buckling, to determine N. The reasoning is identical,
y
but one adds a complementary constraint in order to position the curve correctly by
S
report/ratio with the asymptote.
B - B
0 0
. 1 +

0 0057
.
=
C
11
S
Sb E
= 0 028
.
× 0 0
. 1× 2 10 ×
= 0 8
. 7 MPa
1 - C
B
1 + 0 0057
.
110
. - L/D
where is given by: =
= 0 028
.

S
S
10 (C (L/D
E
) - 1.)
0

Semi-cycle 2 (traction):

.

In traction, one adopts a reduced Young modulus:

(- has 2
6
6
)
11
(-620×1.47 -
3 10)
E = E has + (. -) E has
(.
(
.) E
11
10
2 10
0 88
1 0 88
) 19
. 9 10 MPa
R

5
5

=
×
+ -
=

with A = 10
. + 5
(0
. - L/D)/7 5
. = 0 8
. 8
5

The remainder of the method is identical.

2.2
Results of reference

Normal effort NR constant on the bar

2.3
Uncertainty on the solution

No, the solution is analytical

2.4 References
bibliographical

[1]
Handbook of reference of Code_Aster [R5.03.09].
[2]
S. ANDRIEUX: Thermoelastoplastic TD 1 Three bars perfect Von Mises. In "Initiation with thermoplasticity in Code_Aster", HI-74/96/November 13, 1996 (manual of reference course).
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

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3 Modeling
With

3.1
Characteristics of modeling

The model is made up D `an element of bar (BAR).

Law of behavior: elastoplasticity with linear isotropic work hardening - Criterion of Von Mises

3.2
Characteristics of the grid

2 nodes.
1 mesh SEG2

3.3
Functionalities tested

Orders

DEFI_MATERIAU ECRO_LINE

STAT_NON_LINE COMP_INCR
VMIS_ISOT_LINE

OPTION
SIEF_ELNO_ELGA

4
Results of modeling A

4.1 Values
tested

Identification Moments
Reference
Aster *Variation*
%
normal effort NR
1
1.0000 105
1.0000 105 0
normal effort NR
2
1.0250 105
1.0250 105 0
normal effort NR

3
-9.7500 104
-9.7500 104 0
normal effort NR
4
-1.0395 105
-1.0395 105 0
normal effort NR
5
9.6050 104
9.6050 104 0
normal effort NR
6
1.0587 105
1.0587 105 0
normal effort NR
7
-4.4129 104
-4.4129 104 0

---

5 Modeling *B*

5.1 *Characteristics of modeling*

The model is made up D `an element of bar (BAR).

Law of behavior: elastoplasticity with linear kinematic work hardening - Criterion of Von Mises

5.2
Characteristics of the grid

2 nodes.
1 mesh SEG2

5.3
Functionalities tested

Orders

DEFI_MATERIAU ECRO_LINE

STAT_NON_LINE COMP_INCR
VMIS_CINE_LINE

OPTION
SIEF_ELNO_ELGA

6
Results of modeling B

6.1 Values
tested

Identification Moments
Reference
Aster *Variation*
%
normal effort NR
1
1.0000 105
1.0000 105 0
normal effort NR
2
1.0250 105
1.0250 105 0

normal effort NR
3
-9.7500 104
-9.7500 104 0
normal effort NR
4
-9.9000 104
-9.9000 104 0
normal effort NR
5
1.0100 105
1.0100 105 0
normal effort NR
6
1.0300 105
1.0300 105 0
normal effort NR
7
-4.7000 104
-4.7000 104 0

---

7 Modeling C

7.1 Characteristics of modeling

The model is made up D `an element of bar (BAR).

Law of behavior: model of Pinto-Menegotto without buckling (value of DASH lower than 5).

7.2
Characteristics of the grid

2 nodes.
1 mesh SEG2

7.3
Functionalities tested

Orders

DEFI_MATERIAU PINTO_MENEGOTTO
DASH
:
4.9

STAT_NON_LINE COMP_INCR
PINTO_MENEGOTTO

OPTION
SIEF_ELNO_ELGA

8
Results of modeling C

8.1 Values
tested

Identification Moments
Reference
Aster *Variation*
%
normal effort NR
1
1.0000 105
1.0000 105 0
normal effort NR

2
1.0470 105
1.0470 105 0
normal effort NR
3
-6.0777 104
-6.0777 104 0
normal effort NR
4
-9.1430 104
-9.1430 104 0
normal effort NR
5
7.6082 104
7.6082 104 0
normal effort NR
6
1.0125 105
1.0125 105 0
normal effort NR
7
-3.7965 104
-3.7965 104 0

---

9 Modeling D

9.1 Characteristics of modeling

The model is made up D `1 element of bar (BAR).

Law of behavior: model of Pinto-Menegotto with buckling (value of DASH higher than 5).

9.2 Characteristics of the grid

2 nodes.
1 mesh SEG2

9.3 Functionalities tested

Orders

DEFI_MATERIAU PINTO_MENEGOTTO
DASH
:
5.9

STAT_NON_LINE COMP_INCR
PINTO_MENEGOTTO

OPTION
SIEF_ELNO_ELGA

10 Results of modeling D

10.1 Values tested

Identification Moments
Reference
Aster Variation
%
normal effort NR
1
1.0000 105
1.0000 105 0
normal effort NR
2
1.0470 105
1.0470 105 0
normal effort NR
3
-6.0556 104
-6.0556 104 0
normal effort NR
4
-8.9078 105
-8.9078 105 0
normal effort NR
5
7.6905 105
7.6905 105 0
normal effort NR
6
1.0125 105
1.0125 105 0
normal effort NR
7
-3.8119 104
-3.8119 104 0

11 Summary of the results

The results calculated by Code_Aster are in excellent agreement with the analytical solutions.

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
V6.02.114 document

SSNL114 - Heavy cable with thermal dilation

Summary:

This test validates the calculation of the cables subjected to gravity, with or without thermal dilation.

.
Analyze static
.
Elastic behavior
.
Great displacements
.
2 modelings: CABLE and POU_D_T_GD

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

A cable length 2l0 at rest, in direction X, is subjected its actual weight (gravity in direction - Z). It is embedded with the ends O and B, themselves distant of 2L.

Z
2L
O
X
O
C
2l0
B

Initially, 2l0 = 2L=325m

The surface of the section of the cable is worth: 2.2783E-04 m ²

1.2
Material properties

E = 5.70 E+10 Pa
= 0.3 (modeling B only)
ALPHA: 2.3 E-5 K1
RHO: 2.844230E+03 kg/m3

1.3
Boundary conditions and loadings

Embedding out of O and B

Gravity: (9.81, 0.0, 0.0, - 1.0)

The temperature in the cable varies according to time:

Moment: 0. T=0 temperature. °C

Moment: 1.Température T=39.26 °C

(The temperature of reference is worth: 0.°C)

One thus treats:

at moment 0, a cable subjected to its only actual weight *at moment 1, a heavy cable subjected to a thermal dilation.*

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical solution:

For an extensible cable (elastic), subjected to its actual weight, displacement is worth:

S G
X (S) = aArgsh
L

+ E 0 has
s2
G s2
L 2
2
0
G L
Z (S) = has 1 +

+
- 1+ have
-
0

a2
E 2
a2
E 2
l0 G
solution of the equation L has
= aArgsh
Al
F (A)

has +
=
E
0

With S X-coordinate curvilinear, ranging between - l0 and l0. One is interested here in the arrow in the center (point C):

L 2
G L 2
Z (C) = has - 1 + 0 have -
0
a2
E 2

l0 G
solution of the equation L has
= aArgsh
Al
F (A)

has +
=
E
0

The only difficulty in the calculation of this solution is the resolution of the equation L = F (A). This resolution was numerically made (FORTRAN program using the routine of research of zero of Aster ZEROFO).

Note:

In the case of thermal dilation, the solution is the same one as previously, while considering that the initial length 2l0 is equal to its increased initial length 2L linear dilation:
l0 = L (1+ALPHA*T)*

2.2
Results of reference

.
Displacement in Z at the point C

2.3
Uncertainty on the solution

Semi solution - analytical: the numerical resolution of the equation L = F (A) gives a value to 103 near.

2.4 References
bibliographical

[1]
C.CONEIM "On the approximation of the equations of the statics of the overhead cables in presence of electromagnetic fields of forces". Thesis and note HI/3640-02 (February 1981)

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3 Modeling
With

3.1
Characteristics of modeling

elements CABLE

3.2
Characteristics of the grid

27 elements CABLE

3.3 Functionalities
tested

Orders
Keys
AFFE_MODELE AFFE
MODELING
CABLE
[U4.22.01]
STAT_NON_LINE COMP_ELAS
RELATION
:
CABLE [U4.32.01]
STAT_NON_LINE COMP_ELAS
DEFORMATION
GREEN [U4.32.01]

4
Results of modeling A

4.1 Values
tested

DZ (C)
Moment Not Identification Reference Aster %
(m)
diff
0. C
DZ 6.352
-6.3536
0.025
1. C
DZ 8.195
-8.1945
0.012

4.2 Parameters
of execution

Version: 5.1
Machine: SGI/ORIGIN 2000

Obstruction memory: 64 Mo
Time CPU To use: 6.5 seconds

---

5 Modeling

B

5.1
Characteristics of modeling

elements POU_D_T_GD

In order not to disturb the solution, the values of inertias of inflection are arbitrarily selected small: for a section of surface 2.2783000000000128E-4, one poses IY=IZ= 1.0E-4

Let us announce however that values cannot be taken smaller without causing error in the resolution.

5.2
Characteristics of the grid

27 elements POU_D_T_GD

5.3 Functionalities tested

Orders
Keys
AFFE_MODELE AFFE
MODELING
POU_D_T_GD
[U4.22.01]
STAT_NON_LINE COMP_ELAS
RELATION
:
ELAS_POUTRE_GD
[U4.32.01]
STAT_NON_LINE COMP_ELAS
DEFORMATION
GREEN
[U4.32.01]

6
Results of modeling B

6.1 Values

tested

DZ (C)
Moment Not Identification
Reference Aster %
(m)
diff
0. C
DZ 6.352
-6.3269
0.4
1. C
DZ 8.195
-8.2109
0.2

6.2 Parameters
of execution

Version: 5.1
Machine: SGI/ORIGIN 2000

Obstruction memory: 64 Mo
Time CPU To use: 7.1 seconds

7
Summary of the results

The results show that one can obtain the solution of the problem of the heavy cable with good precision for the elements of cable (0.02%), and a precision acceptable for the elements POU_D_T_GD (0.4%).

Indeed, this mechanical problem is difficult for the algorithm of resolution, because the solution cannot to be obtained that with the assumption of great displacements. Convergence can be obtained only with the geometrical matrix of rigidity.

Titrate:
SSNL115 - Beam cantilever in pure bending

Date:
03/05/02
Author (S):
J.L. Key FLEJOU
:

Organization (S): EDF/ERMEL/PEL

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.115

SSNL115 - Beam cantilever in pure bending

Summary:

This test makes it possible to check the calculation of the internal variables to nodes "VARI_ELNO_ELGA" then values
averages with nodes "VARI_NOEU_ELGA" starting from the "VARI_ELGA". This test relates to the following elements:
POU_D_TG, POU_D_T, POU_D_E.

1

Problem of reference

1.1 Geometry

X
F
F
N1
N2
N3
Z
2000
2000

Length of the bar: 4000.0mm

1.2
Properties of material

Elastic characteristics:

E = 2.1E+05 MPa, NAKED = 0.3, RHO = 7.85E-06 Kg/mm3, ALPHA = 6.7E-06/°C

Plastic characteristics:

ECRO_LINE
:
D_SIGM_EPSI = 1.05E+05 MPa, SY = 240.0 MPa
ECRO_FLEJOU
:
EP = 1.05E+05 MPa, KNOWN = 360.0 MPa, SY = 240.0 MPa, PUISS = 0.65,
VMIS_POUTRE
:
NP = 2.2344E+05 NR, MEY = 3.336336E+06 Nmm, MPY = 5.258208E+06
N.mm,

CAY = 8.100000E-01, CBY = 3.000000E-03, MEZ = 1.490016E+06 N.mm,
MPZ = 2.650968E+06 N.mm, CAZ = 8.100000E-01, CBZ = 3.000000E-03,
MPX = 5.474160E+05 N.mm

Mechanical characteristics of the beam: BEAM: SECTION = "GENERAL",

With (mm2) IY

(mm4) IZ
(mm4) JX
(mm4) JG
(mm6) IZR2
(mm5)
9.3100E+02 6.88087E+05 1.76294E+05 1.52060E+04 5.60390E+06 7.95527E+06

AY
AZ
EY (mm)
EZ (mm)
IYR2 (mm5)
1.1702E+00 1.1964E+00 2.3446E+01 0.0000E+00 0.0000E+00

1.3 Boundary conditions and loadings

With the node N1 blocking of all the DDL: DX, DY, DZ, DRX, DRY, DRZ

Force imposed on the nodes N2 and N3 following axis X: F = 500N.

---

2 Reference solution

2.1 Method

For the following models of beams: POU_D_TG, POU_D_T, POU_D_E, the diagram of integration fact on a finite element of type "SEG2" with 3 points of integration [R3.01.00] [R3.01.01] [R3.08.01]. following figure represents a "SEG2" with the position of the points of integration.

N1 G1
G3
G2 N2
-1
-
G
1

G
0
3
with: G =

5

The function allowing to calculate the values with the nodes starting from the values at the points of integration
is degree 2. The following expression makes it possible to calculate the value interpolated with a X-coordinate, to leave
values known at the point of integration.

V

V

g1
g2

V () =
.
.
1 V

-

+

g3. 1 -
. 1
.
.
1
2

+

+

+

G
G

G

G

2 G
G

with Vg1, Vg2, Vg3 values known at the points of integration.

One finds although V (G) = Vg1, V (0) = Vg3, V (G) = Vg2. The following figure shows an example of interpolation realized with the preceding function.
1.40
1.20
1.00
0.80
0.60
Values at the points of integration

Function of interpolation
0.40
0.20
0.00
-1.00
-0.80
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
1.00

2.2 Sizes and results of reference

Calculation of the variables intern with nodes "VARI_ELNO_ELGA" then average values with the nodes "VARI_NOEU_ELGA" starting from the "VARI_ELGA".

2.3 Uncertainties on the solution

None on the values interpolated with the nodes starting from the values known at the points integration.

3 Modeling
With

3.1
Characteristics of modeling and the grid

The grid consists of 2 linear elements: "POU_D_TG"

3.2 Functionalities
tested

Orders

CALC_ELEM OPTION
VARI_ELNO_ELGA
CALC_NO OPTION VARI_NOEU_ELGA

4
Results of modeling A

4.1 Values
tested

.
The V7 variable at the points of integration G1, G2, G3 for the two meshs.
These values are obtained directly after a STAT_NON_LINE. They are the data
of entry of the functionality to be tested.

VARI_ELGA
V7 at the G1 point
V7 at the G3 point
V7 at the G2 point
Net M1
8.32692E-01
6.01116E-01
3.69098E-01
Net m2
2.67395E-01
1.51149E-01
4.04224E-02

.

The V7 variable with the N1 nodes, N2 and N3.
The theoretical values are obtained using the function of interpolation. Values of Code_Aster are obtained after a CALC_ELEM, option “VARI_ELNO_ELGA”.

VARI_ELNO_ELGA
Theoretical value
Code_Aster
% relative Error
Net M1, V7 with the N1 node
8.99996E-01
8.99996E-01
< 1.0E-04
Net M1, V7 with the node N2
3.01499E-01
3.01498E-01
< 1.0E-04
Net m2, V7 with the node N2
3.02259E-01
3.02259E-01
< 1.0E-04
Net m2, V7 with the N3 node
9.23832E-03
9.23854E-03
2.4E-03

.

The V7 variable with the N1 nodes, N2 and N3.
The “VARI_NOEU_ELGA” are the averages of the “VARI_ELNO_ELGA” calculated with the nodes, they

are obtained for Code_Aster by a CALC_NO.

VARI_NOEU_ELGA
Theoretical value
Code_Aster
% relative Error
V7 with the N1 node
8.99996E-01
8.99996E-01
< 1.0E-04
V7 with the node N2
3.01879E-01
3.01879E-01
< 1.0E-04
V7 with the N3 node
9.23832E-03
9.23854E-03
2.38E-03

5 Synthesis

The results show the correct operation of the passage of the variables of the points of Gauss with nodes.

Organization (S): EDF/AMA, SINETICS

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.116

SSNL116 - Length of cable with gas insulation

Summary:

The problem is quasi-static nonlinear in mechanics of the structures.

One analyzes the behavior of a length of cable with gas insulation, hidden with a low depth modelled by bars. The interaction with the ground is taken into account by elements of bar with nonlinear behavior. In the vertical direction, this behavior is asymmetrical.

Only one modeling implements this IGC, whose grid is obtained by an associated FORTRAN program with the test.

Titrate:
SSNL116 - Length of cable with gas insulation

Date:
19/08/02
Author (S):
J.M. PROIX, B. QUINNEZ, J.C. Key MASSO
:
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1
Problem of reference

1.1 Geometry

A section of C.I.G (correspondent to an experiment carried out on the site of the Renardières). The cable
is modelled by elements of beam of Euler. To model the behavior of the ground, with each
net line, one associates 6 bars: 3 in each node of the mesh. In each node, a bar
is directed in the same direction that the C.I.G, and allows to take into account the axial loads
ground on the C.I.G. A bar is directed according to the vertical, and makes it possible to take into account the action
(asymmetrical) of the ground following the vertical. Third is directed in order to supplement the trihedron.
PC02
PC01

The characteristics of the sections are:

Elements of BEAM: circular section, external Ray 0.25765, thickness 0.01
Elements of BAR: unspecified section, of A=1 surface (without physical significance)

1.2
Material properties

C.I.G

elasticity
E = 7.2E10 Pa
= 0,3

=22.4E-6
plasticity of the beams
NP = 1.2699E6
MEY = 1.248E5,
MEZ = 1.248E5,
MPX = 1.E10

MPY = 1.589E5,
MPZ = 1.589E5,
CAY = 0.84,
CAZ = 0.84,
CBY = 0.0012,
CBZ = 0.0012,
plasticity with work hardening
Ep=3.7E10 Sy=75.E6,
Known = 190.E6,
PUISS = 0.29
of Fléjou

Horizontal bars

elasticity
E = 5000000.Pa = 0,3
= 0.

Linear work hardening
D_SIGM_EPSI
=
SY = 5000. Pa

1000000 Pa
Vertical bars

elasticity
E = 5000000.Pa = 0,3
= 0.

Linear work hardening

DT_SIGM_EPSI =
SY_T =
DC_SIGM_EPSI
=
SY_C = 10000.0
1000000.,
5000.0000000000, 1000000.,
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1.3
Boundary conditions and loadings

The ends (off-line to the IGC) of all the bars are blocked. Point PC01 is embedded. Point PC02 has all its blocked DDL, except DZ for which one imposes the history of displacement following:

Moment
DZ (m)
0
0
1
-0.004
2
-0.004
3

0.002
4
0.002

2
Reference solution

2.1
Method of calculation used for the reference solution

Solution of nonregression.

2.2
Results of reference

Values of vertical displacement and the normal bar tension vertical with the node with T = 0.1, 1. , 2.6 and 4s.

Moment Dz NR
0.1 -4
10-4 -2000
1. -4
10-3 -12000
2.6 -4
10-4 5200
4. 2
10-3 7600

2.3
Uncertainty on the solution

Solution of nonregression.

2.4 References
bibliographical

[1]
J.C. MASSON, A. STROOBANT: "Study of displacements and the constraints due to cyclic heating D `a buried model of Cable with Gas Insulation" Notes EDF RETD HT-2C/99/22//A
Handbook of Validation

---

3 Modeling With

3.1 Characteristics of modeling

Modeling: 10 elements of beam for the C.I.G, 60 elements of bar

3.2 Characteristics of the grid

70 meshs SEG2

3.3 Functionalities tested

Order
Key word factor
Simple key word
Argument
DEFI_MATERIAU
ECRO_FLEJOU
DEFI_MATERIAU
ECRO_ASYM_LINE
VMIKS_POUTRE

STAT_NON_LINE
COMP_INCR
RELATION
VMIS_ASYM_LINE
COMP_INCR
RELATION
VMIS_POU_FLEJOU
COMP_INCR
RELATION
VMIS_ISOT_LINE

4
Results of modeling A

4.1 Values
tested

Vertical displacement Dz, at point PC02

Moment Reference
Aster %
difference
0.1 -4
10-4 -4
10-4 0
1. -4
10-3 -4
10-3 0
2.6 -4
10-4 -4
10-4 0
4. 2
10--3 2
10-3 0

Normal effort NR, at point PC02, in the vertical bar.

Moment Reference
Aster %
difference
0.1 -2000
-2000

0
1. -12000
-12000
0
2.6 5200
5200
0
4. 7600
7600
0

4.2 Remarks

The program making it possible to build the grid as well as the data of this program are associated the test (files ssnl116a.38 and ssnl116a.39).

5
Summary of the results

This test makes it possible to validate behavior VMIS_ASYM_LINE on a real structure.
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Code_Aster ®
Version
6.0

Titrate:
SSNL117 - Bend in elastoplastic inflection

Date:
24/10/02
Author (S):
J.M. PROIX, P.MASSIN Key
:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.117

SSNL117 - Bend in inflection in elastoplasticity

Summary:

This test validates the modeling of the phenomena of ovalization in pipings in the field elastoplastic with the elements PIPE: an elbow, prolonged by right pipes is subjected to an inflection in its plan. Piping is thick (of size similar to the elbows of the primary education circuits). reference solution is numerical: it is obtained with Code_Aster using a grid 3D of the elbow.

Two modelings make it possible to validate the elements PIPE (with right and bent elements with 3 nodes for modeling A and of the right and bent elements with 4 nodes for modeling B) in elastoplasticity.

In modeling B, a term of “total” rotation, developed by EDF, ECA and FRAMATOME [bib2], for pipings under seism, is introduced via a Python macro-order.

Titrate:
SSNL117 - Bend in elastoplastic inflection

Date:
24/10/02
Author (S):
J.M. PROIX, P.MASSIN Key
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1
Problem of reference

1.1 Geometry

Piping bent in plan XY. The right parts have as a length L = 1 Mr.
The elbow has as a radius of curvature: Rc = 1.25m

With
L
B
Rc
L
Y
Mz
C
D
X

The tubular section has for average radius R = 395.5mm and a thickness E = 77mm.

1.2
Properties of materials

The material is elastoplastic with isotropic linear work hardening.
E = 2.E11 Pa
= 0.3
Elastic limit SIGY = 200.106 Pa

Modulate work hardening D_SIGM_EPSI = 2.1010 Pa

1.3
Boundary conditions and loadings

Embedding of A (blocked DDL of beam, but free DDL of ovalization).

Moment MZ imposed in D increasing:

Increment 1
Mz = 3086702.1520853 Nm

10 equal increments until:

Increment 11
Mz = 7091146.5935484 Nm

1.4 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

Comparison with other numerical results obtained with Code_Aster (version 4.3 [bib1]) with one grid 3D of the elbow and the right parts, connected at the ends with right beams. This grid 3D comprises 1024 meshs HEXA20. A modeling of the elbow in elements COQUE_3D gave results comparable with calculation 3D (see [§2.2]).

2.2
Results of reference

For one moment applied Mz in D, displacement DY of the same point D is worth [bib1]:

Moment
Dy not D (m) (3D)
Dy not D (m) (COQUE_3D)
0. 0.
0.
3.08670D+06 1.09349D02
1.08875D02
3.48715D+06 1.23536D02

3.88759D+06 1.37891D02
1.37381D02
4.28804D+06 1.52727D02

4.68848D+06 1.68128D02

5.08892D+06 1.84085D02

5.48937D+06 2.01272D02

5.88981D+06 2.20836D02

6.29026D+06 2.43502D02

6.69070D+06 2.70438D02

7.09115D+06 3.04756D02

2.3
Precision on the results of reference

Owing to the fact that the reference solution is numerical, one can evaluate the precision according to [§2.2] to 2% by
comparison of the 3D solutions and COQUE_3D.

2.4 References
bibliographical

[1]
J.M. PROIX, A. BEN HAJ YEDDER: "Project CACIP: study of a piping bent in inflection". Note EDF/DER HI-75/98/001/0
[2]
C. CHURN (SEPTEN), MN. BERTON, NR. BLAY (ECA), F. THE BRETON ONE (FRAMATOME-ANP): "Project of new coding of the criteria of dimensioning seismic of pipings". Note EDF/SEPTEN E-N-ES-MS/01-01004-A.

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3 Modeling
With

3.1
Characteristics of modeling

The structure is with a grid in elements pipes (meshs SEG3, modeling PIPE).

3.2
Characteristics of the grid

20 meshs SEG3 (the grid is regular: 10 elements in the elbow, 5 in each right pipe)

3.3 Functionalities
tested

Orders

AFFE_MODELE
MODELING
PIPE
STAT_NON_LINE
TUYAU_NCOU
AFFE_CARA_ELEM
ORIENTATION
CARA
GENE_TUYAU
STAT_NON_LINE
TUYAU_NSEC

4
Results of modeling A

4.1 Values
tested

Increment of load
DY of the point D
Reference
Aster %
diff
1: Mz =3.08670D+06Nm

DY (m)
1.09349D02
1.118834D02
2.3
8: Mz =5.88981D+06Nm
DY (m)
2.20836D02
2.269183D02
2.75

5 Modeling B

5.1 Characteristics of modeling

The structure is with a grid in elements pipes with 4 nodes (meshs SEG4, modeling PIPE).

5.2 Characteristics of the grid

11 meshs SEG4 (5 elements in the elbow, 3 in each right pipe)

5.3 Calculation of the term of "Total" Rotation

This term of rotation " total " was developed within the framework of a tripartite action EDF-CEA-FRAMATOME [bib2], for a future integration in the code of dimensioning RCC-M.

It is expressed starting from rotations of two points representative of the elbow (entered and left), by:

$$R_G = \sqrt{R_X^2 + R_y^2 + R_Z^2}$$

where

$R_X = DRX_{sortiecoude} - DRX_{entréecoude}$

$R_y = DRY_{exit\ bend} - DRY_{entry\ bend}$

$R_Z = DRZ_{sortiecoude} - DRZ_{entréecoude}$

This term is calculated by the macro-order Python MACR_ROTA_GLOBALE which is integrated in body of the command file. The result of this macro-order is an Aster function of total rotation according to the moment. A test of not-regression comes to validate this function.

5.4 Functionalities tested

Orders

AFFE_MODELE
MODELING
PIPE
STAT_NON_LINE
TUYAU_NCOU
AFFE_CARA_ELEM
ORIENTATION
CARA
GENE_TUYAU
STAT_NON_LINE
TUYAU_NSEC
CALC_ELEM
EQUI_ELGA_SIGM
EQUI_ELGA_EPSI
CALC_ELEM
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
VMIS
MACR_ROTA_GLOBALE

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6
Results of modeling B

6.1 Values tested

Increment of load
DY of the point D
Reference
***Aster** %*
diff
1: Mz =3.08670D+06Nm
DY (m)
1.09349D02
1.097089D02
0.3
8: Mz =5.88981D+06Nm
DY (m)
2.20836D02
2.185D02
1.1

Test of not-regression for total rotation:

Moment
Aster
5.88981E+06 9.26451E03

Tests of nonregression for the options of CALC_ELEM:

Component option
Net
Not Under-point
Number Aster
of order
EQUI_ELGA_SIGM
VMIS
M1 2
61
1 4.675554583E+07
EQUI_ELGA_SIGM
VMIS
M1 3
55
3 5.608141169E+07
EQUI_ELGA_EPSI
INVA_2
M1 1
77
4 2.590281477E-04
EQUI_ELGA_EPSI
INVA_2
M1 1
8
5 1.769279362E-04

Option Field
Component
Net
Not
Number
Aster
of order
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
MAX
M1 1 1 8.84099E+07
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
MIN

M1 1 5.88318E+06
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NCOUMAX
M2 2 1 1.00000E+00
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NCOUMIN
M3 3 1 1.00000E+00
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NSECMAX
M4 1 1 1.20000E+01
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NSECMIN
M5 2 1 1.60000E+01
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NPCOUMAX
M6 3 1 1.00000E+00
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NPCOUMIN
M7 1 1 2.00000E+00
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NPSECMAX
M8 2 1 3.00000E+00
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
NPSECMIN
M9 3 1 3.00000E+00
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
MAX
M1 2 4 1.27695E+08
VALE_NCOU_MAXI
EQUI_ELGA_SIGM
MIN
M5 3 5 2.20755E+07

7
Summary of the results

The reference solution not being analytical, but numerical (obtained by a modeling 3D), the noted variations (from 1% to 3%) can be regarded as reasonable. To obtain one better correspondence of the 3D solutions and PIPE, it would be appropriate to model the right parts over a bigger length, and to adopt a finer grid for each modeling. This was not made within the framework of this test, to keep reasonable execution times.

V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.118

SSNL118 - Bar subjected to a field speed of wind

Summary:

This test relates to the validation of the application of the loadings of wind on the linear elements. loading is described by fields speeds of wind.

This problem makes it possible to test:
· linear finite elements [bars, cables, beams (except the curved beams)] with loadings follower of nature "wind",
· loadings representing speeds of wind:
- reading of the data of the fields of wind,
- projection of the fields of wind attached to the group of dots on the grid deformed of structure,
- calculation relative speed,
· the taking into account of the function giving the force distributed according to the relative speed of structure,
· the reactualization of the geometry to take account of great displacements and large rotations.

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1
Problem of reference

1.1 Geometry

y
Kbx
B1
Wp
W
B
2
Kby
+o
G
Kax A1
O
X
Kay
Wind
With

Length of the bar: 1.5m
Stiffnesses of the discrete ones: Kax, kay, kbx, kby

1.2
Properties of materials

Material for the linear element: E = 2.0E+08 Pa, = 1000.0 Kg/m3

Mechanical characteristics of the bar: section = "CIRCLE", radius = 0.5 m, ep = 0.5 m

Stiffness of the springs:
Kxa Kya Kxb Kyb
10 N/m
20 N/m
25 N/m
30 N/m

1.3
Boundary conditions and loadings

At points A and b: blocking of the DDL: DX, DY, DZ
At the points A1 and B1: blocking of the DDL: DZ

Characteristics of the field speed of wind, along the axis y:

Vy wind (m/s)
20
10
1.0 1.1
12 12.1
time (dry)

1.4 Conditions
initial

The bar forms an angle of 30° (0 = 30°) compared to the axis "X".
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Version
6.0

Titrate:
SSNL118 - Bar subjected to a field speed of wind

Date:
19/08/02
Author (S):
J.L. *Key* ***FLEJOU***
:
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2
Reference solution

2.1 Equations
of balance

Effort at the A1 point

- kxa. X
has

with displacements of the A1 point

F =
- kya. y
has
teststemxà
= L.co (S O
)/2 - L.co (S O
+)/2 + X

L. (y
a.kya.cos (+) - teststemxà
.kxa.sin (+)) /2 ya
= L.si (
N O
)/2 - L.si (
N O
+)/2 + y
O
O

Effort at the B1 point

- kxb. X
B

with displacements of the point B
1

Bfr =
- kyb. y
B
xb
= - L.co (S O
)/2 + L.co (S O
+)/2 + X

L. (- y
b.kyb.cos (+) + xb
.kxb.sin (+)) /2 yb
= - L.si (
N O
)/2 + L.si (
N O
+)/2 + y
O
O

Effort due to the wind

· Vitesse of the wind in a point M bars
Vvx

Vr = Vvy

with Vvx, Vvy: speed of the wind following the axis “X” and centers it “y”.
0

· Vitesse relating perpendicular to the bar to the point M:
Sin (qo + Q). (Vvy
-
. Cos (qo + Q) +Vvx.Sin (qo + Q))

Vp = Cos (qo + Q). Vvy
(
. Cos (qo + Q) - Vvx.Sin (qo + Q))

0

· Force due to the wind in a point M
Vp
Fvent (M) = Fcx (M).
in our case one chooses Fcx
||V
(M) = ||Vp||
p||

one thus obtains Fvent (M) = Vp
· Résultante from the force due to the wind on the bar
L.Sin (qo + Q). (V
- vy. Cos (qo + Q) +Vvx.Sin (qo + Q))

Fvent = L.Cos (qo + Q). V
(vy. Cos (qo + Q) - Vvx.Sin (qo + Q))

0

Equilibrium equation: F + Bfr + Fvent = 0

2.2
Sizes and results of reference

Displacements of the points A1 and B1 at the moments: 1. S, 1.05 S and 2. S. These moments correspond respectively at speeds of wind of 10, 15 and 20m/s

The resolution of the 3 equilibrium equations, projection of "F + Bfr + Fvent = 0", is done by iterations.
3 unknown factors of the problem are the position of the centre of gravity of the bar G: (X, y) and variation of

the angle: .

In Code_Aster, the effect of the wind is taken into account by a force distributed along the element linear. The expression of the module of this force distributed is as follows:

1
Fcx (v) =. V2.Cx (v). D
2
H

where Fcx (v): is the module of the force distributed along the cable in N/m, depend on speed.

: is the density of the air in kg/m3.
V: is the relative speed of the cable in m/s.
Cx (v): is the coefficient of drag of the cable, depend on relative speed.
Dh: is the hydraulic diameter of the cable in Mr.

To obtain a simple analytical reference solution, the function Fcx (Vp) is taken equalizes with ||Vp||. In the command file of Code_Aster the function of Fcxv is thus defined in a following way
:

```
FCXV=DEFI_FONCTION (
NOM_PARA=' VITE',
VALE= (
0.0 ,
0.0,
10.0 ,
10.0 ),
PROL_GAUCHE=' LINEAIRE',
PROL_DROITE=' LINEAIRE',
)
```

2.3
Uncertainties on the solution

None. The resolution of the equilibrium equation is done by iterations with a <1.0E-09 error.

2.4 Reference bibliographical

[1]
HM77/01/046/A. "M7-01-70 Project. The evolution of Code_Aster for best taken in count loadings of dynamic wind on the linear elements ".
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures

3 Modeling
With

3.1
Characteristics of modeling and the grid

The linear element: “BAR”
The discrete ones: “DIS_T”

3.2 Functionalities
tested

Orders

LIRE_RESU
EVOL_CHAR
VITE_VENT
AFFE_CARA_ELEM
BAR
FCX
AFFE_CHAR_MECA
EVOL_CHAR
DEFI_FONCTION
NOM_PARA
QUICKLY

STAT_NON_LINE
TYPE_CHARGE
SUIV
DEFORMATION
PETIT_REAC

4
Results of modeling A

4.1
Sizes tested and results

Balance is calculated at the moments: 1. S, 1.05 S and 2. S.

Balance to 1. S
Analytical
Code_Aster
Relative error
teststemxà (m)
-0.2092 -0.2036
0.026
ya (m)
0.3276 0.3270
0.002
xb (m)
-0.1418 -0.1434
0.011
yb (m)
0.1965 0.1945
0.010
Balance to 1.05 S
Analytical
Code_Aster
Relative error
teststemxà (m)
-0.2885 -0.2816
0.024
ya (m)
0.5050 0.5029
0.004
xb (m)
-0.1942 -0.1962
0.010

yb (m)
0.3105 0.3074
0.010
Balance to 2. S
Analytical
Code_Aster
Relative error
teststemxà (m)
-0.3502 -0.3423
0.023
ya (m)
0.6890 0.6850
0.006
xb (m)
-0.2327 -0.2352
0.011
yb (m)
0.4324 0.4279
0.010

4.2 Parameters
of execution

Version:
6.02.07
Machine:
IRIX64
Obstruction memory:
20 Megawords
Time CPU To use
:
15.0 seconds
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Version
6.0

Titrate:
SSNL118 - Bar subjected to a field speed of wind

Date:

5 Synthesis

The test shows the good taking into account of the loadings of the speed type of wind on the elements linear.

Organization (S): EDF-R & D /AMA, LMT Cachan

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Document: V6.02.119

SSNL119 - Static response of a concrete beam armed (rectangular section) with behavior not linear

Summary:

The problem consists in analyzing the response of a concrete beam reinforced via a modeling multifibre beam [R3.08]. This test corresponds to a static analysis of a beam having a behavior non-linear. The concrete is modelled with the law of behavior of Borderie in its version 1D [R7.01.07].

1 Characteristics general

1.1 Geometry

y
X
5.400 mm
500 mm
Frameworks HA8 separated by 100 mm
5.000 mm
20 mm
44 mm
20 mm
32 mm
28
y
500 mm
Z
Tally HA8 spaced 100 mm
232
200 mm
44 mm

1.2
Material properties

concrete: E = 37.272 MPa, = 0.2,
1
ft = 3.9 MPa, FC = 38.3 Mpa, FC = 2.0.103, Gf = 110 J/m

steel: E = 200.000 MPa, = 0.33, E = 400 MPa, AND = 3.280 MPa

1.3

Boundary conditions and loadings

Simple support in b: Dy = 0
Support "doubles" in a: dx = Dy = dz = 0 just as X-ray = ry = 0.

Loading: monotonous displacement Dy to the bottom applied to semi-span (deflection test 3 points).

NB: the transverse reinforcements are not taken into account in calculations.

2
Reference solution

The reference solution is a calculation carried out using the computer code EFICOS [bib1]. It is about one
calculation multi-layer (2D) with the same models for materials. The elements do not comprise
that a point of Gauss according to their axis and the total resolution is made by an algorithm with matrix
secant.
To have comparable results in terms of localization and terms of local results
(constraints and deformations at the point of Gauss nearest to the medium of the beam), calculation with
EFICOS (1 point by element) is carried out with 10 elements) by half span while calculation
with ASTER (2 points per element) is realized with 8 elements by half span.
This difference in integration is the principal source of the differences noted in
paragraph 4.

3 Modeling

3.1
Characteristics of modeling

Longitudinal grid of the beam:
It is composed of 17 nodes and 16 pairs of elements POU_D_EM (16 elements for the concrete and 16 for
steel).

Cross section of the beam:
The concrete is modelled by a grid (AFFE_SECT) composed of 2 X 20 quadrilaterals (40 fibres)

Steel is modelled by 4 specific fibres (AFFE_FIBRE)

The concrete is modelled with the model of damage of Christian Borderie in version 1D (LABORD_1D) [R7.01.07].
The parameters material used are as follows:

Y01 = 310 Pa
Y02 = 7000 Pa
A1 = 9,0.10-3 Pa1
A2 = 5,2.10-6 Pa1
B1 = 1,2
B2 = 2,0
1 = 106 Pa
2 = -40.106 Pa
F = -3,5.106 Pa
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3.2 Functionalities tested

Orders

CREA_MAILLAGE CREA_GROUP_MA

AFFE_MODELE GRID

AFFE
ALL
"YES"

PHENOMENON
"MECHANICAL"

MODELING
"POU_D_EM"

DEFI_MATERIAU
"ELAS"

“LABORD_1D”

“ECRO_LINE”

AFFE_MATERIAU
GROUP_MA

MATER

AFFE_CARA_ELEM BEAM
GROUP_MA

SECTION

ORIENTATION
GROUP_MA

CARA
“ANGL_VRIL”

AFFE_SECT
GROUP_MA

MAILLAGE_SECT

TOUT_SECT
“YES”

GROUP_MA

AFFE_PONCT
CARA

VALE
“SURFACE”

MODEL AFFE_CHAR_MECA

DDL_IMPO
GROUP_NO

MODEL STAT_NON_LINE

CHAM_MATER

CARA_ELEM

EXCIT
CHARGE

FONCT_MULT

COMP_INCR
LABORD_1D

VMIS_CINE_LINE

NEWTON
STAMP
“TANGENT”

REAC_ITER

1

CONVERGENCE
RESI_GLOB_RELA

ITER_GLOB_MAXI

CALC_NO OPTION
“REAC_NODA”

REUSE

RESULT

CHAM_MATER

CARA_ELEM

EXCIT

CALC_ELEM OPTION
“EPSI_ELGA_DEPL”

REUSE

RESULT

MODEL

CHAM_MATER

CARA_ELEM

---

4 Results

The following curves compare the ASTER results with those of EFICOS [bib1]. Elements of EFICOS have only one point of integration, which explains the light noted differences. Grid EFICOS is composed of 20 elements of beam, the section is made up of 20 layers (calculation 2D).
1,4E+05
1,2E+05
1,0E+05
8,0E+04
6,0E+04
4,0E+04
ASTER
EFICOS
2,0E+04
0,0E+00
0
0,005
0,01
0,015
0,02
0,025
0,03

Appear 4-a: Reaction on a support (NR) according to the arrow in the center (m)

0,012
0,01
ASTER
EFICOS
0,008
0,006
0,004
0,002
0
0
0,005
0,01
0,015
0,02
0,025
0,03

Appear 4-b: Deformation of the steels tended according to the arrow to the center
4,0E+06
3,0E+06
ASTER
EFICOS
2,0E+06
1,0E+06
0,0E+00
0
0,005
0,01
0,015
0,02
0,025
0,03

Appear 4-c: Extreme constraint concrete tended according to the arrow to the center

---

0
0,005
0,01
0,015
0,02
0,025
0,03
0,0E+00
-1,0E+07
ASTER
EFICOS
-2,0E+07
-3,0E+07
-4,0E+07
-5,0E+07

Appear 4-d: Extreme constraint compressed concrete according to the arrow in the center
4, E+08
3, E+08
2, E+08
ASTER
EFICOS
1, E+08
0, E+00
0
0,005
0,01
0,015
0,02
0,025
0,03

Appear 4th: Constraint steel tended according to the arrow to the center
0
0,005

0,01
0,015
0,02
0,025
0,03
-5,0E+07
-1,5E+08
-2,5E+08
-3,5E+08
ASTER
EFICOS
-4,5E+08

Appear 4-f: Constraint steel compressed according to the arrow in the center

---

Tests of results (TEST_RESU) are carried out with each inflection on the curve arrow-reaction [Figure 4-a], i.e. for arrows of 0,1 cm (not 2), 1,4 cm (not 12) and 3,08 cm (not 20).

NOT 2
EFICOS
ASTER
Relative error %

REACTION

1,71.104
1,78.104
4,20

Deformation

Tended steel
8,84.10-5
9,08.10-5
2,78

Constraint

Tended concrete
3,81.106
3,86.106
1,37

Constraint

Compressed concrete
-4,39.106
-4,41.106
0,46

Constraint

Tended steel
1,77.107
1,89.107
6,98

Constraint

Compressed steel
-2,10.107

-2,18.107
3,72

NOT 12
EFICOS
ASTER
Relative error %

REACTION
1,05.105
1,10.105
5,33

Deformation

Tended steel
1,90.10-3
1,93.10-3
1,72

Constraint

Tended concrete
2,64.104
2,71.104
2,67

Constraint

Compressed concrete
-3,35.107
-3,36.107
0,31

Constraint

Tended steel
3,80.108
3,97.108
4,26

Constraint

Compressed steel
-1,73.108
-1,83.108
6,19

NOT 20
EFICOS
ASTER
Relative error %

REACTION
1,24.105
1,24.105
0,07

Deformation

Tended steel
1,09.10-2
9,95.10-3
8,80

Constraint

Compressed concrete
-3,03.107
-2,98.107

1,65

Constraint

Tended steel
4,29.108
4,28.108
0,37

Constraint

Compressed steel
-4,01.108
-4,02.108
0,26

---

5 Bibliography

[1]
S. GHAVAMIAN, J. MAZARS: Strategy of calculations simplify for the analysis of the behavior reinforced concrete structures: code EFICOS. Re-examined French of civil engineering 1998; 2: 61-90

6
Summary of the results

The results obtained with Code_Aster are in rather good agreement with those of code EFICOS.

SSNL120 - Cyclic response of the law
of behavior of the concrete (model of Borderie)

Summary:

In this example one tests the model of behavior of the concrete of Borderie [R7.01.07] in his version 1D
using a multifibre element of beam [R3.08] under axial stress. The loading is composed of
traction with loading and unloading followed by compression also with loading and unloading. It
allows to test resistances in traction and compression, to highlight the phenomenon of
refermeture of cracks and to test the anelastic deformations.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/03/008/A

---

1 Characteristics
general

1.1 Geometry

Beam comforts length unit, of square section on side unit:

y
X

y
1 m
With
B
Z
1 m
1 m

1.2
Material properties

Young modulus: E = 2. 1010 Pa
Resistance in traction: Rt = 4. 106 Pa
Resistance in compression: Rc = 40. 106 Pa

1.3
Boundary conditions

Embedding in a: dx = Dy = dz = 0 and X-ray = ry = rz = 0.

1.4 Loadings

One decreases to grow and the axial deformation (via a displacement imposed out of B according to X) according to the following sequence:

Moment Deformation
0 0,0
1 1,4.10-4
2 0,5.10-4
3 1,0.10-3
4 -4,0.10-3
5 -2,0.10-3
6 -5,0.10-3
7 0,0

2
Reference solution

The reference solution is the uniaxial response of the model for the parameters selected materials. This solution was obtained using the code Eficos (code with multi-layer beams 2D [bib1]) in which this law was established.

3 Bibliography

[1]
GHAVAMIAN HS., MAZARS J.
: Strategy of calculations simplified for the analysis of
behavior of the reinforced concrete structures: code EFICOS. French review of civil engineering
1998 ; 2 : 61-90.

---

4 Modeling
With

4.1
Characteristics of modeling A

Longitudinal grid of the beam:
We have 2 nodes and 1 element (POU_D_EM).

With
B

The concrete part of the cross section of the beam is with a grid (AFFE_SECT) by 4 fibres:

Note:

The problem being 1D, only one fibre could seem sufficient, but that would lead to

to have null terms in the matrix of rigidity (the own inertia of fibres not being taken in account) and with an error at the time of the solution of the system of equations.

The concrete is modelled with the model of damage of Christian Borderie in version 1D (LABORD_1D) [R7.01.07]. The parameters material used are as follows:

Y01 = 310 Pa
Y02 = 7000 Pa
A1 = 9,0.10-3 Pa-1
A2 = 5,2.10-6 Pa-1
B1 = 1,2
B2 = 2,0
1 = 106 Pa
2 = -40.106 Pa
F = -3,5.106 Pa

4.2 Functionalities tested

Orders

AFFE_MODELE GRID

AFFE
ALL
“YES”
PHENOMENON
“MECHANICAL”
MODELING
“POU_D_EM”
DEFI_MATERIAU
“ELAS”

“LABORD_1D”
AFFE_MATERIAU
GROUP_MA

MATER
AFFE_CARA_ELEM BEAM
GROUP_MA

SECTION

ORIENTATION
GROUP_MA

CARA
“ANGL_VRIL”
AFFE_SECT
GROUP_MA

MAILLAGE_SECT

TOUT_SECT
“YES”

GROUP_MA

MODEL AFFE_CHAR_MECA

DDL_IMPO
GROUP_NO
MODEL STAT_NON_LINE

CHAM_MATER

CARA_ELEM

EXCIT
CHARGE

FONCT_MULT

COMP_INCR
LABORD_1D

NEWTON
STAMP
“TANGENT”
CALC_NO OPTION

“REAC_NODA”

REUSE
RESULT
CHAM_MATER
CARA_ELEM
EXCIT
CALC_ELEM OPTION

“DEGE_ELNO_DEPL”

REUSE
RESULT
MODEL
CHAM_MATER
CARA_ELEM

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/03/008/A

5
Results of modeling A

The stress-strain curve is represented on the figure below:

5,0
0,0
-5,0
-4,0
-3,0
-2,0
-1,0
0,0
1,0
-5,0
-10,0
-15,0
-20,0
-25,0
-30,0
-35,0
-40,0
-45,0
Deformation (x1000)

One tests the constraints obtained for the deformations imposed on the moments indicated in paragraph [§1.4]:

Moment Reference Aster
Relative error %
1 1,707816
106 1,707816
106 <
10-3
2 0,247022
106 0,247022
106 <
10-3
3 0,068862
106 0,068862
106 <
10-3
4 -22,2404
106 -22,2404
106 <
10-3
5 -2,14356
106 -2,14356
106 <
10-3
6 -16,3512
106 -16,3512
106 <
10-3

One also tests the maximum constraints (traction and compression) and the deformations corresponding

Peaks in constraint
Reference
Aster
Relative error %

Traction

Constraint

3,86138 106
3,86138 106
< 10-3
Deformation
1,036 10-4
1,036 10-4
< 10-3

Compression

Constraint
-40,9496 106
-40,9496 106
< 10-3
Deformation
-1,810-3
-1,810-3
< 10-3

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/03/008/A

6
Summary of the results

The results obtained with Code_Aster are in very good agreement with those of code EFICOS.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.122

SSNL122 - Beam cantilever Multifibre subjected
with an effort

Summary:

This test relates to the validation of beam multifibre with a modeling in POU_D_TGM.

This problem makes it possible to test:

·
linear finite elements of beams type with a modeling in POU_D_TGM,
·
the taking into account of the orientation,
·
the calculation of the SIEF_ELGA and the SIEF_ELNO_ELGA.

1
Problem of reference

1.1 Geometry

Z
X
B
Y
C
Lo
With

Length of the bar: 3m
Section of the bar:
Embedding in A
height: 0.04m
Forces out of B
width: 0.02m

1.2
Properties of material

Material with elastoplastic behaviour with a linear work hardening, for the linear element:

Elasticity:
•
Young modulus E = 2.1E+11 Pa
Plasticity:
•
slope of the traction diagram in the plastic range D_SIGM_EPSI = 1.0E+08 Pa
•
yield stress SY = 400.0E+06 Pa

1.3
Boundary conditions and loadings

At the point A, perfect embedding (blocking of displacements and rotations),
.
blocking of the ddl: dx, Dy, dz, DRX, DRY, DRZ.
Loading at point b: F = (X
F, Fy, Z
F).

2
Reference solution

2.1
Sizes and results of reference

Arrow out of B following Z
Arrow out of B following Y
Z
F L
. 3

Fy L
. 3

Z =

=

E
.
3
I
.
y
y
E
.
3
I
. Z

Constraint in a point C of co-ordinates (vy, vz) of the section of the beam

NR
M
M = +F Lo
.
y
M Z
=
+
v
.
-
v
.
Z
y
Z
y
with

S
I
I
y

Z
M = - F Lo
y
Z.

from where:
NR
ELo
.
3
=
-
(.y.vy+z.vz)
éq
2.1-1
S
L3

2.2 Reference bibliographical

[1]
"M7-01-72 Project. Elastoplastic behavior of the beams. New approach." Note HM77/01/140/A.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/04/005/A

---

3 Modeling
With

3.1
Characteristics of modeling and the grid

Linear element: POU_D_TGM.

E00200
E00201
E00202
E00203
E00204
E00100
E00101
E00102
S002: 2m
S001: 1m

Mechanical characteristics of the section (homogeneous units with [m]):

WITH IY
IZ AY AZ JX JG
8.0e-04 2.666667e-08 1.066667e-07 1.191790e+0
1.172840e+0 7.093682e-08 1.438125e-12
0
0

Loading at the point B.

Fx Fy Fz
Moment 1
80.000N
150N
200N
Moment 2
80.000N
280N
400N

At moment 1 the section remains elastic, at moment 2 the section is partially plasticized.

3.2
Classification of fibres

The principal reference mark of inertia (Y0, Z0) of the beam must be turned of 90° so that the strongest inertia
"IZ" is along the axis "Y" of the total reference mark. The goal is to test the key word ORIENTATION of
order AFFE_CARA_ELEM.

In the local reference mark of the beam
In the total reference mark of study

Y0 Y

35
36
49
52
Z0
48
32
31
30
29
53
34
35
41
48
4
32
40
49
39
3
31
Y0
38
2

6
30
Z
Z0
37
1
5
29
52
33
60
53
36

6
5
41
4
3
2
1
60
34
33
40
39
38
37

Several "types" of fibres are used:

.
fibres whose numbers go from 1 to 32. They are affected of a nonnull surface in command file,
.
fibres whose numbers are 33, 34, 35, 36. They are located at the 4 corners of the section. These fibres, in the command file, are affected of a section equal to zero. They are useful that with postprocessing,
.
fibres whose numbers go from 37 to 60. They are located on the edge external of the section. These fibres, in the command file, are affected of a section equal to zero. They are used that for postprocessing.

3.3 Functionalities tested

Orders

DEFI_MODELE POU_D_TGM

AFFE_CARA_ELEM BEAM
AFFE_FIBRE
ORIENTATION
IMPR_RESU
SIEF_ELGA
SIEF_ELNO_ELGA

4
Results of modeling A

4.1
Sizes tested and results

The sizes tested and analyzed are them:
· SIEF_ELGA, at the first point of Gauss of the E00200 element. It is the point of Gauss it more close to embedding, Lo = 2.95491933m.
· SIEF_ELNO_ELGA, with the 2 nodes of the E00200 element. The G00202 node is the point of embedding (Lo = 3.0m), the I00200 node is in Lo = 2.6m.

4.1.1 Behavior
rubber band

Constraints at the point of Gauss: SIEF_ELGA
The constraints calculated by the equation [éq 2.1-1] and by Code_Aster are given in both tables below (values in MPa). The provision of the tables takes again the diagram of provision fibres in the total reference mark. The most requested fibre is the n°36 with a constraint of 390 MPa

Constraints calculated in

Constraints calculated in
fibres by the equation [éq 2.1-1]
fibres by Code_Aster.

35
80.168.257
346.390 35
80
168
257.346.390
21
66.154.243
331.376 21
66

154
243.331.376
-7
37.126.215
303.348 -7
37
126
215.303.348
-35
9 98 187
275.320.-35
9
98
187.275.320
-63.-19 70 158
247.291.-63
-19
70
158.247.291
-91.-47 42 130
219.263.-91
-47
42
130.219.263
-120 -75 13 102
191.235 -120
-75
13
102.191.235
-148 -103 -15 74
163.207 -148 -103
-15
74.163.207
-176 -131 -43 46
134.179 -176 -131
-43
46.134.179
-190 -146 -57 32
120.165 -190 -146
-57
32.120.165

The relative error between two calculations is given in the table below. Whatever the fibre,

it remains lower than 0.1%.

-0.022%	-0.013%	-0.009%	-0.008%	-0.007%	-0.007%
-0.026%	-0.012%	-0.009%	-0.008%	-0.007%	-0.007%
0.014%	-0.010%	-0.007%	-0.006%	-0.006%	-0.006%
-0.010%	0.010%	-0.004%	-0.005%	-0.005%	-0.005%
-0.013%	-0.029%	0.000%	-0.003%	-0.004%	-0.004%
-0.014%	-0.021%	0.012%	0.000%	-0.002%	-0.003%
-0.014%	-0.019%	0.069%	0.004%	-0.001%	-0.002%
-0.015%	-0.018%	-0.094%	0.012%	0.002%	0.000%
-0.015%	-0.018%	-0.043%	0.029%	0.006%	0.003%
-0.015%	-0.018%	-0.036%	0.049%	0.009%	0.005%

Constraints with the nodes: SIEF_ELNO_ELGA
The constraints calculated by the equation [éq 2.1-1] and by Code_Aster are given in the table below (values in MPa)

Analytical node Code_Aster
Relative error
G00202
SIMAX = 394.307
SIMAX = 394.276
-0.008%

SIMIN = -194.307

SIMIN = -194.276
-0.016%
I00200
SIMAX = 355.066
SIMAX = 355.057
-0.002%

SIMIN = -155.066
SIMIN = -155.057
-0.006%

4.1.2 Behavior
plastic

Constraints at the point of Gauss: SIEF_ELGA
The table below gives the values of the constraints, after plasticization partial of the section, obtained with Code_Aster. The behavior of material is elastoplastic "almost perfect", slope of work hardening is weak. The maximum constraint, which is beyond the yield stress, remains thus very close to the elastic threshold of 400MPa.

8
79
223
366
400
400
-16
55
199
342
400
400
-64
7
151
294
400
400
-112
-41
103
246
390

400
-160
-89
55
198
342
400
-208 -137
7
150
294
365
-256 -185
-41
102
246
317
-305 -233
-89
54
198
269
-353 -281 -137
6
150
221
-377 -305 -161
-18
126
197

This calculation is carried out for the test of nonregression of Code_Aster.

Constraints with the nodes: SIEF_ELNO_ELGA
The table below gives the values of the constraints to the nodes, after plasticization partial of section, obtained with Code_Aster. These values are interpolated by Code_Aster from SIEF_ELGA. The behavior of material is elastoplastic "almost perfect", the slope of work hardening is weak. The maximum constraint, which is beyond the yield stress, thus remains very neighbor of the elastic threshold of 400MPa.

Node
Code_Aster
G00202

SIMAX = 400.091

SIMIN = -385.441
I00200
SIMAX = 400.053

SIMIN = -306.905

This calculation is carried out for the test of nonregression of Code_Aster.

5
Summary of the results

This case test shows the correct operation of a modeling of the behavior of the beams by one approach multifibre. The postprocessing of the beams does not require any more, with this modeling, of
to calculate the SIGM_ELNO_SIEF or the SIPO_ELNO_SIEF.

Titrate:
SSNL123 - Buckling of a beam Multifibre

Date:
19/08/02
Author (S):
J.L. Key FLEJOU
:
V6.02.123-A Page:
1/4

Organization (S): EDF/TESE

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.123

SSNL123 - Buckling of a beam Multifibre

Summary:

This test relates to the validation of the buckling of a beam multifibre with a model POU_D_TGM.

This problem makes it possible to test:

· linear finite elements of beams type with a model POU_D_TGM,

· ***the taking into account of the orientation,***
· ***the calculation of the first modes of buckling.***
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HR-17/02/019/A

1
Problem of reference

1.1 Geometry

Z
X
B
Y
With

Length of the bar: 3m
Section of the bar:
Articulated in A
height: 0.04m
Simply supported out of B
width: 0.02m
Forces out of B

1.2
Properties of material

Material for the linear element:

Elasticity: E = 2.1E+11 Pa

1.3
Conditions with the loadings

At point a: blocking of the DDL: DX, DY, DZ, DRX
At point b: blocking of the DDL: DY, DZ, DRX

Loading at point b: F, = (Fx, 0, 0).

2
Reference solution

2.1
Sizes and results of reference

For an Bi-articulated beam, the theory of the buckling of Euler gives as solution:

2
2 .EI
Ncr = N.
or N is the number of the mode.
2
L

3 Modeling With

3.1 Characteristics of modeling and the grid

Linear element: POU_D_TGM

E00200
E00201
E00202
E00203
E00204
E00100
E00101
E00102
S002: 2m
S001: 1m

Mechanical characteristics of the section (homogeneous units with [m])

WITH IY IZ AY AZ JX JG
8.0e-04 2.666667e-08 1.066667e-07 1.191790e+0
1.172840e+0 7.093682e-08 1.438125e-12
0
0

Loading at the point B.
Fx
Moment 1
1.000N
Moment 2
2.000N

3.2 Functionalities tested

Orders

DEFI_MODELE

POU_D_TGM
AFFE_CARA_ELEM
BEAM
AFFE_FIBRE
ORIENTATION
CALC_MAT_ELEM
CHARGE
INST
CREA_CHAMP
RESULT
NUME_ORDRE
MODE_ITER_SIMULT

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HR-17/02/019/A

4
Results of modeling A

4.1
Sizes tested and results

The sizes tested and analyzed are the first values of the loads of buckling in the 2 directions.

Values
Values Code_Aster Code_Aster Values

Relative variation
Theoretical
Moment 1
Moment 2
1st Mode/Iz
6.141 NR
6.141 NR
6.141 NR
0.00%
1st Mode/Iy
24.564 NR
24.554 NR
24.554 NR
0.04%
2nd Mode/
24.564 NR
24.566 NR
24.566 NR
-0.008%
Iz
3rd Mode/
55.270 NR
55.365 NR
55.365 NR
-0.17%
Iz
2nd Mode/
98.257 NR
98.136 NR
98.136 NR
0.12%
Iy
4th Mode/
98.257 NR
98.914 NR
98.914 NR
-0.67%
Iz

The moments of calculation 1 and 2 give the same results. The calculation of the vector of prestressed afterwards
the STAT_NON_LINE is thus carried out in a correct way.

5
Summary of the results

This case test shows the correct operation of a modeling of the behavior of the beams by one approach multifibre. A loop, carried out with the language python, makes it possible to recover them information with the various steps of time.

· The calculation of the matrix of rigidity, option RIGI_MECA, is carried out from one AFFE_CHAR_MECA_F.
· The calculation of the vector of the internal efforts is carried out by a CREA_CHAMP from one STAT_NON_LINE by recovering the SIEF_ELGA.

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.125

SSNL125 - Traction of a fragile bar: damage with gradient

Summary:

This test allows the validation of the fragile law of damage gradient in a unidimensional situation nonhomogeneous. From its character 1D, this problem admits an analytical solution which exhibe two modes
boundary layers: one finite length (existence of a free border enters the damaged zone and the zone healthy) and the other infinite length (it extends to the border from the part).

1
Problem of reference

1.1 Geometry

= 0
= E
0
X E X
E
X
X
L = 5 mm
X = 0
L
10 mm
0
-
1 =

The studied structure is a 15 mm length bar. The problem being purely 1D, its section is without influence.

1.2
Properties of material

The material obeys a law of fragile elastic behavior (ENDO_FRAGILE) to gradient of damage (modeling *_GRAD_VARI).

ELAS ECRO_LINE
NON_LOCAL
E = 20.000 Mpa
SY = 2 Mpa
NAKED = 0
D_SIGM_EPSI = - 20.000 MPa
LONG_CARA = 5.099 mm

1.3
Conditions of loading

One forces the left part of the bar (5 mm length) to remain rigid (blocking of the degrees of freedom of displacement). As for the right part of the bar, it is subjected to an axial deformation uniform 0, i.e. with an imposed displacement whose spatial distribution is linear. Only one

parameter thus controls the intensity of the loading: the level of imposed deformation 0.
In the directions perpendicular to the axis of the bar, displacements are blocked: the problem is purely 1D. Moreover, as the Poisson's ratio is null, no constraint of fastening develops in these directions.

2
Reference solution

In the case of the law of behavior to gradients of damage [R5.03.18], two equations with derivative partial must be solved: the equilibrium equation and the equation of behavior. To obtain an analytical solution proves generally delicate, even for unidimensional structures.
To validate nevertheless this model, one sticks to a simpler problem for which the equation of balance need does not have to be solved, i.e. the field of displacement is fixed everywhere.
The equation of behavior is then controlled by the elastic deformation energy W known in all not space.

2.1
Characterization of the solution

More precisely, one considers a bar of which a part is obligation to remain without deformation while the other is subjected to a homogeneous deformation. One studies the boundary layer then of damage which develops with the interface of these two zones. The differential equation of behavior is as follows in the zones where the criterion is reached, i.e. where the damage evolves/moves:

2

2
D
y
1+
W = K (D) - C
where
K (D) = W

éq
2.1-1
2

^x
1+ - D

where
y
W, and C are parameters of material, to see again [R5.03.18] for the correspondence with the sizes provided in DEFI_MATERIAU, while x^ indicates the variable of space. One henceforth standardize the variables of the problem while introducing:

W
y
2
E =
X = x^ (1+)
W
= 1+ - éq
2.1-2
W y (1+)
has
D
2
C

With the help of these changes of variables, the equation of behavior is written:

2
1
D has
E (X) =

+ 2

éq 2.1-3
2
2
has
dx
There one recognizes an equation of motion in a gravitational field under an imposed force.
It admits an integral first in each of the two zones of the bar (subscripted by I):

da 2
1

- - E has = C
I
I
I
{ ,
0 }
1
e0 = 0 e1 = E
éq
2.1-4
dx
has

To these two constants of integration Ci come to be added two other constants resulting from the integration of [éq 2.1-4]. These four constants are fixed by the two conditions of edge and them conditions of jump to the interface:

da
da
da
da
(L) =
(L) = 0
+

-
+
-
0
1
has (0) - has (0) = 0
(0) - (0) = 0 éq
2.1-5
dx
dx
dx
dx

One substitutes as of now for the two constants of integration C the two extreme values of
I
field of damage has = has (L) and has = has (L) by evaluating the integral first [éq 2.1-4] in
0
0
1
1
L and L:
0
1
1
1

C0 = -
1
C = -
- E 1
has
éq
2.1-6
a0
1
has

2.2
Resolution of the problem in the discharged zone

In the zone with null deformation (I = 0), the integral first [éq 2.1-4] seems an equation differential with separable variable. Taking into account [éq 2.1-6] and definition of a0, its integration
conduit initially with the following implicit equation:

has (X)
1
1 -1 2
X = L0 - - D éq
2.2-1

a0
0
has
In particular, in X = 0, one obtain:

has (0)
1
1 -1 2
L0 = - D éq
2.2-2

a0
a0

As it is about a clean integral in a0, the second member has a finished value. Moreover, the intégrande being positive and has ()
0 undervalued by, the ultimate value of the field has (which corresponds to one
total damage D = 1), one observes that 0
L is limited by:

1 1 -12
0
L - D éq
2.2-3

a0
0
has

Consequently, if the length of the zone noncharged is larger than this terminal, the solution [éq 2.2-1] is not valid any more. That comes owing to the fact that it was supposed that the criterion was reached everywhere for
to write the equation [éq 2.1-1].
Henceforth, it is supposed that length 0
L is higher on the terminal [éq 2.2-3]. The boundary layer
develop at a finite distance B completely included in this zone. It is about a news
0
unknown factor, but the extreme value of damage A is now known: indeed, by
0
continuity with the not damaged zone which is spread out of 0
L with 0
B, one a:

= 1 has

éq
2.2-4
0
+

Finally, the equation [éq 2.2-1] must be corrected; it is written:

has (X)
1
1 -1 2
X = 0
B - -

D
éq
2.2-5
1 +
+
1

By expressing this equation in X again = 0, one express 0
B according to A ()
0 :

has (0)
1
1 -1 2
0
B = -

D
éq
2.2-6
1 +
+
1

Finally, in substituent [éq 2.2-6] in [éq 2.2-5], one obtains the following implicit equation:

has (X)
has (
1
- 2

X
1
1
+ -

+ -
X = -
-
D =

(1+) 3
(1
)
)
1
2
- arccos

éq
2.2-7
1 +
1 +
1

+ has (0)
has (0)

Thus, it appears that the profile of damage is completely controlled by its value into 0, i.e., taking into account the condition of continuity [éq 2.1-5], by what occurs in the zone charged.

2.3
Resolution of the problem in the zone charged

In the zone with null deformation (I = 1), the integral first [éq 2.1-4] also seems
a differential equation with separable variable. Taking into account [éq 2.1-6] and definition of 1
has,
its integration leads initially to the following implicit equation (with the help of
change of variable U = has - 1
has):

has (X) - a1

1 2
a1 (a1 + U)

X = L1 -

éq
2.3-1
E has u2
2
1
+ (ea1 -)

1 U
0

Again, it is about a clean integral, except in the case
2
E has
1
1 =, i.e.
the damage corresponding to the request E in a homogeneous problem. That means that
the extreme damage 1
A is all the more close to the homogeneous solution the bar is
long: the boundary layer in the zone charged is not limited and asymptotically extends towards
homogeneous answer.

6/10

By expressing the equation [éq 2.3-1] in X = 0, one obtain an equation making it possible to determine
1
has in
function of A ()
0 :
has (0) - a1

1 2
a1 (a1 + U)

L1 =

éq
2.3-2
E has u2
2
1
+ (ea1 -)

1 U
0

However, to simplify the analytical resolution of this problem, it is supposed henceforth that the bar is sufficiently long, so that an approximate solution of [éq 2.3-2] is given by:

2
1 2
E 1
has
= 1
-

1
= E has

éq
2.3-3

As for the profile of damage in the charged zone, it is him also completely parameterized by
has ()
0, since while combining [éq 2.3-1], [éq 2.3-2] and [éq 2.3-3] one obtains:

has (0)
has (0)
1 2

1
has
1
has
X =
D

= 2 1
has -
1
arg tanh has

éq
2.3-4
- 1
has

has (X)
has (X)

2.4
Determination of the damage to the interface

Let us reconsider the step of integration. Initially, we awaited four constants of integration:
C0, 1
C and two resulting from the integration of the integrals first [éq 2.1-4]. Then, to both constant C and C were substituted the two extreme values of damage has and
0
1
0
1
has, they also unknown. By exploiting the boundary conditions of Neumann in [éq 2.1-6], one has implicitly given two complementary constants of integration not to express the profiles of damage that according to the only values a0 and 1
has, to see the equations [éq 2.2-1] and [éq 2.3-1]. Finally, one substituted for the constants a0 and 1

with the value of the damage with
the interface has ()
0, equalize on the left and on the right since the jump of A is null there. This substitution is operated by noticing that the damaged zone is of size finished in the discharged zone, contrary to the zone charged where we privileged an approached solution, simpler on analytical plan.
Consequently, there remains nothing any more but one constant of integration to be determined, the damage with
the interface has ()
0 thanks to the last unutilised condition, the nullity of the jump of derived with the interface.
Thus, by evaluating the two integrals first in X = 0 and calculating their difference, one obtain:

1
1
E has ()
0 = E has +
-

éq
2.4-1
1
has
has
1
0
By taking account of the expressions [éq 2.2-4] and [éq 2.3-3], one deduces the expression from it from
the damage with the interface:
has (= 2
)
0
-
1
éq
2.4-2
E
E (1+)

2.5 Application numerical

For elasticity, work hardening and the internal length, one adopts the following characteristics:

E = 2.104 MPa
y
= 2 MPa
B
L = 26 mm éq 2.5-1
= 0
T
E = 2
- .104 MPa

These choices lead to the following parameters in the differential equation [éq 2.1-1]:

W y = 10-4 MPa
= 1
C = 8.10-4 NR éq
2.5-2
As for standardization, it becomes:

*X = x^*
= 2 - D has
W
-4
= 4.10
E
éq
2.5-3

The load evolves/moves between the value of initiation of the damage and that for which the damage would reach its maximum value D = 1 in a homogeneous context. That is translated for the imposed deformation:

1
-4
-4
E 1

10
10
.
2

éq
2.5-4
4

2.6
Results of reference

The reference solution is obtained by taking a bar length L = 5
0
- and L
10
1 =
. One
examine the value of the field of damage D for three levels of loading and of them two
places, one in the discharged zone, the other in the zone charged.

E
D (X =)
1
-
D (X =)
1
1.414 10-4 0.50 0.0251 0.3437
1.732 10-4 0.75 0.1106 0.6045
2.000 10-4 1.00 0.1877 0.7897
Count 2.6-1 - Results of reference

1
E = 0.50
E = 0.75
0,8

E = 1.00
0,6
0,4
Damage D
0,2
0-5
0
5
10
position X (mm)

Appear 2.6-a: Profile of damage for the reference solution

---

3 Modeling With

3.1 Characteristics of modeling and the grid

It is about an axisymmetric modeling (AXIS_GRAD_VARI). Geometry corresponding is a rectangle, i.e. the bar is laid out of manner vertical and its section (without influence) are circular.

The grid consists of only one element according to the ray. According to the axis, smallest elements have a size of 0.1 mm along the interface and grow in progression *geometrical of reason 1.05 while moving away from the interface. Grid thus generated finally consists of 59 quadrangular elements with 8 nodes.*

4
Results of modeling A

4.1
Sizes tested and results

One validates the modeling and the algorithm of integration of nonlocal laws by examining the level of damage (variable V1 intern) on the various levels of loading and the various places geometrical listed in [Table 2.6-1]. The results are joined together in the extract of the file of result below.

Identification Moment
Reference
Aster
Difference
V (
1 X = -)
1 1.414.104 2.5100000000000E-02 2.5300980013184E-02
0.801 %
V (
1 X = -)
1 1.414.104 3.4370000000000E-01 3.4334039567418E-01
-0.105 %
V (
1 X = -)
1 1.732.104 1.1060000000000E-01 1.1070787251591E-01 0.098
%
V (
1 X = -)
1 1.732.104 6.0450000000000E-01 6.0422953501431E-01 -0.045
%
V (
1 X = -)
1 2. 104 1.8770000000000E-01
1.8805237130425E-01
0.188
%
V (
1 X = -)

1 2. 104 7.8970000000000E-01
7.8950184194123E-01
-0.025
%

5
Summary of the results

One notes a very good agreement between modeling and the analytical solution.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.126

SSNL126 - Elastoplastic buckling of one right beam

Summary:

A slim right beam of circular section is subjected to a compressive force at an end, and is embedded at the other end. The behavior of material is elastoplastic, with an isotropic work hardening linear. During the rise in load, one calculates the critical loads of elastic buckling, then plastic.

Two modelings make it possible to test the criterion of buckling in elastoplasticity:

Voluminal modeling a: grid, small deformations and small displacements.
Modeling b: voluminal grid, small deformations and great displacements (GREEN).

1
Problem of reference

1.1 Geometry

Surface force

Right beam, length L = 1m
Circular section of ray R = 0.01m.

Embedding

1.2
Material properties

Elastoplastic material with isotropic linear work hardening:

Young modulus: E = 210000 MPa
Poisson's ratio: = 0. (assumption of beam of Euler-Bernoulli)
Elastic limit: Y = 4 MPa
Tangent module: AND = 70000 MPa

1.3
Boundary conditions and loadings

·
C.L. : embedding on all basic surface
·
Surface force on the higher face: with T = 1s, F = 6.5 MPa

This load is applied in 10 steps of time équirépartis.

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical solution:

In small displacements:

· in elastic mode (for F< Y) the theoretical breaking value corresponds to the load of Euler. Within the framework of a kinematics of beam, the critical load is worth:

2
I.E.(internal excitation)
2 I.E.(internal excitation)
F =
Cr

, therefore critical pressure: P =

2
Cr

4 L
2

4 SL
4
R
2
ER 2
with I =
and
2
S = R is P =
4
Cr

2
16 L

· in elastoplastic mode, as one considers a uniform compression without discharge rubber band and because of law of behavior, the critical load of buckling is worth:

2
Et.I
2
EtR2
F =
Cr
that is to say a pressure criticizes: P =
2
Cr

4 L
2
16L

2.2
Results of reference

Values of the critical load for the two loading cases.

In elastic mode, for F < 4 MPa, is T < 0.61538462, one must obtain: Pcr = 12.95 MPa.

In plastic mode the critical value of pressure of buckling is: 4,32 MPa.

The critical coefficients according to the loading are:

No time
Surface force
Critical coefficient
Critical load
(in MPa)
(in MPa)
1
0.65
19.9290 12.9539
2
1.3
9.9645 12.9539
3
1.95
6.6430 12.9539
4
2.6
4.9823 12.9539
5
3.25
3.9858 12.9539
6
3.9
3.3215 12.9539
7
4.55
0.9490
4.3180
8
5.2
0.8304
4.3180
9

5.85
0.7381
4.3180
10
6.5
0.6643
4.3180

---

3 Modeling
With

3.1
Characteristics of modeling

Voluminal grid 3D.

3.2
Characteristics of the grid

A number of nodes: 600
A number of meshs and types: 90 HEXA20

3.3 Functionalities tested

Orders

STAT_NON_LINE CRIT_FLAMB

STAT_NON_LINE COMP_INCR
DEFORMATION
GREEN
STAT_NON_LINE COMP_INCR
RELATION
VMIS_ISOT_LINE

4 Results of modeling A

4.1 Values tested

Moment	Reference	Aster	% difference
0.2	-9.9645	-9.9763	0.16
1	-0.6643	-6.752	2.3

7.2

5 Modeling
B

5.1
Characteristics of modeling

Voluminal grid 3D. Great displacements and deformations (but small rotations)

The surface force applied is worth 20 here MPa with T = 1s, in order to pass, during the evolution of loading, by the critical point.

This load is applied in 10 steps of time équirépartis.

Two complete calculations are carried out: one with a purely elastic behavior, in order to be able to compare the result with the elastic solution of reference, and the other with a behavior elastoplastic.

5.2
Characteristics of the grid

A number of nodes: 600
A number of meshs and types: 90 HEXA20

5.3 Functionalities
tested

Orders

STAT_NON_LINE CRIT_FLAMB

STAT_NON_LINE COMP_INCR
DEFORMATION
GREEN

STAT_NON_LINE COMP_INCR
RELATION
VMIS_ISOT_LINE
STAT_NON_LINE COMP_INCR
RELATION
ELAS

6
Results of modeling B

6.1 Values
tested

In elastic behavior

One tests the end value of the critical coefficient: (test of nonregression)

Moment Reference Aster %
difference
1 -19.0657
-19.0657
0

In the case of great displacements or great deformations, the value of the critical coefficient must to be interpreted differently of the case small displacements: the structure becomes unstable when "critical load" is cancelled.

The evolution of this coefficient in the course of time is as follows:

No time
Surface force
Critical coefficient
Critical load Euler
(in MPa)
Aster
1
2
27.5797 12.9539
2
4
22.8250 12.9539
3
6
17.9808 12.9539
4
8
13.0407 12.9539
5
10
7.9975 12.9539
6
12
2.8434 12.9539
7
14
-2.4301
12.9539
8
16
-7.8324

12.9539
9
18
-13.3738
12.9539
10
20
-19.0657
12.9539

The critical coefficient thus passes well by 0 between moments 6 and 7, and more precisely (curved cf following) in the neighbourhoods of moment 6.5, which corresponds well to the critical load in elasticity.

Coefficient criticizes Aster
30.0000
20.0000
10.0000
0.0000
0
1
2
3
4
5
6
7
8
9
10
-10.0000
-20.0000
-30.0000

In elastoplasticity, one tests the moments when the critical coefficient changes sign. The tests are of not regression since one does not have analytical solution in this case.

Moment Reference Aster %
difference
0.4 4.9917
4.9917

0
0.5 -1.3186
-1.3186
0

7 Summary of the results

The results as of modeling in small displacements is in conformity with the analytical reference (less than 2% of variation in plasticity). The results in great displacements cannot be compared with a reference solution, but the change of sign of the critical coefficient is conform to the awaited solution.

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.127

SSNL127 - Tensile test with the model CORR_ACIER

Summary:

This test of nonlinear quasi-static mechanics makes it possible to validate the elastoplastic model endommageable CORR_ACIER.

5 modelings make it possible to validate the behavior:

· modelings A, B, C in 1D for the elements BARS, POU_D_EM, POU_D_TGM;
· modeling D in 3D in the case of an axisymmetric test-tube (state of stresses and of homogeneous deformation) subjected to a simple tensile test; modeling 3D of the test-tube is realized with elements CU20;
· modeling E in COQUE_3D in the case of a plate subjected to a simple traction, with one net QUAD9.

1
Problem of reference

1.1 Geometry

The geometry is selected voluntarily simple, to translate a state of stresses and of deformations homogeneous, as it is the case in uniaxial traction. In the case 1D and 3D, it acts here of a bar of diameter = 6 mm and length 100mm. In 3D, one nets only one quarter of bar. Traction is done with displacement imposed in 1D and 3D with the length of the test-tube. In
2

case COQUE_3D, the plate is square on side 100mm, and thickness
(so that the efforts are
4
identical to the case 1D).

y

Z
Li3

1D
Surf_int
3D

Y
Y

Li2

Surf_2
With
B

X

X

Surf_1
Surf_ext
Li1

COQUE_3D

X
1.2
Properties of material

YOUNG modulus = 2.E11 Pa
Poisson's ratio = 0.33

Key word CORR_ACIER:
Coefficient of damage D_CORR = 0.2
Parameters of work hardening ECRO_K = 500 MPa
Elastic limit
ECRO_M = 2.781

SY = 500. MPa
The degree of corrosion is given using order CREA_CHAM:
NOM_CMP = "CORR" VALE = 0.0, 2.5, 13 (in percent)

1.3
Boundary conditions and loadings

Modeling 1D
Displacements DX DZ and DY blocked at point A
Displacement DX and DZ imposed on the point B

Modeling 3D
Displacement DX prevented on Surf_int

Displacement DY prevented on Surf_1
Displacement DZ prevented on Surf_2
Displacement DX imposed on Surf_ext

Modeling COQUE_3D:
Displacement DX prevented on Li4
Displacement DY prevented on Li1
Displacement DX imposed on Li3

1.4 Conditions initial

Null constraints and deformations.

2 Reference solution

2.1 Method of calculation

The reference solution is consisted the results of the tensile tests carried out on bars corroded (the initial diameter is 6 mm). Following these tests, one notes the reduction in plastic deformation with rupture with increase in the degree of corrosion.

2.2
Results of reference

Evolution of the plastic deformation with rupture of the bars corroded according to the degree of corrosion (the reduction of the diameter of bars or thickness of flat reinforcement compared to those not corroded) is presented on [Figure 2.2-a] and it [Figure 2.2-b].

0.24
2 %
2.5 %
0 %

with

R
upture
13 %
0.16
17.5 %
22.4 %
S
T
ic
35 %
0.08
has
T
ion pla
m
50 %
é
for
D
0

0
10
20
30
40
50

Rate of corrosion, %

Appear 2.2-a: Influence corrosion on
Appear 2.2-b: Evolution of the deformation
behavior of steel according to the rate
plastic with rupture according to the rate of
of corrosion
corrosion

2.3
Uncertainties on the solution

Precision of the codes.

2.4 References
bibliographical

[1]
A.A. ALMUSALLAM: "Effect of dismantles of corrosion one the properties of reinforcing steel bars ", Construction and Building Materials 15, 2001.
[2]
A. OUGLOVA, Y. BERTHAUD, I. PETRE-LAZAR: "Experimental Characterization of corrosion of steels in the concrete on old analogues. First approach of modeling ", HT-25/02/030/A, EDF, 2002.

***3 Modeling
With***

***3.1
Characteristics of modeling***

It is about an element BARS. Maximum displacement at the point B is of 0.021m, it is reached into 50 increments.

***3.2
Characteristics of the grid***

***A number of nodes: 10
A number of meshs and type: 10 (SEG2)***

***3.3 Functionalities
tested***

Orders

CREA_CHAM CORR

DEFI_MATERIAU CORR_ACIER

***STAT_NON_LINE COMP_INCR RELATION
CORR_ACIER***

***4
Results of modeling A***

The efforts maximum (in NR) are:

***Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.019
21857.1
21857.1
0
2.5% of corrosion***

0.0164
21451.6
21451.6
0
13% of corrosion
0.0075
19610.1
19610.1
0

the efforts corresponding to maximum displacement at the point B are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
21193.7
21193.7
0
2.5% of corrosion
0.018
20557.6
20557.6
0
13% of corrosion
0.008
18758.6
18758.6
0

The cumulated equivalent plastic deformation maximum is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
0.19625
0.19625

0
2.5% of corrosion
0.018
0.17636
0.17636
0
13% of corrosion
0.008
0.07668
0.07668
0

The damage is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.0192
0.00229
0.00229
0
2.5% of corrosion
0.0164
0.01371
0.01371
0
13% of corrosion
0.0075
0.01188
0.01188
0

Titrate:

5 Modeling B

5.1 Characteristics of modeling

It is about an element POU_D_EM (beam multifibre). Maximum displacement at the point B is of 0.021m, it is reached in 50 increments.

5.2 Characteristics of the grid

A number of nodes: 10
A number of meshs and type: 10 (SEG2)

5.3 Functionalities tested

Orders

CREA_CHAM CORR

DEFI_MATERIAU CORR_ACIER

STAT_NON_LINE COMP_INCR RELATION CORR_ACIER

6 Results of modeling B

The efforts maximum (in NR) are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.019
21857.1
21860
0.02
2.5% of corrosion
0.0164
21451.6
21455
0.02
13% of corrosion
0.0075
19610.1
19613
0.02

the efforts corresponding to maximum displacement at the point B are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
21193.7
21197
0.02
2.5% of corrosion
0.018
20557.6
20560
0.02
13% of corrosion
0.008
18758.6
18761

0.02

The cumulated equivalent plastic deformation maximum is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
0.19625
0.19625
0
2.5% of corrosion
0.018
0.17636
0.17636
0
13% of corrosion
0.008
0.07668
0.07668
0

The damage is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.0192
0.00229
0.00229
0
2.5% of corrosion
0.0164
0.01371
0.01371
0
13% of corrosion
0.0075

0.01188
0.01188
0

---

7 Modeling
C

7.1
Characteristics of modeling

It is about an element POU_D_TGM (beam multifibre). Maximum displacement at the point B is of 0.021m, it is reached in 50 increments.

7.2
Characteristics of the grid

A number of nodes: 10
A number of meshs and type: 10 (SEG2)

7.3 Functionalities
tested

Orders

CREA_CHAM CORR

DEFI_MATERIAU CORR_ACIER

STAT_NON_LINE COMP_INCR RELATION CORR_ACIER

8 Results of modeling C

The efforts maximum (in NR) are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.019
21857.1
21860
0.02
2.5% of corrosion
0.0164
21451.6
21455
0.02
13% of corrosion
0.0075
19610.1
19613
0.02

the efforts corresponding to maximum displacement at the point B are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
21193.7

21197
0.02
2.5% of corrosion
0.018
20557.6
20560
0.02
13% of corrosion
0.008
18758.6
18761
0.02

The cumulated equivalent plastic deformation maximum is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
0.19625
0.19625
0
2.5% of corrosion
0.018
0.17636
0.17636
0
13% of corrosion
0.008
0.07668
0.07668
0

The damage is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion

0.0192
0.00229
0.00229
0
2.5% of corrosion
0.0164
0.01371
0.01371
0
13% of corrosion
0.0075
0.01188
0.01188
0

---

9 Modeling
D

9.1
Characteristics of modeling

It is about a modeling 3D.

Z

Surf_int

Y

P1
9.2
Characteristics of the grid
Surf_2

A number of nodes: 39
A number of meshs and type: 3 (HEXA20)
Surf_1
Surf_ext

9.3 Functionalities
tested

X
Orders

CREA_CHAM CORR

DEFI_MATERIAU CORR_ACIER

STAT_NON_LINE COMP_INCR RELATION
CORR_ACIER

10 Results of modeling D

The efforts maximum (in NR) are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.019
7.730 108 7.730
108 0
2.5% of corrosion
0.0164

7.588 108 7.588
108 0
13% of corrosion
0.0075
6.936 108 6.936
108 0

the efforts corresponding to maximum displacement at the point B are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
7.487 108 7.487
108 0
2.5% of corrosion
0.018
7.261 108 7.261
108 0
13% of corrosion
0.008
6.612 108 6.612
108 0

The cumulated equivalent plastic deformation maximum is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
0.19625
0.19625
0
2.5% of corrosion
0.018
0.17636
0.17636
0

13% of corrosion
0.008
0.07668
0.07669
0.02

The damage is worth:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.0192
0.00345
0.00345
0
2.5% of corrosion
0.0164
0.01505
0.01505
0
13% of corrosion
0.0075
0.015
0.015
0
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Code_Aster ®
Version
8.1

Titrate:
SSNL127 - Tensile test with model CORR_ACIER

Date:
01/09/05
Author (S):
I. PETRE-LAZAR, A. ASSIRE, L. DAVENNE Key
:

11 Modeling
E

11.1 Characteristics of modeling

y
It is about a modeling
Li3
COQUE_3D.

Li2

11.2 Characteristics of the grid
X

A number of nodes: 9
Li1
A number of meshs and type: 1 (QUAD9)
COQUE_3D

11.3 Functionalities
tested

Orders

CREA_CHAM CORR

DEFI_MATERIAU CORR_ACIER

STAT_NON_LINE COMP_INCR RELATION
CORR_ACIER

12 Results of modeling E

The efforts maximum (in NR) are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.019
21857.1
22676
3.7
2.5% of corrosion
0.0164
21451.6
22798
6
13% of corrosion
0.0075
19610.1
20221
3

the efforts corresponding to maximum displacement at the point B are:

Identification Displacement
Reference
Aster %
difference
imposed (m)
0% of corrosion
0.02
21193.7
21534
2
2.5% of corrosion
0.018
20557.6
20749
1
13% of corrosion
0.008
18758.6
18813
0.3

---

13 Summary of the results

For modelings A, B, C, D, E the results correspond well to those obtained
in experiments.
The curves effort-displacement obtained for the 3 rates of corrosion tested are as follows:

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Code_Aster ®
Version
8.1

Titrate:
SSNL127 - Tensile test with model CORR_ACIER

Date:
01/09/05
Author (S):
I. PETRE-LAZAR, A. ASSIRE, L. DAVENNE Key

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Titrate:
SSNL129 Validation of the viscoplastic laws on tensile test Dates
:
20/10/04
Author (S):
Key S. MICHEL-PONNELLE
:
V6.02.129-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.129

SSNL129 Validation of laws VISC_ISOT_TRAC and VISC_ISOT_LINE on a tensile test

Summary:

This test consists in applying to an elementary volume a loading of traction. Three speeds of loading are modelled.

Modelings A, B and C make it possible to validate the law of behavior VISC_ISOT_TRAC (DEFORMATION=' SIMO_MIEHE') in 3D, D_PLAN and AXIS. For that, the results obtained are compared
with the viscous law of Rousselier ROUSS_VISC and degenerated DEFORMATION=' PETIT_REAC' in order to it
that the evolution of porosity is negligible. Modelings D, E and F make it possible to validate the integration of
law VISC_ISOT_LINE (DEFORMATION=' SIMO_MIEHE') in 3D, D_PLAN and AXIS. For that, results
obtained are compared with those given by law VISC_ISOT_TRAC for the same linear work hardening.

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1
Problem of reference

1.1 Geometry

It is a question of testing the 2 viscoplastic laws of behavior VISC_ISOT_TRAC and VISC_ISOT_LINE on an Elementary Volume representative R of dimension 1mm, is a cube in 3D, the equivalent of one bar in plane deformations or of a cylinder into axisymmetric.

1.2
Properties of material

Isotropic elasticity
Young modulus: E =
MPa

215000

Poisson's ratio: = 0.3
Traction diagram (MOD. With, B and C)
Traction diagram
1100
1000
900
has
)
P
M
800

T
E
(
700
T
R
has
in
N
C
O
600
500
400
0
0,2
0,4
0,6
0,8
1
deformation

Linear work hardening (MOD. D, E and F)
= 477.
MPa

1267117
y

= 529.853045MPa
T
E

Coefficient for viscous law

MPa

6176
0 =

VISC_SINH
13
0 =

10

483
3.31131121

m = 6.76

Coefficients of the model of Rousselier
9
-
f0 = 510
used to obtain the solution of
D = 0.0001
reference (MOD. With, B and C)

MPa

1575
1 =

1.3
Boundary conditions and loadings

The element of volume is subjected to a homogeneous simple tensile test. It is thus blocked in X on the face [3,4] and in y on the face [1,3] (and possibly in direction Z) and subjected to one displacement U (T) in the direction y
However on the face [1, 2].
3 values of T are used 2000 S, 0.2 S and 0.002s, corresponding to speeds of deformations & of 10-3 s-1, 10 s-1 and 103 s-1.

y

U (mm)
1
2
2
1 mm
T (S)
T
3
4
X

1 mm

1.4 Conditions
initial

Null constraints and deformations with T = 0.

2
Results of reference

For the model VISC_ISOT_TRAC which one tests in modelings A, B and C, the validation is done by comparison with the results obtained with the model ROUSS_VISC whose parameters were selected in order to make negligible the evolution of porosity and thus to be reduced to the model viscoplastic "traditional".
For model VISC_ISOT_LINE tested in modelings D, E and F, one compares the solution obtained with VISC_ISOT_TRAC for which one defined a linear work hardening (one only preserves the points ends of the curve used to validate this model).

3 Modeling With

3.1 Characteristics of modeling

Modeling 3D: 1 HEXA20

S5
S1
S2
S4
S2y
S3
X
Z
S6
Z

The imposed loading is as follows:

- *The S6 face is blocked according to the direction y,*
- *The S2 face is blocked according to direction X,*
- *The S1 face is blocked according to direction Z*

.

The S5 face undergoes a displacement of 2 mm in 2000 S, 0.2 S or 0.002 S in 100 increments.

The law of behavior tested is law VISC_ISOT_TRAC.

3.2 Functionalities
tested

Order
Key word factor
Simple key word
Argument
AFFE_MODELE AFFE
MODELING
3D'
DEFI_MATERIAU TRACTION

VISC_SINH

STAT_NON_LINE COMP_INCR
RELATION
"VISC_ISOT_TRAC"
COMP_INCR
DEFORMATION
"SIMO_MIEHE"
CONVERGENCE
ITER_INTE_MAXI
10
CONVERGENCE
RESI_INTE_RELA
10-09

4
Results of modeling A

One tests the effort of reaction on the S5 face for 3 speeds of deformation for the values of displacement: 0.1mm, 1mm and 2mm.

Displacement U = 0.1 mm

Identification	Reference	Aster	% difference
Slow speed	639.207	639.294	0.014
Mean velocity	697.092	697.070	-0.003
Fast speed	772.983	772.885	-0.013

Displacement U = 1 mm

Identification	Reference	Aster	% difference
Slow speed	484.913	484.672	-0.050
Mean velocity	516.997	513.863	-0.606

Fast speed
555.633 552.167 -0.624

Displacement U = 2 mm

Identification Reference
Aster %
difference
Slow speed
347.473
347.661
0.054
Mean velocity
369.458
365.992
-0.938
Fast speed
393.799 390.046 -0.953

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling D_PLAN: 1 QUAD8

L23
2
3
L12
L34
y
X
1
L41
4

The imposed loading is as follows:

- *The L41 side is blocked in the direction y,*
- *The L12 side is blocked in direction X,*
- *The L23 side undergoes a displacement of 2 mm in 2000 S, 0.2 S or 0.002 S in 100 increments.*

The law of behavior tested is law VMIS_ISOT_TRAC_V.

5.2 Functionalities tested

Order
Key word factor
Simple key word
Argument
AFFE_MODELE AFFE
MODELING
“D_PLAN”
DEFI_MATERIAU TRACTION

VISC_SINH

STAT_NON_LINE COMP_INCR
RELATION
“VISC_ISOT_TRAC”

COMP_INCR
DEFORMATION
“SIMO_MIEHE”
CONVERGENCE
ITER_INTE_MAXI
10
CONVERGENCE
RESI_INTE_RELA
10-09

6
Results of modeling B

One tests the effort of reaction on the L23 face for 3 speeds of deformation for the values of displacement: 0.1mm, 1mm and 2mm.

Displacement U = 0.1 mm

Identification Reference
Aster %
difference
Slow speed
752.473
750.523
-0.259

Mean velocity
820.703
818.465
-0.273
Fast speed
910.274 907.610 -0.293

Displacement U = 1 mm

Identification Reference
Aster %
difference
Slow speed
575.182
572.674
-0.436
Mean velocity
609.788
607.023
-0.453
Fast speed
655.218 652.093 -0.477

Displacement U = 2 mm

Identification Reference
Aster %
difference
Slow speed
413.295
411.243
-0.496
Mean velocity
435.051
432.815
-0.514
Fast speed
463.612 461.120 -0.538

7 Modeling
C

7.1
Characteristics of modeling

Modeling AXIS: 1 QUAD8

L23
L12
L34
y
X
L41

The imposed loading is as follows:

- *The L41 side is blocked in the direction y,*
- *The L23 side undergoes a displacement of 2 mm in 2000 S, 0.2 S or 0.002 S in 100 increments.*

The law of behavior tested is law VISC_ISOT_TRAC.

7.2 Functionalities
tested

Order
Key word factor

Simple key word
Argument
AFFE_MODELE AFFE
MODELING
“AXIS”
DEFI_MATERIAU TRACTION

VISC_SINH

STAT_NON_LINE COMP_INCR RELATION
“VISC_ISOT_TRAC”
COMP_INCR
DEFORMATION
“SIMO_MIEHE”
CONVERGENCE
ITER_INTE_MAXI
10
CONVERGENCE
RESI_INTE_RELA
10-09

8
Results of modeling C

One tests the effort of reaction on the L23 face for 3 speeds of deformation for the values of displacement: 0.1mm, 1mm and 2mm.

Displacement U = 0.1 mm

Identification Reference
Aster %
difference
Slow speed
319.604
319.647
0.013
Mean velocity
348.483
348.535
0.015
Fast speed
386.388 386.442
0.014

Displacement U = 1 mm

Identification Reference
Aster %
difference
Slow speed
242.457
242.336
-0.050
Mean velocity
257.078
256.931
-0.057
Fast speed
276.269 276.084 -0.067

Displacement U = 2 mm

Identification Reference
Aster %
difference
Slow speed
174.061
173.831

-0.132
Mean velocity
183.251
182.996
-0.139
Fast speed
195.314 195.023 -0.149

---

9 Modeling D

9.1 Characteristics of modeling

Modeling 3D: 1 HEXA20

S5
S1
S2
S4
S2y
S3
X
Z
S6

Z

The imposed loading is as follows:

.
The S6 face is blocked according to the direction y,
.
The S2 face is blocked according to direction X,
.
The S1 face is blocked according to direction Z
.
The S5 face undergoes a displacement of 2 mm in 2000 S, 0.2 S or 0.002 S in 100 increments.

The law of behavior tested is law VISC_ISOT_LINE.

9.2 Functionalities
tested

Order
Key word factor
Simple key word
Argument
AFFE_MODELE AFFE
MODELING
3D'
DEFI_MATERIAU ECRO_LINE

VISC_SINH

STAT_NON_LINE COMP_INCR RELATION
“VISC_ISOT_LINE”
COMP_INCR
DEFORMATION
“SIMO_MIEHE”
CONVERGENCE
ITER_INTE_MAXI
10
CONVERGENCE
RESI_INTE_RELA
10-09

Handbook of Validation

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10 Results of modeling D

One tests the effort of reaction on the S5 face for 3 speeds of deformation for the values of displacement: 0.1mm, 1mm and 2mm.

Displacement U = 0.1 mm

Identification	Reference	Aster	% difference
Slow speed	498.936	499.026	0.018
Mean velocity	556.844	556.945	0.018
Fast speed	632.832	362.948	0.018

Displacement U = 1 mm

Identification	Reference	Aster	% difference
Slow speed			

433.411
433.422
0.003
Mean velocity
462.578
462.591
0.003
Fast speed
500.853 500.868 0.003

Displacement U = 2 mm

Identification Reference
Aster %
difference
Slow speed
360.757
360.740
-0.005
Mean velocity
379.083
379.066
-0.005
Fast speed
403.131 403.113 -0.004

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---

11 Modeling E

11.1 Characteristics of modeling

Modeling D_PLAN: *1 QUAD8*

L23
L12
L34
y
X
L41

The imposed loading is as follows:

- *The L41 side is blocked in the direction y,*
- *The L23 side undergoes a displacement of 2 mm in 2000 S, 0.2 S or 0.002 S in 100 increments.*

The law of behavior tested is law VISC_ISOT_LINE.

11.2 Functionalities tested

Order
Key word factor

Simple key word
Argument
AFFE_MODELE AFFE
MODELING
“D_PLAN”
DEFI_MATERIAU ECRO_LINE

VISC_SINH

STAT_NON_LINE COMP_INCR RELATION
“VISC_ISOT_LINE”
COMP_INCR
DEFORMATION
“SIMO_MIEHE”
CONVERGENCE
ITER_INTE_MAXI
10
CONVERGENCE
RESI_INTE_RELA
10-09

12 Results of modeling E

One tests the effort of reaction on the L23 face for 3 speeds of deformation for the values of displacement: 0.1mm, 1mm and 2mm.

Displacement U = 0.1 mm

Identification Reference
Aster %
difference
Slow speed
583.729
583.873
0.025
Mean velocity
651.843
652.008
0.025
Fast speed
741.214 741.406 0.026

Displacement U = 1 mm

Identification Reference
Aster %
difference
Slow speed
530.975
531.065
0.017
Mean velocity
565.249
565.350
0.018
Fast speed
610.221 610.335 0.019

Displacement U = 2 mm

Identification Reference
Aster %
difference
Slow speed
448.942
449.007
0.014
Mean velocity
470.456

470.528
0.015
Fast speed
498.687 498.767 0.016

13 Modeling
F

13.1 Characteristics of modeling

Modeling AXIS: 1 QUAD8

L23
L12
L34
y
X
L41

The imposed loading is as follows:

.
The L41 side is blocked in the direction y,
.
The L23 side undergoes a displacement of 2 mm in 2000 S, 0.2 S or 0.002 S in 100 increments.

The law of behavior tested is law VMIS_ISOT_LINE

13.2 Functionalities
tested

Order
Key word factor
Simple key word
Argument
AFFE_MODELE AFFE
MODELING
"AXIS"
DEFI_MATERIAU ECRO_LINE

VISC_SINH

STAT_NON_LINE COMP_INCR RELATION
'VMIS_ISOT_LINE
COMP_INCR
DEFORMATION
"SIMO_MIEHE"
CONVERGENCE
ITER_INTE_MAXI
10
CONVERGENCE
RESI_INTE_RELA
10-09

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14 Results of modeling F

One tests the effort of reaction on the L23 face for 3 speeds of deformation for the values of displacement: 0.1mm, 1mm and 2mm.

Displacement U = 0.1 mm

Identification	Reference	Aster	% difference
Slow speed	249.468	249.513	0.018
Mean velocity	278.422	278.473	0.018
Fast speed	316.416	316.474	0.018

Displacement U = 1 mm

Identification	Reference	Aster	% difference
Slow speed	216.706	216.711	0.002
Mean velocity	231.289	231.296	0.003
Fast speed	250.426	250.434	0.003

Displacement U = 2 mm

Identification Reference

Aster %
difference
Slow speed
180.379
180.370
-0.005
Mean velocity
189.542
189.533
-0.005
Fast speed
201.566 201.557 -0.005

---

15 Summary of the results

With less than 1% of difference between model ROUSS_VISC (degenerated) and the model VISC_ISOT_TRAC whatever the rate loading applied, one can admit that the addition viscous component in model VISC_ISOT_TRAC is correct.
In addition very weak variations (lower than 0.02%) observed between the solutions obtained with VISC_ISOT_LINE and VISC_ISOT_TRAC for a linear work hardening, also allow to validate the establishment of model VISC_ISOT_LINE.
In all the cases, less than 10 local iterations are necessary to reach convergence (precision 10-9).

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Titrate:
SSNL130 Plates indeformable on a carpet of springs
Date
:

01/09/05
Author (S):
J.L. Key FLEJOU
:
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Organization (S): EDF-R & D /AMA

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V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.130

SSNL130 Plates indeformable on a carpet of springs

Summary:

The objective is to test and validate one of the possibilities of the order AFFE_CARA_ELEM, option RIGI_PARASOL, coupled with behavior DIS_CHOC. This case test models a plate, considered as indeformable, posed on a carpet of springs.

· The springs are modelled by DIS_T (K_T_D_L), that makes it possible to impose conditions on limits at the ends of the springs which are not related to the solid.
· Behavior DIS_CHOC allows a unilateral behavior of the springs, which leaves one possibility of separation of the plate with respect to the carpet of spring.

1
Problem of reference

1.1 Geometry

A rectangular plate of width "is" and length "B", pressed on a carpet of springs.

Z
With
ep B y

B

Appear 1.1-a: Diagram of the plate and the springs in plan (y, Z)

Dimensions:
= 1m has
B = 2 m
ep = 0.30m

1.2
Properties of material

Young modulus: 2.0E+11 Pa
Poisson's ratio: 0.3
Total stiffness of the carpet of springs: K = 10000.0 N/m

1.3
Boundary conditions and loadings

The loading is a loading of pressure of the form P = p. (y-b) 2, with p = 5N/m2

Displacements imposed at the ends of the springs off-line to the plate:

· in the interval of time [0,1] displacement is imposed on 0.0 following DX, DY and DZ,
*· in the interval of time [1,2] displacement is imposed on 0.0 following DX and DY. According to DZ it is imposed by the Dz function = (t-1.0) *0.5E-02.*

1.4 Conditions
initial

Without object for a static analysis.

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8.1

Titrate:
SSNL130 Plates indeformable on a carpet of springs
Date

2 Reference solution

2.1 Method of calculation of the continuous problem

Z
B
With
y
y 0

Appear 2.1-a: Diagram of the plate and the springs after loading

The resolution of the problem consists in calculating vertical displacements of the corners of the plate and
position of the point of separation with respect to the carpet of springs.

The equilibrium equations are as follows:

Effort resulting due to the loading:
3
B
FP =
.
P ds =.
a.
p

éq
2.1-1
3
S

Moment resulting at point “A” due to the loading:
4
B
Mp =
.
P.
y ds =.
a.
p
With

éq
2.1-2
12
S

y
The plate is regarded as rigid, its displacement is form Z (y) = Ua .1-

. With

y0
U has the vertical displacement of point “A” and y0 the position of separation.

Effort of reaction of the springs:
K

y
y
Fr =
Ua
. . 1-
ds = K Ua
. 0

éq
2.1-3
B has
.

y

B
.
2
S

0
Moment of reaction of the springs at point “A”:

K

y
y2
Mr. =
U
.
. 1-
.y ds
.
= K U
.
. 0
With

éq
2.1-4
B has
has
.

y
has

B
.
6
S

0

The resolution of the equations [éq 2.1-1], [éq 2.1-2], [éq 2.1-3], [éq 2.1-4] (balance of the efforts and of
moments) gives the following result:

3.b
.
8 p has
. B
. 3
U
y =
U = -
one deduces some
has
U = -

0
4
has
K
.
9
B
3

2.2
Method of calculation of the discretized problem

In this analysis the carpet of springs is not regarded any more as continuous. The springs are regularly distributed. As previously vertical displacements of the corners of the plate and position of the line of separation with respect to the carpet of springs will be calculated.

Z
With
B
y
y 0
Appear 2.2-a: Diagram of the plate and the springs after loading
k4
C
D
be
Ag
k1
k2
p
U
éco
D
X
N
With
B
k3
ny cuttings

Appear 2.2-b: Discretization of the plate in the plan (X, y)

The figure above locates the springs according to their stiffness. This stiffness is calculated by option RIGI_PARA_SOL of order AFFE_CARA_ELEM. The assignment of the values is done in function of the surface of the zone which they affect. If K is the total stiffness of the carpet of spring, one has
thus:

K
k4
K
k4
K
k4 =

k2 = k3 =
=
k1 =
=

nx ny
.
2
nx
.
2
ny
.
4
nx
.
4
ny
.

The equilibrium equations are as follows:

Effort of reaction of the springs:

N
'
"
B
(
Fr
U. K
K.
1 J

éq
2.2-1
J) =
has
X +
X -

j=1
ny.y0

Moment of reaction of the springs along line "AB":

N
"
B
B
(
Mr.
The U.K.
.
.
1 J
. J

éq
2.2-2
J) =
has
X -

j=1
ny.y0 ny

'
K
"
K
with
K = (K
.
2 1+ K. (
4 nx -))
1 =
K = (K
.
2 3 + K. (
4 nx
X
-))
1 =
ny
X
.
2
ny
B

N.
y0 (+) B
N 1
ny
ny

The resolution of the equations [éq 2.1-1], [éq 2.1-2], [éq 2.2-1], [éq 2.2-2] (balance of the efforts and of
moments) the solution of balance gives:

3
.
p.
B .ny has (.3.ny - 8.n - 4)
.
B N (.1+ N) (.3.ny - 8.n - 4)
U =
y
has

O =

6.K (
2
.1 + N + N)
3.ny (.ny + 2.n (.ny - 2)
2
- 4.n)

or N and must there observe the following conditions:
O

B
N.
y +

0
(
) B
N 1
ny
ny
0 y

0 B
N whole

2.3 Sizes and results of reference

The sizes tested will be vertical displacements with the 4 corners of the plate.

2.4 Uncertainties on the solution

Aucunes, the solution is analytical.
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/05/005/A

---

3 Modeling With

3.1 Characteristics of modeling

The plate is modelled by elements DKT. The springs are modelled by affected SEG2 of a modeling DIS_T whose characteristics are K_T_D_L. They are the discrete ones in translation having a diagonal matrix, cf the documentation of AFFE_CARA_ELEM.

3.2 Characteristics of the grid

The plate is cut out with ny = 16 and nx = 4. Dimensions of the plate are has = 1m and B = 2m.

3.3 Functionalities tested

Orders

AFFE_CARA_ELEM HULL

RIGI_PARA_SOL
K_T_D_L
"TOTAL"
RIGI_PARA_SOL

GROUP_MA_SEG2

ORIENTATION
CARA
“ANGL_NAUT”
AFFE_CHAR_MECA_F FORCE_COQUE
GROUP_MA

DEFI_MATERIAU ELAS

DIS_CONTACT
DIST_1

STAT_NON_LINE COMP_INCR
RELATION
“DIS_CHOC”

3.4
Sizes tested and results

For the step of time n°1, displacements of the ends of the springs, off-line to the plate, are imposed on zero. The results of Code_Aster are compared with the discrete solution, which corresponds to the solution of the modelled problem. This solution is obtained for N = 12.

Nature of the results
UA=UB
UC=UD
Continuous solution
4
-
-
4
555555555
.
3
E - 03
185185185
.
1
E - 03
1125
3375
Discrete solution

208
-
-
176
532908705
.
3
E - 03
149763188
.
1
E - 03
58875
153075
Results Code_Aster -3.5334390124E-03
1.142045709828E-03
Relative error
1.50E-04 6.71E-03
Code_Aster/discrete Solution

For the step of time n°2, displacements of the ends of the springs, off-line to the plate, are moved of +5.0E-03m. The results of Code_Aster are compared with the discrete solution, which corresponds to the solution of the modelled problem.

Nature of the results
UA=UB
UC=UD
Continuous solution
1.444444444E-03
6.185185185E-03
Discrete solution (n=12)
1.467091295E-03
6.149763188E-03
Results Code_Aster 1.466560457E-03
6.142046322E-03
Relative error
3.62E-04
1.25E-03
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HT-66/05/005/A

Code_Aster ®

4
Summary of the results

The use of the discrete, affected elements on nodes or segments, with a material of the type DIS_CONTACT and used with STAT_NON_LINE (behavior COMP_INCR and relation DIS_CHOC) allows to model a unilateral behavior of the springs.
The use of key word RIGI_PARASOL of order AFFE_CARA_ELEM makes it possible to affect to springs of the stiffnesses proportional to the surface of the elements to which they are connected.

The behavior being unilateral, it is necessary that Code_Aster makes several iterations for to find the position of balance. It is also possible to encounter problems of convergence dependent on a loss of precision, had with a bad conditioning of the matrix of stiffness during iterations. Stiffness of the springs being able to cancel itself from one iteration to another.

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Organization (S): EDF/MTI/MMN, DeltaCAD

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.501

SSNL501 - Beam fixed at the two ends
subjected to a uniform pressure

Summary:

This test represents a quasi-static calculation of a fixed beam subjected to a uniform pressure, composed of a perfectly plastic elastic material. This test makes it possible to validate modelings elements
stop following:

·
COQUE_C_PLAN (SEG3),
·
DKT (TRIA3 and QUAD4),
·
COQUE_3D (TRIA7 and QUAD9),
·
POU_D_T (SEG2).

The limiting pressure is compared with an analytical reference solution.

1
Problem of reference

1.1 Geometry

y
Z
p
B

F
, y
C
, Z
H
B
X
L = 1.5 m
With

E
D
B = 0.15m
, X

L
H = 0.025 m

1.2
Properties of material

The properties of material constituting the beam are:

E = 2. 1011 Pa
Young modulus
= 0.3
Poisson's ratio

The material follows a perfectly plastic law of elastic behavior:

= 2.35 108 Pa
Yield stress
E
= 1.175 10-3
Limiting elastic strain
E

1.3
Boundary conditions and loadings

-
C.L. : Dimensioned embedded AB and CD

-
Imposed displacement following Z in E (x=L/2):

Q L4
DZ
E
=
E = 6.60910-3 m (DZ
)
E
384EI

DZ (E) varies from 0 to 30 DZe

1.4 Conditions
initial

Without object

2
Reference solution

2.1
Method of calculation used for the reference solution

Q = p B
E
With
D
L
(A)
Q
E
With
D
M
With
E
M

p
p
L/2
(b)
(c)

The ruin of the beam appears when there are plastic kneecaps at points A, D and E (figure b). The static balance of the left half of the beam, makes it possible to determine the pressure limits (figure c)

L L

16M
M = 2 M - Q () () = 0
p
=> Q =

With
p
L
2 4
L
L2
where:
qL represents the limiting pressure
bh2
M
=
p
represent the plastic moment (M p
E
4)

The appearance of the first plastic point on fibre external of the beam has place at points A and D, them
bh2
other fibres being in elastic mode. The pressure limits elastic is of Q = 2
E
E
.
L2

2.2
Results of reference

Pressure limits qL= 39 166.67 N/m

2.3
Uncertainties on the solution

Analytical solution

2.4 References
bibliographical

[1]
WILLIAM A. NASH: Theory and problems of Strength of material, Schaum' S outline series, 2/ed, McGRAW-HILL
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

3 Modeling
With

3.1
Characteristics of modeling

E
y
Modeling COQUE_C_PLAN
Not A (2.1; 0.7) (node n1)
78.5°
With

Boundary conditions: Not a: U = v = z= 0
Conditions of symmetry: Not E: z= 0
Z
X
the beam being tilted with 78.5°, the value of displacement
imposed is then: DXe=6.609 10-3 Mr. sin (78.5°)

3.2
Characteristics of the grid

A number of nodes: 21
A number of meshs and type: 10 SEG3

3.3 Functionalities
tested

Orders Key word
factor
Key word
AFFE_MODELE AFFE
MODELING
= ' COQUE_C_PLAN'
DEFI_MATERIAU ECRO_LINE
D_SIGM_EPSI
SY
AFFE_CARA_ELEM HULL
THICK
A_CIS =0.833333
AFFE_CHAR_MECA FORCE_COQUE NEAR
STAT_NON_LINE COMP_INCR
VMIS_ISOT_LINE

COQUE_NCOU
PILOTING
TYPE: "DDL_IMPO"
TEST_RESU
RESU
PARA: "ETA_PILOTAGE"

4
Results of modeling A

4.1 Values

tested

DX (E) DX Identification Moments Reference
Aster %
difference
E
10
ETA_PILOTAGE
10 1.0 1.0699
6.9
12
ETA_PILOTAGE
12 1.0 1.0699
6.9

4.2 Remarks

The width for modeling COQUE_C_PLAN is imposed on 1 in Code_Aster. In consequence, we multiplied by 1/b the loading to take account of the real width of beam.
In this analysis one uses to find the solution, a technique of resolution of the type imposed displacement ("DDL_IMPO"). This method provides for each value of displacement imposed, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.

4.3
Influence refinement of the grid

EDF
Mechanical department and Digital Models
Electricity
Eta according to displacement
from France
INFLUENCE GRID
ON SOLUTION COQUE1D
COMPARISON WITH
1.0
THE SOLUTION BEAM
0.8
AGE
0.6
OT
I
L
P
_
With
T
COQUE1D email 20
E
COQUE1D email 10
BEAM email 20
0.4
0.2
0.0
0
2
4
6
8
10x10-2
displacement (m)
agraf 12/04/2001 (c) EDF/DER 1992-1999

The reference being taken compared to the solution beam with 20 elements, one observes one improvement of results COQUE_C_PLAN when the grid is refined.

4.4 Parameters

of execution

Version:
NEW 5.04.19

Machine:
SGI-Origin2000 R12000

Obstruction memory: 16 megabytes
Time CPU To use: 16.26 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

5 Modeling
B

5.1
Characteristics of modeling

Z
zl
Modeling DKT (TRIA3)
yl
F
OE = OA = L/2 2
xl
AB // EF // centers Z
O
Boundary conditions (reference mark gobal)

y
E
- side AB: U = v =w =
B
x= y= z= 0
Conditions of symmetry
- side EF: U = 0 (local reference mark x1 y1 z1)
- side EF:
X
z= 0 (total reference mark)
With
the beam being tilted with 45°, the value of displacement
imposed is then: DXe=6.609 10-3 Mr. sin (45°)

5.2
Characteristics of the grid

A number of nodes: 43
A number of meshs and type: 20 TRIA3

5.3 Functionalities
tested

Orders Key word
factor
Key word
AFFE_MODELE AFFE
MODELING
= ' DKT'
DEFI_MATERIAU ECRO_LINE
D_SIGM_EPSI
SY
AFFE_CARA_ELEM HULL
THICK
AFFE_CHAR_MECA FORCE_COQUE NEAR
STAT_NON_LINE COMP_INCR
VMIS_ISOT_LINE

COQUE_NCOU
PILOTING
TYPE: “DDL_IMPO”
TEST_RESU
RESU
PARA: “ETA_PILOTAGE”

6
Results of modeling B

6.1 Values
tested

DX (E) DX Identification Moments Reference
Aster %
difference
E
5
ETA_PILOTAGE
5 1.0 1.11133 11.11
25
ETA_PILOTAGE
15 1.0
1.142 11.42

6.2 Remarks

In this analysis, one uses to find the solution, a technique of resolution of the type imposed displacement ("DDL_IMPO"). This method provides for each value of displacement imposed, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.
Calculations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

7/16

6.3
Influence refinement of the grid

EDF
Mechanical department and Digital Models
Electricity
Eta according to displacement
from France
1.2
INFLUENCE GRID
ON MODELING
DKT TRIA3
COMPARISON WITH
1.0
THE SOLUTION BEAM
0.8
AGE
OT
I
L
P
0.6
_
With
T
DKT 10
E
DKT 20
DKT 50
DKT 100
POU_D_T 50
0.4
0.2
0.0
0
2
4
6
8
10
12

14x10-2
displacement (m)
agraf 12/04/2001 (c) EDF/DER 1992-1999

The reference being taken compared to the solution beam with 50 elements, one observes one improvement of results DKT TRIA3 when the grid is refined.

6.4 Parameters of execution

Version:
NEW 5.04.19

Machine:
SGI-Origin2000 R12000

Obstruction memory: 16 megabytes
Time CPU To use: 20.48 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

7 Modeling
C

7.1
Characteristics of modeling

Z
Modeling DKT (QUAD4)
zl
yl
OE = OA = L/2 2
F
AB // EF // centers Z
xl
Boundary conditions (reference mark gobal)
O
- side AB: U = v =w =
y
x= y= z= 0
E
B
Conditions of symmetry
- side EF: U = 0 (local reference mark x1 y1 z1)
- side EF: z= 0 (total reference mark)
X
With
the beam being tilted with 45°, the value of displacement
imposed is then: DXe=6.609 10-3 Mr. sin (45°)

7.2
Characteristics of the grid

A number of nodes: 43
A number of meshs and type: 10 QUAD4

7.3 Functionalities
tested

Orders Key word
factor
Key word
AFFE_MODELE AFFE
MODELING
= ' DKT'
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI
SY
AFFE_CARA_ELEM HULL
THICK
AFFE_CHAR_MECA FORCE_COQUE NEAR
STAT_NON_LINE COMP_INCR VMIS_ISOT_LINE

COQUE_NCOU
PILOTING
TYPE: "DDL_IMPO"
TEST_RESU
RESU
PARA: "ETA_PILOTAGE"

8
Results of modeling C

8.1 Values
tested

DX (E) DX ***Identification Moments Reference***
Aster *%*
difference
E
5
ETA_PILOTAGE
5 1.0 1.0837 8.37
25

ETA_PILOTAGE
25 1.0 1.0998 9.98

8.2 Remarks

In this analysis, one uses to find the solution, a technique of resolution of the type imposed displacement ("DDL_IMPO"). This method provides for each value of displacement imposed, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.
Calculations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

8.3
Influence refinement of the grid

Eta according to displacement

1.2
INFLUENCE GRID
ON MODELING
DKT (QUAD4)
COMPARISON WITH
1.0

THE SOLUTION BEAM
0.8
AGE
OT
I
L
P
0.6
_
With
T
DKT 10 QUAD4
E
DKT 20 QUAD4
DKT 50 QUAD4
DKT 100 QUAD4
BEAM POU_D_T 50
0.4
0.2
0.0
0
2
4
6
8
10
12
14x10-2
displacement
agraf 12/04/2001 (c) EDF/DER 1992-1999

The reference being taken compared to the solution beam with 50 elements, one observes one improvement of results DKT QUAD4 when the grid is refined.

8.4 Parameters
of execution

Version:
NEW 5.04.19

Machine:
SGI-Origin2000 R12000

Obstruction memory: 16 megabytes
Time CPU To use: 27.55 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

9 Modeling
D

9.1
Characteristics of modeling

Z
Modeling COQUE_3D (TRIA7)
zl
yl
OE = OA = L/2 2
F
AB // EF // centers Z
xl
Boundary conditions (reference mark gobal)
O
- side AB: U = v =w =
y
x= y= z= 0
E
B
Conditions of symmetry
- side EF: U = 0 (local reference mark x1 y1z1)

- side EF: z= 0 (total reference mark)
X
With
the beam being tilted with 45°, the value of displacement
imposed is then: DXe=6.609 10-3 Mr. sin (45°)

9.2
Characteristics of the grid

A number of nodes: 83
A number of meshs and type: 20 TRIA7

9.3 Functionalities
tested

Orders Key word
factor
Key word
AFFE_MODELE AFFE
MODELING
= ' COQUE_3D'
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI
SY
AFFE_CARA_ELEM HULL
THICK
A_CIS =0
AFFE_CHAR_MECA FORCE_COQUE NEAR
STAT_NON_LINE COMP_INCR VMIS_ISOT_LINE

COQUE_NCOU
PILOTING
TYPE: “DDL_IMPO”
TEST_RESU
RESU
PARA: “ETA_PILOTAGE”

10 Results of modeling D

10.1 Values
tested

DX (E) DX Identification Moments Reference
Aster %
difference

E
5
ETA_PILOTAGE
5 1.0 1.1143 11.43
15
ETA_PILOTAGE
15 1.0 1.1682 16.82

10.2 Remarks

In this analysis, one uses to find the solution, a technique of resolution of the type imposed displacement ("DDL_IMPO"). This method provides for each value of displacement imposed, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.
Calculations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

10.3 Influence refinement of the grid

ON MODELING
COQUE_3D TRIA7
COMPARISON WITH
1.0
THE SOLUTION BEAM
0.8
AGE
OT
I
L
P
0.6
_
With
T
10 COQUE_3D TRIA7
E
20 COQUE_3D TRIA7
50 COQUE_3D TRIA7
100 COQUE_3D TRIA7
BEAM POU_D_T 50
0.4
0.2
0.0
0
2
4
6
8
10
12
14x10-2
displacement (m)
agraf 12/04/2001 (c) EDF/DER 1992-1999

The reference being taken compared to the solution beam with 50 elements, one observes one improvement of the results hulls 3D TRIA7 when the grid is refined.

10.4 Parameters
of execution

Version:
NEW 5.04.19

Machine:
SGI-Origin2000 R12000

Obstruction memory: 16 megabytes
Time CPU To use: 72.54 seconds

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

Code_Aster ®
Version
5.0

Titrate:
SSNL501 - Fixed beam subjected to a uniform pressure
Date:
19/10/01
Author (S):
P. MASSIN, F. LEBOUVIER Key
:
V6.02.501-A Page:
12/16

11 Modeling
E

11.1 Characteristics of modeling

Z
zl
Modeling COQUE_3D (QUAD9)
yl
F
OE = OA = L/2 2
xl
AB // EF // centers Z
O
Boundary conditions (reference mark gobal)
y
E
- side AB: U = v =w =
B

x= y= z= 0
Conditions of symmetry
- side EF: U = 0 (local reference mark x1 y1 z1)
- side EF:
X
z= 0 (total reference mark)
With
the beam being tilted with 45°, the value of displacement
imposed is then: DXe=6.609 10-3 Mr. sin (45°)

11.2 Characteristics of the grid

A number of nodes: 54
A number of meshs and type: 10 QUAD9

11.3 Functionalities
tested

Orders Key word
factor
Key word
AFFE_MODELE AFFE
MODELING
= ' COQUE_3D'
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI
SY
AFFE_CARA_ELEM HULL
THICK
A_CIS = 105
AFFE_CHAR_MECA FORCE_COQUE NEAR
STAT_NON_LINE COMP_INCR VMIS_ISOT_LINE

COQUE_NCOU
PILOTING
TYPE: “DDL_IMPO”
TEST_RESU
RESU
PARA: “ETA_PILOTAGE”

12 Results of modeling E

12.1 Values
tested

DX (E) DX Identification Moments Reference
Aster %
difference
E
5
ETA_PILOTAGE
5 1.0 1.0978 9.78
25
ETA_PILOTAGE
25 1.0 1.1085 10.85

12.2 Remarks

In this analysis, one uses to find the solution, a technique of resolution of the type imposed displacement ("DDL_IMPO"). This method provides for each value of displacement imposed, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.
Calculations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

12.3 Influence refinement of the grid

Eta according to displacement
from France
1.2
INFLUENCE GRID
ON MODELING
COQUE_3D (QUAD 9)
1.0
COMPARISON WITH
SOLUTION BEAM
0.8
AGE
OT
I
L
P
0.6
_
With
T
COQUE_3D 10 QUAD9
E
COQUE_3D 20 QUAD9
COQUE_3D 50 QUAD9
BEAM POU_D_T 50
COQUE_3D 100 QUAD9
0.4
0.2
0.0
0
2
4
6
8
10
12
14x10-2
displacement (m)
agraf 12/04/2001 (c) EDF/DER 1992-1999

The reference being taken compared to the solution beam with 50 elements, one observes one improvement of the results hulls 3D QUAD9 when the grid is refined.

12.4 Parameters
of execution

Version:
NEW 5.04.19

Machine:
SGI-Origin2000 R12000

Obstruction memory: 16 megabytes
Time CPU To use: 74.93 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

13 Modeling
F

13.1 characteristics of modeling

Modeling POU_D_T
E
y
A= 2.1 0.7
0.
AE =0.75 m
78.5°
With
O
Boundary conditions (reference mark gobal)

X
- node a: U = v =w = qx= qy= qz= 0
Conditions of symmetry
- node E: U = 0, Q
Z
z= 0
the beam being tilted with 78.5°, the value of displacement imposed is then: DXe=6.609 10-3 Mr. sin (78.5°)

13.2 characteristics of the grid

A number of nodes: 21
A number of meshs and type: 10 SEG2

13.3 Functionalities tested

Orders Key word
factor Key word
AFFE_MODELE AFFE
MODELING
= ' POU-D_T'
DEFI_MATERIAU ECRO_LINE
D_SIGM_EPSI

SY
VMIS_POUTRE

AFFE_CARA_ELEM BEAM
SECTION
CARA
AFFE_CHAR_MECA FORCE_POUTRE
FY
STAT_NON_LINE COMP_INCR
VMIS_POU_LINE
PILOTING
TYPE: "DDL_IMPO"
TEST_RESU
RESU
PARA: "ETA_PILOTAGE"

14 Results of modeling F

14.1 Values tested

DX (E)	DX	Identification	Moments	Reference	Aster	% difference
E	5	ETA_PILOTAGE	5	1.0	1.1083	10.83
	25	ETA_PILOTAGE	25	1.0	1.1107	11.07

In this analysis, one uses to find the solution, a technique of resolution of the type imposed displacement ("DDL_IMPO"). This method provides for each value of displacement imposed, a multiplying coefficient of the loading ("ETA_PILOTAGE"). The value of the loading imposed in "AFFE_CHAR_MECA" is equal to the limiting pressure, consequently the value of reference of parameter "ETA_PILOTAGE" is equal to 1.

Calculations were stopped when the value of parameter ETA_PILOTAGE was stabilized.

14.2 Influence refinement of the grid

EDF
Mechanical department and Digital Models
Electricity

Eta according to displacement
from France
1.2
INFLUENCE GRID
ON MODELING
BEAM POU_D_T
1.0
0.8
AGE
OT
I
L
P
0.6
_
With
T
POU_D_T 10
E
POU_D_T 20
POU_D_T 100
POU_D_T 50
0.4
0.2
0.0
0
2
4
6
8
10x10-2
displacement (m)
agraf 12/04/2001 (c) EDF/DER 1992-1999

the solution beam improves appreciably when the grid is refined.

14.3 Parameters
of execution

Version:
NEW 5.04.19

Machine:

SGI-Origin2000 R12000

Obstruction memory: 16 megabytes
Time CPU To use: 74.93 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

15 Summary of the results

On the figure below, we present the evolution of normal displacement at the center of the plate in function of the parameter of piloting.

Eta according to displacement

1.2
COMPARISON OF THE SOLUTIONS
1.0
0.8
E ETA
ETR
M
0.6
With
R
Modeling A

With
P
Modeling B
Modeling C
Modeling D
Modeling E
0.4
Modeling F
0.2
0.0
0
2
4
6
8
10
12
14
16x10-2
displacement (m)
agraf 12/04/2001 (c) EDF/DER 1992-1999

It is observed that:

- ***modelings comprising of the quadrangles give better results, by report/ratio with the meshs triangles.***

Calculations were stopped when the value of parameter ETA_PILOTAGE was stabilized, or when calculation was not possible any more. Taking into account the grids used, the results obtained are satisfactory. The errors observed are for modelings:

- ***COQUE_C_PLAN: 6.9% (A),***
- ***DKT: 11.4% for mesh TRIA3 (B) and 9.9% for mesh QUAD4 (C),***
- ***COQUE_3D: 16% for mesh TRIA7 (D) and 10.8% for mesh QUAD9 (E),***
- ***POUT_D_T: 11% (F).***

But one notes that with a finer grid at the ends and the center of the plate, place or

plasticization appears, it is possible to minimize the error compared to the reference solution.

Handbook of Validation
V6.02 booklet: Non-linear statics of the linear structures
Document: V6.02.502

SSNL502 - Beam in buckling

Summary:

This test represents a calculation of stability of a beam comforts subjected to a compressive force to one end. It makes it possible to validate modelings finite elements COQUE_3D with meshs TRIA7 and QUAD9 and modeling POU_D_T_GD with meshs SEG2 in the non-linear quasi-static field into large displacements and in great rotations in the presence of instability (Buckling of Euler)

Displacements and the moments obtained are compared with an analytical reference solution.

Handbook of Validation
V6.02 booklet: Non-linear statics of the linear structures
HT-66/03/008/A

1
Problem of reference

1.1 Geometry

Z, W
P
Z
C
B
H
Length:
L = 0.5 m
Width:
B = 0.075 m
B
L
Thickness:
H = 0.0045 m
Moment of inertia I = 5.7 10-10 m4 (bh3/12)
y
y, v
D
y
With
X, U
X

1.2
Properties of material

The properties of material constituting the plate are:

E = 2. 1011 Pa
Young modulus

= 0.3
Poisson's ratio

1.3
Boundary conditions and loadings

- C.L. : Embedded side AD

- One seeks the successive states of balance under the loading imposed on side BC:

p (T) = p T
Cr

with
T pseudo_temps

p

Cr critical load of Euler
2EI
The load applied corresponds to the critical load of Euler P =
1124 21
.

2
=
NR
Cr
4L

1.4 Conditions
initial

2
Reference solution

2.1
Method of calculation used for the reference solution

The solution of the problem known as of the elastic " " is presented in [bib1] by making the assumption of not
extension of the average axis. The analytical solution is obtained by considering integrals
elliptic.

2.2
Results of reference

The results of reference retained for the checks are indicated in **heavy** *type in*
table below. Displacements are defined in the reference mark of definition of the geometry [§1.1].

P/Pcr
uB/L wB/L
°
MAL/EI

Charge
P uB
wB
MA
(NR)
(m)
(m)
(N.M)
1,015 0,220 0,030 20°
0,56 1141.07
0.1100
0.0150
127.58
1,063 0,422 0,119 40°
1,09 1195.03
0.2110
0.0595
248.32
1,152 0,593 0,259 60°
1,67 1295.09
0.2965
0.1295
380.45
1,293 0,719 0,440 80°
2,28 1453.60
0.3595
0.2200
519.41
1,518 0,792 0,651 100°
2,96 1706.55
0.3960
0.3255
674.33
1,884 0,803 0,877 120°
3,73 2118.01
0.4015
0.4385
849.74
2,541 0,750 1,107 140°
4,70 2856.62
0.3750
0.5535
1070.72

4,029 0,625 1,340 160°
6,20 4529.44
0.3125
0.6700
1412.44
9,116 0,421 1,577 176°
9,44 10248.29
0.2105
0.7885
2150.55

10
P/Pcr
9
10
W
P/Pcr
8
U
9
Moment
7
8
6
7
5
6
4
5
3
4
2
3
1
2
Displacement (m)
0
1
Bending moment (N.m)
0,00
0,10
0,20
0,30

0,40
0,50
0,60
0,70
0,80
0
0
250
500
750
1000
1250
1500
1750
2000

2.3
Uncertainties on the solution

Analytical solution

2.4 References
bibliographical

[1]
S.P. TIMOSHENKO, J.M. MANAGES: Theory of elastic stability, second edition, DUNOD
1966.
[2]
J.L. BATOZ: Great displacements and great rotations of elastic thin beams,
Mechanical department of engineering University of Technology of Compiegne 1981.

---

3 Modeling
With

3.1
Characteristics of modeling

Z, W
C
2
Modeling COQUE_3D (TRIA7)
Modeling COQUE_3D (TRIA7)
Z
B
Boundary conditions:
- Dimensioned AD:
U = v = W = = = = 0
y, v
X
y Z
10
y
D
With
0.03

X, U
X

3.2
Characteristics of the grid

A number of nodes: 145
A number of meshs and type: 40 TRIA7

3.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = “COQUE_3D”

AFFE_CARA_ELEM HULL
THICK

COEF_RIGI_DRZ = 0.001
AFFE_CHAR_MECA
FORCE_ARETE
FX, FZ

STAT_NON_LINE PILOTING
TYPE=' LONG_ARC'

---

4 Results of modeling A

4.1 Values tested

DZ
Identification Moments Reference Aster % difference
-0.0150
DX
1.04532 0.1100
0.1025 0.230

DZ
1.04532 -0.0150 -0.0154 2.498

ETA_PILOTAGE
1.04532 1.015
1.0380 2.271

-0.0595
DX
1.09778 0.2110
0.2081 -1.340
DZ
1.09778 -0.0595 -0.0580 -2.572

ETA_PILOTAGE
1.09778 1.063
1.098 3.274

-0.22
DX
1.20824 0.3595
0.3579 -0.451
DZ
1.20824 -0.22
-0.22 -0.010

ETA_PILOTAGE
1.20824 1.293
1.39
7.483

-0.3255
DX
1.26646 0.396
0.3937 -0.581
DZ
1.26646 -0.3255 -0.3298
1.32

ETA_PILOTAGE
1.26646 1.518
1.688 11.182

-0.5535
DX
1.38521 0.375
0.3668 -2.186
DZ
1.38521 -0.5535
-0.554
0.094

ETA_PILOTAGE
1.38521 2.541
3.038 19.562

-0.67
DX
1.46121 0.3125
0.2971 -4.924
DZ
1.46121 -0.67 -0.6711 0.166

ETA_PILOTAGE
1.46121 4.029
5.28 31.053

4.2 Remarks

The strategy of calculation used breaks up into two stages:

· ***Imposed Chargement**: one imposes a disturbing load of 1/1000 of the critical load according to X to reveal the mode of buckling. This load is applied for P/Pcr=0.98 and until P/Pcr=1.015.*

· ***Imposed Déplacement****: beyond 1.01, the structure became very flexible, one imposes one increase in displacement DZ (option DDL_IMPO in STAT_NON_LINE) for to determine the behavior postbuckling.*

The use of the technique length of arc makes difficult the definition of the value of reference to to introduce into order TEST_RESU, since these values cannot be imposed. For to define the values of reference, we sought the values of the closest possible DZ those listed in the table of [§2.2] and we deferred the values of the parameter of piloting and of DX which one was to obtain for the values of DZ in question.

---

5 Modeling B

5.1 Characteristics of modeling

Z, W
C
2
Modeling CO
Modeling
QUE_3D (
COQUE_3D
QUAD9)

(QUAD9)
Z
B
Boundary conditions:
- Dimensioned AD:
U = v = W = = = = 0
y, v
X
y Z
10
y
D
With
0.03

X, U
X

5.2
Characteristics of the grid

A number of nodes: 105
A number of meshs and type: 20 QUAD9

5.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "COQUE_3D"

AFFE_CARA_ELEM HULL
THICK

COEF_RIGI_DRZ = 0.001
AFFE_CHAR_MECA
FORCE_ARETE
FX, FZ

STAT_NON_LINE PILOTING
TYPE=' LONG_ARC'

6
Results of modeling B

6.1 Values
tested

DZ
Identification Moments Reference
Aster *%*
difference
-0.0150
DX
1.03356 0.1100
0.1086
-1.255

DZ
1.03356 -0.0150
-0.0149

-0.656

ETA_PILOTAGE
1.03356 1.015
1.028
1.366

-0.0595
DX
1.08921 0.2110
0.2115
0.228
DZ
1.08921 -0.0595
-0.0599
0.689

ETA_PILOTAGE
1.08921 1.063
1.087
2.256

-0.22
DX
1.20259 0.3595

0.3618
0.653
DZ
1.20259 -0.22
-0.226
2.932

ETA_PILOTAGE
1.20259 1.293
1.36
5.215

-0.3255
DX
1.25521 0.396
0.3944
-0.384
DZ
1.25521 -0.3255
-0.3247
-0.231

ETA_PILOTAGE
1.25521 1.518
1.594
5.034

-0.5535
DX
1.37521 0.375
0.374
-0.099
DZ
1.37521 -0.5535
-0.5501
-0.608

ETA_PILOTAGE
1.37521 2.541
2.6875
5.767

-0.67
DX
1.45321 0.3125
0.3088
-1.194
DZ
1.45321 -0.67
-0.672
0.3

ETA_PILOTAGE
1.45321 4.029
4.388
8.903

6.2 Remarks

The strategy of calculation used breaks up into two stages:

· ***Imposed Chargement****: one imposes a disturbing load of 1/1000 of the critical load according to X to reveal the mode of buckling. This load is applied for P/Pcr=0.98 and until P/Pcr=1.015.*
· ***Imposed Déplacement****: beyond 1.01, the structure became very flexible, one imposes one increase in displacement DZ (option DDL_IMPO in STAT_NON_LINE) for to determine the behavior postbuckling.*

The use of the technique length of arc makes difficult the definition of the value of reference to to introduce into order TEST_RESU, since these values cannot be imposed. For to define the values of reference, we sought the values of the closest possible DZ those listed in the table of [§2.2] and we deferred the values of the parameter of piloting and of DX which one was to obtain for the values of DZ in question.

7
Graphic results of modelings A and B

---

8 Modeling C

8.1 Characteristics of modeling

Z, W
Modeling P
Modeling
OU_D_T_G
POU_D_T_GD D (SEG
(SEG2) 2)
Z
B
Boundary conditions:

y, v
- Not a:
U = v = W = x= y = z= 0
y
10

X, U
With
X

8.2
Characteristics of the grid

A number of nodes: 11
A number of meshs and type: 10 SEG2

8.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "POU_D_T_GD"
AFFE_CARA_ELEM BEAM
SECTION
RECTANGLE
AFFE_CHAR_MECA
FORCE_NODALE
FX, FZ

STAT_NON_LINE
PILOTING
TYPE = "LONG_ARC"

9
Results of modeling C

9.1 Values tested

DZ
Identification Moments Reference
Aster *%*
difference
-0.22
DX
1.18684 0.3595
0.3587 -0.64

DZ
1.18684 -0.22
-0.2129 -3.2

ETA_PILOTAGE
1.18684 1.293
1.292 -0.09

MYY
1.18684 519.41
519.1
0.06

-0.3255
DX
1.24521 0.396
0.397
0.1

DZ
1.24521 -0.3255
-0.321
-1.4

ETA_PILOTAGE
1.24521 1.518
1.5171 -0.06

MYY
1.24521 674.3
676.5
0.3

-0.4385
DX
1.30521 0.4015
0.4038
0.56
DZ
1.30521 -0.4385
-0.4362 -0.54

ETA_PILOTAGE
1.30521 1.884
1.885 0.053

MYY
1.30521 849.74
854.73
0.6

9.2 Remarks

The strategy of calculation used breaks up into two stages:

· ***Imposed Chargement****: one imposes a disturbing load of 1/1000 of the critical load according to X to reveal the mode of buckling. This load is applied for P/Pcr=0.98 and until P/Pcr=1.015.*

· ***Imposed Déplacement****: beyond 1.01, the structure became very flexible, one imposes one increase in displacement DZ (option DDL_IMPO in STAT_NON_LINE) for to determine the behavior postbuckling.*
· The results are in good adequacy with the reference solution from ETA_PILOTAGE = 1.293. Before this value, the disturbing load (necessary to obtain buckling) degrades the solution, and the variations with the analytical solution are important (up to 80%). The corresponding values are the subject of tests of nonregression. But this variation is only related to the disturbing load, since by increasing the loading vertical, the good solution is found.

9.3
Graphic results of modeling C

Handbook of Validation
V6.02 booklet: Non-linear statics of the linear structures
HT-66/03/008/A

---

10 Summary of the results

Displacement following Z according to the critical load
Displacement following X according to the critical load
2,0
2,0
1,8
1,8
1,6
R

)
1,6
/Pc
QUAD9
P
1,4
Reference
TRIA7
QUAD9
1,4
TRIA7
R
itic (
Ge C
1,2
1,2
Critical load (P/Pcr)
Tank
1,0
1,0
Reference
0,8
0,8
0,00
0,05
0,10
0,15
0,20
0,25
0,30
0,00
0,02
0,04
0,06
0,08
0,10
Displacement DX (m)

Displacement DZ (m)

The critical load is well detected. The first two results corresponding to the loads P/Pcr =1.015 and 1.063 are correct, the maximum error is 3.5% for mesh TRIA7 and 2.2% for mesh QUAD9. Mesh QUAD9 gives better results.

If one continues calculations with the elements of hulls mesh QUAD9 continues to give better results. In the zone where displacements in DZ are most important, the error made on the load 9% reach on the quadrangles and go up to 30% on the triangles. Errors increase in this area because of the slopes of the curves. The solution beam of the code provides *good results compared to the solution beam of reference.*

The coefficient of correction of transverse shearing A_CIS was put at 0.833, corresponding to thick hulls. The value (9000=106xH/L) which would have being taken into account does not allow to carry out calculations. It introduces a bad conditioning of the matrices of rigidity in increasing their disparities.
Handbook of Validation
V6.02 booklet: Non-linear statics of the linear structures
HT-66/03/008/A

Intentionally white left page.

Code_Aster ®

Version
5.0

Titrate:
SSNL503 - Elastoplastic ruin of a thin bent pipe

Date:
29/10/01
Author (S):
***P. MASSIN**, F. LEBOUVIER Key*
:
V6.02.503-A Page:
1/10

Organization (S): EDF/MTI/MMN, DeltaCAD

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
Document: V6.02.503

SSNL503 - Elastoplastic ruin of a bent pipe
thin

Summary:

This test consists in calculating the elastoplastic ruin of a thin bent pipe subjected to an inflection in

its plan
and with a pressure interns with basic effect. It makes it possible to validate modeling finite elements PIPE (SEG3
and SEG4) and TUYAU_6M (SEG3) in the quasi-static field in non-linear material.

The results obtained are compared with a numerical reference solution obtained with the computer code
(ABAQUS).
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

1
Problem of reference

1.1 Geometry
With
0.407m
1,83
y
p
0.0104m
B
X
R= 0.61m
C
D
M

Z
0.61m

1.2
Properties of material

The properties of material constituting the pipe are:

E = 193. 109 Pa
Young modulus
= 0.2642
Poisson's ratio

Constraint
Deformation
(x108 Pa)
5
Pa
Plastic p
4
2,72E+08
0.
3
3,46E+08
0.00473
3,79E+08
0.01264
2
4,04E+08
0.02836
1
4,24E+08
0.04910
5,28E+08
0.10500
0.02 0.04 0.06 0.08 0.10
= +
E
p

1.3
Boundary conditions and loadings

-
C.L. : - Embedded Section A
- Rigid Section D (no deformation of the section)

-
Loading: one seeks the successive states of balance under the following loadings:
·
Stage a: 0 T < T1
-
the pressure varies from 0 to 3.45 106 Pa
-
The force (basic effect) at the point D varies from 0 to 4.0414 105 NR
-
the moment is null
·
Stage b: T1 T < t2
-
the pressure is constant and is worth 3.45 106 Pa
-
the force (basic effect) at the point D is constant and is worth 4.0414 105 NR
-
the moment varies from 0 to 2.534 105 N.m

1.4 Conditions
initial

Without object.

3/10

2 Reference solution

2.1 Method of calculation used for the reference solution

The reference solution was obtained numerically with ABAQUS 5.5. The grid used is constituted of elements ELBOW31 to 2 nodes with 6 modes of Fourier. The discretization used is following:

- *Part AB: 24 elements,*
- *Part BC: 8 elements,*
- *Part CD: 12 elements.*

Integration in the section is as follows:

- *7 layers in the thickness,*
- *18 sectors in the circumferential direction.*

2.2 Results of reference

Moment limits = 253.4 103 N.m for a rotation around Z of 0.22 rad to point D.

2.3 Uncertainties on the solution

< 2%

2.4 References bibliographical

[1] Standard ABAQUS/Version 5.5: Example Problems Manual Volume 2, pp 4.2.2-1.

Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling PIPE (SEG3)
y, v
y
With
Cutting for numerical integration
- A Number of layers: 7
- A Number of sectors: 18
12
Boundary conditions:
Not a:
B
- DDL of Beam: DX = DY = DZ = DRX = DRY = DRZ = 0

- DDL of Hull: UIm = VIm = Wim = 0 (m=2,3)
6
D
X, U
C
UOm = VOm = WOm = 0 (m=2,3)

Z, v
WI1 = WO1 = WO = 0
4

Not D:
Z
X
- DDL of Hull: UIm = VIm = Wim = 0 (m=2,3)
UOm = VOm = WOm = 0 (m=2,3)
WI1 = WO1 = WO = 0

3.2
Characteristics of the grid

A number of nodes: 45
A number of meshs and type: 22 SEG3

3.3 Functionalities
tested
Orders Key word
factor Key word
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI, SY
AFFE_MODELE AFFE
MODELISATION=' TUYAU'
AFFE_CARA_ELEM ORIENTATION
CARA=' GENE_TUYAU'
AFFE_CHAR_MECA FORCE_TUYAU
NEAR
STAT_NON_LINE COMP_INCR
“VMIS_ISOT_LINE”

TUYAU_NCOU, TUYAU_NSEC
PILOTING
TYPE=' DDL_IMPO'
TEST_RESU RESU
PARA=' ETA_PILOTAGE'
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

4
Results of modeling A

4.1 Values
tested

DRZ
Identification Moments Reference
Aster %
difference
0.32
ETA_PILOTAGE
18 1.0 1.1699 16.99
0.34
ETA_PILOTAGE
18.5 1.0
1.1787
17.87
0.36
ETA_PILOTAGE
19 1.0 1.1869 18.69
0.38
ETA_PILOTAGE
19.5 1.0
1.1946
19.46
0.40
ETA_PILOTAGE

20 1.0 1.2020 20.20

4.2 Remarks

At the time of stage A, one gradually imposes the internal pressure and the effort due to the basic effect on
the interval of time 0<t<10. Then (stage B), one gradually imposes the bending moment on
the interval of time 10<t<20. To solve, one forces at the time of the stage B an increase in
rotation DRZ of 0.4 rad to the solution obtained at the time of stage A.

4.3 Parameters of execution

Version:
NEW 5.04.18

Machine:
SGI-Origin2000 R12000

Obstruction memory: 256 megabytes
Time CPU To use: 221.44 seconds

---

5 Modeling B

5.1
Characteristics of modeling

Modeling TUYAU_6M (SEG3)
y, v
y
With
Cutting for numerical integration
- A Number of layers: 7
- A Number of sectors: 18
12
Boundary conditions:
Not a:
B
- DDL of Beam: DX = DY = DZ = DRX = DRY = DRZ = 0

- DDL of Hull: UIm = VIm = Wim = 0 (m=2,6)
6
D
X, U
C
UOm = VOm = WOm = 0 (m=2,6)
Z, v
WI1 = WO1 = WO = 0
4

Not D:
Z
X
- DDL of Hull: UIm = VIm = Wim = 0 (m=2,6)
UOm = VOm = WOm = 0 (m=2,6)
WI1 = WO1 = WO = 0

5.2
Characteristics of the grid

A number of nodes: 45
A number of meshs and type: 22 SEG3

5.3 Functionalities

tested

Orders Key word
factor
Key word
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI, SY
AFFE_MODELE AFFE
MODELISATION=' TUYAU_6M'
AFFE_CARA_ELEM ORIENTATION
CARA=' GENE_TUYAU'
AFFE_CHAR_MECA FORCE_TUYAU
NEAR
STAT_NON_LINE COMP_INCR
“VMIS_ISOT_LINE”

TUYAU_NCOU, TUYAU_NSEC
PILOTING
TYPE=' DDL_IMPO'
TEST_RESU RESU PARA=' ETA_PILOTAGE'

6
Results of modeling B

6.1 Values tested

DRZ
Identification Moments Reference
Aster %
difference
0.32
ETA_PILOTAGE
18 1.0 1.0296 2.96
0.34
ETA_PILOTAGE
18.5 1.0
1.0379
3.79
0.36
ETA_PILOTAGE
19 1.0 1.0456 4.56
0.38
ETA_PILOTAGE
19.5 1.0
1.0528
5.28
0.40
ETA_PILOTAGE
20 1.0 1.0597 5.97

6.2 Remarks

At the time of stage A, one gradually imposes the internal pressure and the effort due to the basic effect on the interval of time $0<t<10$. Then (stage B), one gradually imposes the bending moment on the interval of time $10<t<20$. To solve, one forces at the time of the stage B an increase in rotation DRZ of 0.4 rad to the solution obtained at the time of stage A.

6.3 Parameters of execution

Version:
NEW 5.04.18

Machine:

SGI-Origin2000 R12000

Obstruction memory: 256 megabytes
Time CPU To use: 585.95 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

---

7 Modeling
C

7.1
Characteristics of modeling

Modeling PIPE (SEG4)
y, v
y
With
Cutting for numerical integration
- A Number of layers: 7
- A Number of sectors: 18
12
Boundary conditions:
Not a:
B
- DDL of Beam: DX = DY = DZ = DRX = DRY = DRZ = 0

- DDL of Hull: UIm = VIm = Wim = 0 (m=2,3)

6
D
X, U
C
UOm = VOm = WOm = 0 (m=2,3)
Z, v
WI1 = WO1 = WO = 0
4

Not D:
Z
X
- DDL of Hull: UIm = VIm = Wim = 0 (m=2,3)
UOm = VOm = WOm = 0 (m=2,3)
WI1 = WO1 = WO = 0

7.2
Characteristics of the grid

A number of nodes: 67
A number of meshs and type: 22 SEG4

7.3 Functionalities
tested

Orders Key word
factor
Key word
CREA_MAILLAGE MODI_MAILLE

OPTION: “SEG3_4”
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI, SY
AFFE_MODELE AFFE
MODELISATION=' TUYAU'
AFFE_CARA_ELEM ORIENTATION CARA=' GENE_TUYAU'
AFFE_CHAR_MECA FORCE_TUYAU NEAR
STAT_NON_LINE COMP_INCR “VMIS_ISOT_LINE”

TUYAU_NCOU, TUYAU_NSEC
PILOTING

TYPE=' DDL_IMPO'
TEST_RESU RESU PARA=' ETA_PILOTAGE'

8
Results of modeling C

8.1 Values
tested

DRZ
Identification Moments Reference
Aster %
difference
0.32
ETA_PILOTAGE
18 1.0 1.1681 16.81
0.34
ETA_PILOTAGE
18.5 1.0
1.1678
16.78
0.36
ETA_PILOTAGE
19 1.0 1.1758 17.58
0.38

ETA_PILOTAGE
19.5 1.0
1.1834
18.34
0.40
ETA_PILOTAGE
20 1.0 1.1905 19.05

8.2 Remarks

At the time of stage A, one gradually imposes the internal pressure and the effort due to the basic effect on the interval of time 0<t<10. Then (stage B), one gradually imposes the bending moment on the interval of time 10<t<20. To solve, one forces at the time of the stage B an increase in rotation DRZ of 0.4 rad to the solution obtained at the time of stage A.

8.3 Parameters of execution

Version:
NEW 5.04.20

Machine:
SGI-Origin2000 R12000

Obstruction memory: 256 megabytes
Time CPU To use: 427.64 seconds
Handbook of Validation
V6.02 booklet: Nonlinear statics of the linear structures
HI-75/01/010/A

9
Summary of the results

Rotation at the loose lead according to the moment
3,5E+05
Moment (N.m)
3,0E+05
2,5E+05
2,0E+05
PIPE (SEG4
TUYAU_6M (SEG3)
1,5E+05
PIPE (SEG3)
1,0E+05
5,0E+04
Rotation (Rad)
0,0E+00
0,00
0,05
0,10
0,15
0,20
0,25
0,30

The results obtained for modeling PIPE (SEG3 and SEG4) are rather far away from the solution of reference, (error of 20%). On the other hand, they are better for modeling TUYAU_6M (error from 6%).

The deformation of the transverse section in the elbow is represented better by modeling TUYAU_6M, adapted better to the modeling of the thin pipes. In this modeling, them displacements of the average surface of the pipe are broken up into Fourier series until order 6, instead of 3 for modeling PIPE. The modeling of reference uses a decomposition in Fourier series until order 6.

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.005

SSNP05 - Plate in traction-shearing:
viscoelasticity of Lemaître

Summary:

This test of nonlinear quasi-static mechanics consists in charging in traction-shearing a square plate. One thus validates the relation of nonlinear behavior of viscoelasticity of Lemaître (in 3D) for one nonradial loading. This test is drawn from guide VPCS of the SFM.
The plate is modelled by a voluminal element (HEXA8).
The results obtained by Code_Aster are very close to the reference solution.

---

1 Problem of reference

1.1 Geometry

Square plate
C

B
D

D
D
D
D
D
With
y
X

1.2 Material properties

E = 178.600 MPa
= 0.3
Viscoelastic relation of behavior of Lemaître
1
-
1
N = 11
= 328410 4
.
(K =
)
3045
= 017857
.
(m = 5.)
6

K
m
1.3
Boundary conditions and loadings
On a: ux = uy = 0
On side AB: ux = 0
Loading below:
Ways OA and AB, of duration 30 seconds,
Time of maintenance in A and 3600 second old B
3D MPa
(
)
B
420
With (210, 210)
D MPa
(
)
0

2
Reference solution
2.1
Method of calculation used for the reference solution
Calculation carried out with various codes of finite elements using various explicit algorithms, semi-implicit or implicit.
2.2
Results of reference

v and at the moment T = 30 S, T = 3630 S, T = 3660 S and T = 3720 S
xx
vxy

2.3
Uncertainty on the solution

Uncertainty lower than 0.01%.

2.4 References
bibliographical

[1]
Card-index SSNP05/89 of Commission VPCS

---

3 Modeling
With

3.1
Characteristics of modeling

Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X

The loading and the boundary conditions are modelled by:
DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)

DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
1
1
FORCE_NODALE: (NODE: (N01 N03 N05 N07), FX: -
( )
T, FY: -
( )
T)
D
D
4
4
1
FORCE_NODALE: (NODE: (N03 N04 N07 N08), FX: -
( )
T)
D
4
1
FORCE_NODALE: (NODE: (N02 N04 N06 N08), FY:
( )
T)
D
4
1
FORCE_NODALE: (NODE: (N01 N02 N05 N06), FX:
( )
T)
D
4

3.2
Characteristics of the grid

A number of nodes:
8
A number of meshs and types:
1 HEXA8

3.3 Functionalities
tested

Orders
Key
DEFI_MATERIAU

LEMAITRE
NR
[U4.23.01]
UN_SUR_K
UN_SUR_M
AFFE_CHAR_MECA
FORCE_NODALE
NODE
[U4.25.01]
STAT_NON_LINE
COMP_INCR
RELATION
LEMAITRE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/96/043 - Ind A

4
Results of modeling A
4.1 Values
tested
Variables
Moments (S)
Reference
Aster
% difference

v
30
2.465 104
2.457 104
0.333%
xx
v
30
2.135 104
2.128 104
0.333%
xy
v
3630
2.867 103
2.876 103
0.316%
xx
v
3630
2.483 103
2.491 103
0.326%
xy
v
3660
2.879 103
2.889 103
0.337%
xx
v
3660
2.565 103
2.562 103
-0.101%
xy
v
3720
2.879 103
2.889 103
0.337%
xx
v

3720
3.272 103
3.271 103
-0.037%
xy

4.2 Parameters of execution

Version: 3.02.11
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
39.37 seconds

5

Summary of the results

The precision necessary for this test was fixed at 0.5% instead of 0.1% not not to lengthen time too much of calculation. However, one checks that by refining the discretization in time, the error made compared to the reference solution tends towards zero.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.014

SSNP14 - Plate in traction-shearing -
Von Mises (kinematic work hardening)

Summary:

This test quasi-static 2D forced plane, from guide VPCS, enters within the framework of the validation of relations of elastoplastic behavior. A plate, made up of a plastic material with work hardening linear kinematics, is subjected at the same time to a shearing and tractive effort.
The principal interest of this test lies in the nonradial character of the loading.

1
Problem of reference

1.1 Geometry

y
1
2
1 mm
3

4
X
1 mm
1.2
Material properties
Elastoplastic law of behaviour to linear kinematic work hardening.

E

T
Y
E = 195000 MPa
= 0.3
Y
E
= 181 MPa
E

T = 1930 MPa
1.3
Boundary conditions and loadings
The plate is blocked according to OX along the side [2,4] while being subjected to a traction D and one shearing force D.
D
D
D
D
D
The way of loading is as follows:
D
D
D
With
(MPa) (MPa)
To 151.2
93.1
B
B 257.2
33.1
D
0
C
C
259.3 0

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The constraint is fixed by the way of loading (piloting in constraint), that is to say:

D D

0
D

=

0

0

0
0

0
One deduces the elastic share from it from the deformation:
D

(1+) D 0

1

E =
(1+) D - D
0

E 0
0
- D

If it is supposed now that one knows the total deflection, then one can deduce some plastic deformation:
p E
= -
Note:
p
p
p
p
p
p
p
p
xx
+
+
= 0 and
=
thus
=
= -
xx
yy zz
yy zz
yy zz
2
then the constraint of recall:
=
2 1
1
1
C p
with
.

=

-

3 C

E T

E

C: constant of Prager

2.2

Results of reference

The data of the total deflection is necessary for preceding calculations. It is obtained like average of the results of several codes.

2.3 References

bibliographical

[1]

Guide Validation of the Software packages of Structural analysis - SFM. Technical AFNOR

Handbook of Validation

V6.03 booklet: Nonlinear statics of the plane systems

HI-75/98/040 - Ind A

---

3 Modeling
With
3.1
Characteristics of modeling
HEXA8
Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X
The loading and the boundary conditions are modelled by:
· DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin) (1, 5, 6, 2), (1, 5, 7, 3), (3, 4, 8, 7) and (4, 8, 6, 2).
3.2
Characteristics of the grid
A number of nodes: 8
A number of meshs and types: 1 HEXA8 + 4 QUAD4 (faces)
3.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU

ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

4
Results of modeling A
4.1 Values
tested
Identification
Moments
Reference
Aster
% difference
xx

With
151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.48297 E2
1.4818 E2
0.079
xy
With
1.36014 E2
1.3586 E2
0.113
X
With
1.82640 E+1
1.82640 E+1
0
xx
X
With
1.68688 E+1
1.68688 E+1
0
xy
X
With
0.91320 E+1
0.91320 E+1
0
yy
xx
B
4.0444 E2
4.0672 E-2
0.563
xy

B
1.9917 E2
1.9667 E-2
-1.253
xx
C
4.4177 E2
4.4104 E-2
-0.166
xy
C
1.9205 E2
1.8913 E-2
-1.520
xx
O
4.2848 E2
4.2774 E-2
-0.173
xy
O
1.9203 E2
1.8913 E-2
-1.510

4.2 Remarks

To obtain a correct precision, it is necessary to use a rather significant number of increments for way AB, in fact, 20 in this case.

4.3 Parameters
of execution

Version: 4.03
Machine:
Obstruction memory:
8 megawords
Time CPU To use:
83 seconds

---

5 Modeling
B
5.1
Characteristics of modeling
PENTA6
Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X
The loading and the boundary conditions are modelled by:
· DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin) (1, 5, 6, 2), (1, 5, 7, 3), (3, 4, 8, 7) and (4, 8, 6, 2).
5.2
Characteristics of the grid
A number of nodes: 8
A number of meshs and types: 1 PENTA6 + 4 QUAD4 (faces)
5.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]

SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

6
Results of modeling B
6.1 Values
tested
Identification
Moments
Reference
Aster
% difference
xx
With
151.2
151.2

0
xy
With
93.1
93.1
0
xx
With
1.48297 E2
1.4818 E2
0.079
xy
With
1.36014 E2
1.3586E2
0.113
X
With
1.82640 E+1
1.82640 E+1
0
xx
X
With
1.68688 E+1
1.68688 E+1
0
xy
X
With
0.91320 E+1
0.91320 E+1
0
yy
xx
B
4.0444 E2
4.0672 E-2
0.563
xy
B
1.9917 E2
1.9667 E-2

-1.253
xx
C
4.4177 E2
4.4104 E-2
-0.166
xy
C
1.9205 E2
1.8913 E-2
-1.520
xx
O
4.2848 E2
4.2774 E-2
-0.173
xy
O
1.9203 E2
1.8913 E-2
-1.510

6.2 Parameters of execution

Version: 4.03
Machine:
Obstruction memory:
8 megawords
Time CPU To use:
32 seconds

---

7 Modeling

C

7.1

Characteristics of modeling

PENTA15
Z
N19
N07
N05
N22
N20
N18
N16
N14
N21
N08
N06
y
N10
N03
N17
N01
N13
N15
N11
N09
N04
N02
N12
X

The loading and the boundary conditions are modelled by:

· DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
DDL_IMPO: (NODE: N15, DX: 0.)
DDL_IMPO: (NODE: N21, DX: 0.)
DDL_IMPO: (NODE: N17, DX: 0.)
DDL_IMPO: (NODE: N12, DX: 0.)

· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin)
(1, 14, 5, 18, 6, 15, 2, 9), (1, 14, 5, 19, 7, 16, 3, 10), (3, 13, 4, 17, 8, 22, 7, 16) and (4, 17, 8, 21,

6, 15, 2, 12).

7.2

Characteristics of the grid

A number of nodes: 22

A number of meshs and types: 1 PENTA15 + 4 QUAD8 (faces)

7.3 Functionalities

tested

Orders

Keys

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

8
Results of modeling C
8.1 Values
tested
Identification
Moments
Reference
Aster
% difference
xx
With
151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.48297 E2
1.4818 E2
0.079
xy
With
1.36014 E2
1.3586 E2
0.113
X
With
1.82640 E+1
1.82640 E+1
0
xx
X
With
1.68688 E+1
1.68688 E+1
0
xy
X
With

0.91320 E+1
0.91320 E+1
0
yy
xx
B
4.0444 E2
4.0671 E-2
0.562
xy
B
1.9917 E2
1.9667 E-2
-1.254
xx
C
4.4177 E2
4.4103 E-2
-0.167
xy
C
1.9205 E2
1.8913 E-2
-1.521
xx
O
4.2848 E2
4.2773 E-2
-0.174
xy
O
1.9203 E2
1.8913 E-2
-1.511

8.2 Parameters of execution

Version: 4.03
Machine:
Obstruction memory:
8 megawords
Time CPU To use:
42 seconds
Handbook of Validation

---

9 Modeling D

9.1 Characteristics of modeling

PYRAM5
Z
N07
N05
N09
N08
N06
y
N03
N01
N04
N02
X

The loading and the boundary conditions are modelled by:

·
DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)

· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin) (1, 5, 6, 2), (1, 5, 7, 3), (3, 4, 8, 7) and (4, 8, 6, 2).

9.2 Characteristics of the grid

A number of nodes: 9

A number of meshs and types: 6 PYRAM5 + 4 QUAD4 (faces)

9.3 Functionalities
tested

Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

10
Results of modeling D

10.1 Values
tested

Identification
Moments
Reference
Aster
% difference
xx
With
151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.48297 E2
1.4818 E2
0.079
xy
With
1.36014 E2
1.3685 E2
0.113
X
With
1.82640 E+1
1.82640 E+1
0
xx
X
With
1.68688 E+1
1.68688 E+1
0
xy
X
With
0.91320 E+1
0.91320 E+1
0
yy

xx
B
4.0444 E2
4.0672 E-2
0.563
xy
B
1.9917 E2
1.9667 E-2
-1.253
xx
C
4.4177 E2
4.4104 E-2
-0.166
xy
C
1.9205 E2
1.8913 E-2
-1.520
xx
O
4.2848 E2
4.2774 E-2
-0.173
xy
O
1.9203 E2
1.8913 E-2
-1.510
10.2 Parameters
of execution
Version: 4.03
Machine:
Obstruction memory:
8 megawords
Time CPU To use:
32 seconds

---

11 Modeling

E

11.1 Characteristics of modeling

PYRAM13
Z
N18
N07
N05
N20
N17
N13
N15 N19
N08
N06
N10
y
N03
N01
N16
N14
N12
N09
N04
N02
N11
X

The loading and the boundary conditions are modelled by:

· DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
DDL_IMPO: (NODE: N11, DX: 0.)

DDL_IMPO: (NODE: N14, DX: 0.)
DDL_IMPO: (NODE: N16, DX: 0.)
DDL_IMPO: (NODE: N19, DX: 0.)
· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin)
(1, 13, 5, 17, 6, 14, 2, 9), (1, 13, 5, 18, 7, 15, 3, 10), (3, 12, 4, 16, 8, 10, 7, 15) and (4, 16, 8, 19, 6, 14, 2, 11).

11.2 Characteristics of the grid

A number of nodes: 29
A number of meshs and types: 6 PYRAM13 + 4 QUAD8 (faces)

11.3 Functionalities
tested
Orders
Keys

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

---

12 Results of modeling E

12.1 Values tested

Identification	Moments	Reference	Aster	% difference
xx	With	151.2	151.2	0
xy	With	93.1	93.1	0
xx	With	1.48297 E2	1.4818 E2	0.079
xy	With	1.36014 E2	1.3685 E2	0.113
X	With	1.82640 E+1	1.82640 E+1	0
xx *X*	With	1.68688 E+1	1.68688 E+1	

0
xy
X
With
0.91320 E+1
0.91320 E+1
0
yy
xx
B
4.0444 E2
4.0671 E-2
0.562
xy
B
1.9917 E2
1.9667 E-2
-1.254
xx
C
4.4177 E2
4.4103 E-2
-0.167
xy
C
1.9205 E2
1.8913 E-2
-1.521
xx
O
4.2848 E2
4.2773 E-2
-0.174
xy
O
1.9203 E2
1.8913 E-2
-1.511

12.2 Parameters of execution

Version: 4.03
Machine:
Obstruction memory:

8 megawords
Time CPU To use:
65 seconds
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SSNP14 Plates in traction-shearing - Von Mises
Date:
01/12/98
Author (S):
E. LORENTZ, P. MIALON
Key:
V6.03.014-C Page:
14/18

13 Modeling F

13.1 Characteristics of modeling

TETRA4
Z
N07
N05
N06
N08
y
N03
N01
N04
N02
X

The loading and the boundary conditions are modelled by:

· DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)

· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin) (1, 5, 6), (1, 2, 6), (1, 5, 7), (1, 3, 7), (3, 4, 7), (4, 7, 8), (2, 4, 6) and (4, 6, 8).

13.2 Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 6 TETRA4 + 8 TRIA3 (faces)

13.3 Functionalities tested

Orders
Keys
DEFI_MATERIAU
ECRO_LINE

D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
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14
Results of modeling F
14.1 Values
tested
Identification
Moments
Reference
Aster
% difference
xx
With

151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.48297 E2
1.4818 E2
0.079
xy
With
1.36014 E2
1.3685 E2
0.113
X
With
1.82640 E+1
1.82640 E+1
0
xx
X
With
1.68688 E+1
1.68688 E+1
0
xy
X
With
0.91320 E+1
0.91320 E+1
0
yy
xx
B
4.0444 E2
4.0671 E-2
0.562
xy
B

1.9917 E2
1.9667 E-2
-1.254
xx
C
4.4177 E2
4.4103 E-2
-0.167
xy
C
1.9205 E2
1.8913 E-2
-1.521
xx
O
4.2848 E2
4.2773 E-2
-0.174
xy
O
1.9203 E2
1.8913 E-2
-1.511

14.2 Parameters of execution

Version: 4.03
Machine:
Obstruction memory:
8 megawords
Time CPU To use:
31 seconds

---

15 Modeling
G

15.1 Characteristics of modeling

TETRA10
Z
N23
N07
N05
N26
N24
N17
N22
N14
N19
N06
N08
N20
N25
N10
N15
y
N03
N01
N18
N21
N13
N16
N11
N09
N04
N02
N12
X

The loading and the boundary conditions are modelled by:

· DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
DDL_IMPO: (NODE: N12, DX: 0.)

DDL_IMPO: (NODE: N16, DX: 0.)
DDL_IMPO: (NODE: N18, DX: 0.)
DDL_IMPO: (NODE: N21, DX: 0.)
DDL_IMPO: (NODE: N25, DX: 0.)
· of the surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin) (1, 14, 5, 22, 6, 15), (1, 9, 2, 16, 6, 15), (1, 14, 5, 23, 7, 17), (1, 10, 3, 19, 7, 17), (3, 13, 4, 20, 7, 19), (4, 20, 7, 26, 8, 21), (2, 12, 4, 18, 6 16) and (4, 18, 6, 25, 8, 21).

15.2 Characteristics of the grid

A number of nodes: 26
A number of meshs and types: 6 TETRA10 + 8 TRIA6 (faces)

15.3 Functionalities
tested
Orders
Keys

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_CINE_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

16
Results of modeling G
16.1 Values
tested
Identification
Moments
Reference
Aster
% difference
xx
With
151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.48297 E2
1.4818 E2
0.079
xy
With
1.36014 E2
1.3685 E2
0.113
X
With
1.82640 E+1
1.82640 E+1
0
xx
X
With
1.68688 E+1

1.68688 E+1
0
xy
X
With
0.91320 E+1
0.91320 E+1
0
yy
xx
B
4.0444 E2
4.0672 E-2
0.563
xy
B
1.9917 E2
1.9667 E-2
-1.253
xx
C
4.4177 E2
4.4104 E-2
-0.166
xy
C
1.9205 E2
1.8913 E-2
-1.520
xx
O
4.2848 E2
4.2774 E-2
-0.173
xy
O
1.9203 E2
1.8913 E-2
-1.510

16.2 Parameters of execution

Version: 4.03
Machine:

Obstruction memory:
8 megawords
Time CPU To use:
44 seconds

17
Summary of the results

The results are identical whatever the type of selected element. The results are close to reference solution since the variations are overall lower than 1.52%.

Organization (S): EDF/IMA/MMN

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems

Document: V6.03.015
SSNP15 - Plate in traction-shearing -
Von Mises (isotropic work hardening)

Summary:
This test quasi-static 2D forced plane, from guide VPCS, enters within the framework of the validation of relations of elastoplastic behavior. A plate, made up of a plastic material with work hardening isotropic linear, is subjected to a one and tractive effort of shearing.
The principal interest of this test lies in the nonradial character of the loading.

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

1
Problem of reference
1.1 Geometry

y
1
2
1 mm
3
4
X
1 mm

1.2
Material properties

Elastoplastic law of behaviour to linear kinematic work hardening.

AND
Y
E = 195.000 MPa
= 0.3

E
Y = 181 MPa

AND = 1930 MPA
1.3
Boundary conditions and loadings
The plate is blocked according to *OX* along the side [2,4] while being subjected to a traction *D* and one shearing force *D.*
D
D
D
D
D
The way of loading is as follows:
D
D
D
With
(MPa) (MPa)
To 151.2
93.1
B
B 257.2
33.1
D
0

2

Reference solution
2.1
Method of calculation used for the reference solution
In the plan (,
3), the standard of von Mises results in the traditional distance, so that one
can immediately predict the phases of load and discharge at the time of the way of loading,
since they are respectively the phases where the standard grows or decrease:
Way of loading
Numerical values (;)
Phases of loading
3
With
A0 (123,8; 76,23)
O-A0 charges elastic
B0
To (151,2; 93,1)
A0-A charges plastic
A0
B0 (158,23; 89,12)
A-B0 discharges
B (257,2; 33,1)
B0-B charges plastic
B

2.1.1 Step of resolution
Mechanically, it is about a test 0D controlled in constraint, the material being elastoplastic with criterion of von Mises and linear isotropic work hardening. For a loading controlled in constraint, one determines easily cumulated plastic deformation:
y
-
F (, *p*)
y
eq
= - - *R* *p* 0
p =
eq
in load
éq 2.1.1-1
R
The integration of the plastic deformation is of course more delicate. The equation of flow is written:
~

p

3

3

=

eq

p

p

~

=

2

2 *R*

in load

éq 2.1.1-2

eq

eq

Lastly, one will deduce the deformation via the relation from state:

p

p

= **p** + **-**

E 1:

xx = *xx* +

and

xy = *xy* +

éq 2.1.1-3

E

2 µ

2.1.2 Treatment of the phase of radial loading

Let us notice that in phase of radial loading, the law of flow [éq 2.1.2-1] is integrated directly:

~
p

= 3 *p*
2

éq 2.1.2-1

eq

The cumulated plastic deformation is then given by [éq 2.1.1-1], the plastic deformation by [éq 2.1.2-1] and total deflection by [éq 2.1.1-3]. With:

E
= 195.000 MPa
2µ
= 150.000 MPa
R'
= 1.949, 29 Mpa

One obtains:

p (A)
= 2, 0547 102
pxx (A)
= 1, 4054 102
xx (A)
= 1, 4830 102
pxy (A)
= 1, 2981 102
xy (A)
= 1, 3601 102

2.1.3 Treatment of the phase of nonradial loading

In the phase of loading nonradial B0 - B, one can parameterize the way of constraint by:

0
0
(*Q*) = **B** + *Q* (**B - B)**
with
0 *Q* 1
éq 2.1.3-1

fixed direction
As the way of loading remains confined in the traction-shearing plan (,), there will be interest with
to represent the state of stress by a complex number:
= +
0
0
I

= and (*Q*) = *B* + *Q B*
3
0
eq
(-) **éq 2.1.3-2**

fixed direction
The integration of the law of flow [éq 2.1.1-2], followed by an integration by part, makes it possible to express
plastic deformation:
1
1
2 *R* [

p] 1
1
eq
1
~
~
~
2
=
dq = ln ()

eq
-
ln
dq

3
0

[
]
eq
0
2
( )
eq
0 0
0
~ *B*
- ~B

The adoption of the complex plan allows an easy calculation of the last integral:
1
1
1
1
1
1
(

ln () -
ln 2
=

=

+

=

eq) *dq*
(
ln
) *dq* (
ln
) *dq* (
ln
) *dq* 2Re (
ln

) *dq* = 2Re

B
B0
0
0
0
0
0

-
0
Finally, the increment of plastic deformation on the B0 way - B is worth:
[
B
ln () -
p] *B*
3
B
3
~ *B*
~ *B0*
=
ln () ~
-
Re

-
éq 2.1.3-4
0
eq
B
[
]
2 *R*
B0
2 *R*
B
B0
( )
-
B0

2.2 Results of reference

By calculating the plastic deformation cumulated by [éq 2.1.1-1], the plastic deformation by [éq 2.1.3-4] and the total deflection by [éq 2.1.1-3], one obtains:

p (B)
= 4, 2329 102
pxx (B)
= 3, 3946 102
xx (B)
= 3, 5265 102

One obtains:

pxy (B)
= 2, 0250 102
xy (B)
= 2, 0471 102

One will be interested in the values of the constraints, the deformations and the cumulated plastic deformation
at points A and B of the way of loading.

2.3 References bibliographical

[1]
French company of the Mechanics. Guide validation of the software packages of structural analysis (VPCS). Technical AFNOR, 1990.

3 Modeling With

3.1 Characteristics of modeling

HEXA8
Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X

The loading and the boundary conditions are modelled by:
DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
surface forces imposed (key word FORCE_FACE) on the faces (meshs of skin) (1, 5, 6, 2), (1, 5, 7, 3), (3, 4, 8, 7) and (4, 8, 6, 2).

3.2 Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8, 4 QUAD4

3.3 Functionalities tested

Orders
Keys

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_ISOT_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
CALC_ELEM
OPTION
RADI_ELNO_SIGM
[U4.61.02]
DCHA_ELNO_SIGM

---

4 Results of modeling A

4.1 Values tested

Identification
Moments
Reference
Aster
% difference
xx
With
151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.4830 102
1.4830 102
0.002
xy
With
1.3601 102
1.3601102
0.003
p
With
2.055 102
2.055 102
0.001
p
With
xx
1.4054 102
1.4054 102
0.002
p
With
1.2981 102
1.2981 102
0.002
xy
xx

B
3.5265 102
3.5325 102
0.170
xy
B
2.0471 102
2.0351 102
0.584
p
B
4.2329 102
4.2329 102
0.001
p
B
xx
3.3946 102
3.4006 102
0.176
p
B
2.0250 102
2.0131 102
0.589
xy
as well as the indicators of load-discharge:
Identification
Moments
Reference
Aster
% difference
IND_ENER
With
0.
0
0
IND_SEUIL
With
0.
0
0
IND_ENER

B
3.26 102
3.33 102
2.5
IND_SEUIL
B
9.71 102
9.64 102
0.7

4.2 Notice

The phases A and B are tested. 41 increments of loading are used:
· 1 for phase A,
· 40 for the phase B.

4.3 Parameters
of execution

Version: 5.00.09
Machine:
Obstruction memory:
8 MW
Time CPU To use:
84 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling in plane constraints: C_PLAN
y

N01
N02
N03
N04
X
The loading and the boundary conditions are modelled by:
DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
(NODE: N02, DX: 0.
)
surface forces imposed (key word FORCE_CONTOUR) on the faces (meshs of skin SEG2)
(1, 2), (2, 4), (4, 3) and (3, 1).

5.2

Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4, 4 SEG2

5.3 Functionalities
tested

Orders
Keys

DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_ISOT_LINE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.02]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
CALC_ELEM
OPTION
RADI_ELNO_SIGM
[U4.61.02]
DCHA_ELNO_SIGM
Handbook of Validation

6
Results of modeling B
6.1 Values
tested
Identification
Moments
Reference
Aster
% difference
xx
With
151.2
151.2
0
xy
With
93.1
93.1
0
xx
With
1.4830 102
1.4830 102
0.002
xy
With
1.3601 102
1.3601102

0.003
p
With
2.055 102
2.055 102
0.001
p
With
xx
1.4054 102
1.4054 102
0.002
p
With
1.2981 102
1.2981 102
0.002
xy
xx
B
3.5265 102
3.5325 102
0.170
xy
B
2.0471 102
2.0351 102
0.584
p
B
4.2329 102
4.2329 102
0.001
p
B
xx
3.3946 102
3.4006 102
0.176
p
B
2.0250 102
2.0131 102

0.589
xy
as well as the indicators of load-discharge:

Identification	Moments	Reference	Aster	% difference
IND_ENER	With	0.	0	0
IND_SEUIL	With	0.	0	0
IND_ENER	B	3.26 102	3.33 102	2.5
IND_SEUIL	B	9.71 102	9.64 102	0.7

6.2 Notice

The phases A and B are tested. 41 increments of loading are used:
· 1 for phase A,
· 40 for the phase B.

6.3 Parameters of execution

Version: 5.00.09
Machine:
Obstruction memory:
8 MW
Time CPU To use:
84 seconds

7 Modeling
C
7.1
Characteristics of modeling

Modeling hull DKT-DKQ

7.2 Geometry

2
N01
N06
N02
MA2
Z
1
4
MA3
0,8 mm
MA1
N03
N05
N04
y
3
0,6 mm
X

Dimensions of the structure do not change compared to the problem of reference, only differs its orientation.

Co-ordinates of the nodes:

Nodes
X
y
Z

N01
0
0.8
0.6
N02
0
0.2
1.4
N03
0
0
0
N04
0
0.6
0.8
N05
0
0.3
0.4
N06
0
0.5
1

Boundary conditions:

DDL_IMPO: (NODE: N04, DY: 0. , DZ: 0.)
(ALL: YES DX: 0.)
LIAISON_DDL:
(NODE: (N02 N02) DDL: (“DY” “DZ”)
COEF_MULT: (0.75 1.) COEF_IMP: 0.)

Loading:

One imposes surface forces (key word FORCE_ARETE) on the faces (meshs of skin SEG2) (1,2), (2,4), (4,3) and (3,1).

Specificity DKT and DKQ:

Two layers in the thickness for plasticity.

7.3 Characteristics of the grid

A number of nodes: 6
A number of meshs and types: 2 TRIA3 and 1 QUAD4

7.4 Values tested

Displacements tested are those of the problem of reference by taking account of the rotation of structure.
The generalized strains, stresses and efforts are tested in the reference mark definite user by order ANGL_REP. The values are thus those given by the problem of reference.

7.5 Functionalities tested

Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
AFFE_CARA_ELEM
HULL
THICK
[U4.24.01]
ANGL_REP
AFFE_CHAR_MECA
LIAISON_DDL
[U4.25.01]
FORCE_ARETE
STAT_NON_LINE
COMP_INCR
VMIS_ISOT_LINE
[U4.32.01]
COQUE_NCOU

8 Results of modeling C

8.1 Values tested

The values are tested at point A of the way of loading OA. One tests as follows:
Displacements (DEPL). It result easily from the reference solution since the deformation is homogeneous.

Identification	**Reference**	**Aster**	**% difference**
DY N01	1.86722 102	1.86722 102	0
DZ N01	3.25413 102	3.25413 102	0
DY N06	1.224 102	1.224 102	0
DZ N06	1.88485 102	1.84485 102	0
DY N02	5.8O782 103		

5.80782 103
0
DZ N02
4.35586 103
4.35586 103
0
Constraints (SIGM_ELNO_VARI).
Identification
Reference
Aster
% difference
SIXX MA2 N01
1.512 102
1.51199 102
2.27 106
SIXY MA2 N01
93.1
93.1002
2.82 106
SIXX MA1 N03
1.512 102
1.51199 102
2.27 106
SIXY MA1 N03
93.1
93.1002
2.82 106
SIXX MA2 N03
1.512 102
1.51199 102
2.27 106
SIXY MA2 N03
93.1
93.1002
2.82 106
SIXX MA3 N02
1.512 102
1.51199 102
2.27 106
SIXY MA3 N02
93.1
93.1002
2.82 106

Efforts generalized by elements with nodes (SIEF_ELNO_ELGA).

Identification	**Reference**	**Aster**	**% difference**
NXX MA2 N01	3.024 102	3.02399 102	2.27 106
NXY MA2 N01	1.862 102	1.862005 102	2.82 106
NXX MA1 N03	3.024 102	3.02399 102	2.27 106
NXY MA1 N03	1.862 102	1.862005 102	2.82 106
NXX MA2 N03	3.024 102	3.02399 102	2.27 106
NXY MA2 N03	1.862 102	1.862005 102	2.82 106
NXX MA3 N02	3.024 102	3.02399 102	2.27 106
NXY MA3 N02	1.862 102	1.862005 102	2.82 106

Deformations by element with the nodes starting from displacements (EPSI_ELNO_DEPL).

Identification	**Reference**	**Aster**	**% difference**
EPXX MA2 N01	1.48297 102	1.48296 102	3.65 106
EPYY MA2 N01	7.25977 103	7.25972 103	7.14 106
EPXY MA2 N01	1.36014 102	1.36014 102	2.48 106
EPXX MA1 N03	1.48297 102	1.48296 102	3.65 106
EPYY MA1 N03	7.25977 103	7.25972 103	7.14 106
EPXY MA1 N03	1.36014 102	1.36014 102	2.48 106
EPXX MA2 N03	1.48297 102	1.48296 102	3.65 106

EPYY MA2 N03
7.25977 103
7.25972 103
7.14 106
EPXY MA2 N03
1.36014 102
1.36014 102
2.48 106
EPXX MA3 N02
1.48297 102
1.48296 102
3.65 106
EPYY MA3 N02
7.25977 103
7.25972 103
7.14 106
EPXY MA3 N02
1.36014 102
1.36014 102
2.48 106
EPXX MA3 N04
1.48297 102
1.48296 102
3.65 106
EPYY MA3 N04
7.25977 103
7.25972 103
7.14 106
EPXY MA3 N04
1.36014 102
1.36014 102
2.48 106
Elastic constraints by element with the nodes starting from displacements (use in elasticity) (SIGM_ELNO_DEPL)
Identification
Reference
Aster
% difference
SIXX MA2 N01
2.71109 103
2.71108 103
3.05 106
SIYY MA2 N01

6.02328 102
6.02320 102
103
SIXY MA2 N01
2.04021 103
2.04021 103
2.48 106
SIXX MA1 N03
2.71109 103
2.71108 103
3.05 106
SIYY MA1 N03
6.02328 102
6.02320 102
103
SIXY MA1 N03
2.04021 103
2.04021 103
2.48 106
SIXX MA2 N03
2.71109 103
2.71108 103
3.05 106
SIYY MA2 N03
6.02328 102
6.02320 102
103
SIXY MA2 N03
2.04021 103
2.04021 103
2.48 106
SIXX MA3 N02
2.71109 103
2.71108 103
3.05 106
SIYY MA3 N02
6.02328 102
6.02320 102
103
SIXY MA3 N02
2.04021 103
2.04021 103
2.48 106

8.2 Parameters
of execution

Version: 4.02.31
Machine: CRAY C90
Obstruction memory:
15.32 MW
Time CPU To use:
26.93 seconds

---

9 Modeling
D

9.1
Characteristics of modeling

Modeling hull COQUE_3D

9.2 Geometry

N01
N012
N08
N016
N02
2
MA2
N014
MA3
Z
1
4
N010

N09
N017
N05
N07
0,8 mm
N013
y
3
MA1
0,6 mm
N03
N04
X
N011
N06
N015
Dimensions of the structure do not change compared to the problem of reference, only differs its orientation.

Co-ordinates of the nodes:

Nodes	**X**	**y**	**Z**
N01	0	0.8	0.6
N02	0	0.2	1.4
N03	0	0	0
N04	0	0.6	0.8
N05	0	0.4	0.3

N06
0
0.3
0.4
N07
0
0.2
1.1
N08
0
0.5
1
N09
0
0.1
0.7
N010
0
0.25
0.5
N011
0
0.15
0.2
N012
0
0.65
0.8
N013
0
0.06666
0.466666
N014
0
0.433333
0.533333
N015
0
0.45
0.6
N016
0
0.35

1.2
N017
0
0.05
0.9

Boundary conditions:

DDL_IMPO: (NODE: N04, DY: 0. , DZ: 0.)
(ALL: YES DX: 0.)
LIAISON_DDL: (NODE: (N02 N02) DDL: (“DY” “DZ”)
COEF_MULT: (0.75 1.) COEF_IMP: 0.)
LIAISON_DDL: (NODE: (N07 N07) DDL: (“DY” “DZ”)
COEF_MULT: (0.75 1.) COEF_IMP: 0.)

Loading:

One imposes surface forces (key word FORCE_ARETE) on the faces (meshs of skin SEG3) (1,2), (2,4), (4,3) and (3,1).

9.3
Characteristics of the grid

A number of nodes: 17
A number of meshs and types: 2 TRIA7 and 1 QUAD9

9.4 Values
tested

Displacements tested are those of the problem of reference by taking account of the rotation of structure.
The generalized strains, stresses and efforts are tested in the reference mark definite user
by order ANGL_REP. The values are thus those given by the problem of reference.

9.5 Functionalities
tested

Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
AFFE_CARA_ELEM
HULL
THICK
[U4.24.01]
ANGL_REP
AFFE_CHAR_MECA
LIAISON_DDL
[U4.25.01]
FORCE_ARETE
STAT_NON_LINE
COMP_INCR
VMIS_ISOT_LINE
[U4.32.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

---

10 Results of modeling D

10.1 Values tested

The values are tested at point A of the way of loading OA. One tests as follows:
Displacements (DEPL). It result easily from the reference solution since the deformation is homogeneous.

Identification	**Reference**	**Aster**	**% difference**
DY N01	1.86722 102	1.86722 102	0
DZ N01	3.25413 102	3.25413 102	0
DY N08	1.224 102	1.224 102	0
DZ N08	1.84485 102	1.84485 102	0
DY N02	5.80782 103	5.80782 103	0

DZ N02
4.35586 103
4.35586 103
0
Efforts generalized by elements with nodes (SIEF_ELNO_ELGA).
Identification
Reference
Aster
% difference
NXX MA1 N01
3.024 102
3.02399 102
2.2 106
NXY MA1 N01
1.862 102
1.862005 102
2.9 106
NXX MA1 N03
3.024 102
3.02399 102
2.2 106
NXY MA1 N03
1.862 102
1.862005 102
2.9 106
NXX MA2 N03
3.024 102
3.02399 102
2.2 106
NXY MA2 N03
1.862 102
1.862005 102
2.9 106
NXX MA3 N02
3.024 102
3.02399 102
2.2 106
NXY MA3 N02
1.862 102
1.862005 102
2.9 106
Deformations by element with the nodes starting from displacements (EPSI_ELNO_DEPL).
Identification

Reference
Aster
% difference
EPXX MA1 N01
1.48297 102
1.48296 102
3.24 106
EPYY MA1 N01
7.25977 103
7.25973 103
6.69 106
EPXY MA1 N01
1.36014 102
1.36014 102
2.91 106
EPXX MA1 N03
1.48297 102
1.48296 102
3.24 106
EPYY MA1 N03
7.25977 103
7.25973 103
6.69 106
EPXY MA1 N03
1.36014 102
1.36014 102
2.91 106
EPXX MA2 N03
1.48297 102
1.48296 102
3.24 106
EPYY MA2 N03
7.25977 103
7.25973 103
6.69 106
EPXY MA2 N03
1.36014 102
1.36014 102
2.91 106
EPXX MA3 N02
1.48297 102
1.48296 102
3.24 106

EPYY MA3 N02
7.25977 103
7.25973 103
6.69 106
EPXY MA3 N02
1.36014 102
1.36014 102
2.91 106
EPXX MA3 N04
1.48297 102
1.48296 102
3.24 106
EPYY MA3 N04
7.25977 103
7.25973 103
6.69 106
EPXY MA3 N04
1.36014 102
1.36014 102
2.91 106

Elastic constraints by element with the nodes starting from displacements (use in elasticity) (SIGM_ELNO_DEPL)

Identification
Reference
Aster
% difference
SIXX MA1 N01

2.71109 103
2.71108 103
2.64 106
SIYY MA1 N01
6.02328 102
6.02321 102
103
SIXY MA1 N01
2.04021 103
2.04021 103
2.91 106
SIXX MA1 N03
2.71109 103
2.71108 103
2.64 106
SIYY MA1 N03
6.02328 102
6.02321 102
103
SIXY MA1 N03
2.04021 103
2.04021 103
2.91 106
SIXX MA2 N03
2.71109 103
2.71108 103
2.64 106
SIYY MA2 N03
6.02328 102
6.02321 102
103
SIXY MA2 N03
2.04021 103
2.04021 103
2.91 106
SIXX MA3 N02
2.71109 103
2.71108 103
2.64 106
SIYY MA3 N02
6.02328 102
6.02321 102
103

SIXY MA3 N02
2.04021 103
2.04021 103
2.91 106

10.2 Parameters
of execution

Version: 4.02.31
Machine: CRAY C90
Obstruction memory:
15.32 MW
Time CPU To use:
10.11 seconds

---

11 Modeling
E

11.1 Characteristics of modeling

Modeling hull 3D (MEC3TR7H)

y
N08
N01
N02
N010
N05
N07
N09
N03
N06 N04
X

Boundary conditions:
DDL_IMPO:
(NODE: N04, DX: 0. , DY: 0.)
(NODE: N02, DX: 0.
)
(NODE: NO7, DX: 0.)
(NODE: (N01, N02, N03) DZ: 0.)
Loading
FORCE_NODALE:
(NODE: N01, FX: -9.683333, FY: - 15.516666)
(NODE: N02, FX: 15.516666, FY: 15.516666)
(NODE: N03, FX: - 40.716666, FY: - 15.516666)
(NODE: N04, FX: - 15.516666, FY: 15.516666)
(NODE: N05, FX: - 100.8, FY: - 62.066666)
(NODE: N06, FX: - 62.066666)
(NODE: N07, FX: 62.066666)
(NODE: N08, FX: 62.066666)

11.2 Characteristics of the grid

A number of nodes: 11
A number of meshs and types: 2 TRIA7

11.3 Functionalities
tested

Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
AFFE_CARA_ELEM
HULL
THICK
[U4.24.01]
STAT_NON_LINE
COMP_INCR
VMIS_ISOT_LINE
[U4.32.01]

12
Results of modeling E
12.1 Values
tested

The displacement of the N01 node results easily from the reference solution since the deformation
D
D
is homogeneous. It is tested not of A but also in a point *O*
(=1238. = 762.) way
OA. The cumulated plastic deformation is also tested.

Identification
Moments
Reference
Aster
% difference
DX N01

O
6.349 104
6.349 104
0
DY N01

O
1.207 103
1.207 103
0
DY N01
With
3.431 102
3.446 102
0.4
p

With
2.055 10-2
2.055 10-2
0.

12.2 Notice

Only portion OA of the way of the loading is actually tested.

12.3 Parameters
of execution

Version: 4.01.05
Machine: CRAY C98
Obstruction memory:
8 MW
Time CPU To use:
8.5 seconds

13
Summary of the results

The results are identical whatever the selected modeling. The results are close to reference solution since the variations are overall lower than 0.6%.

Organization (S): EDF/IMA/MMN

Handbook of Validation

V6.03 booklet: Nonlinear statics of the plane systems

Document: V6.03.101

SSNP101 - Plate in traction-shearing:
viscoelasticity of Lemaître (D_PLAN)

Summary:

This test of nonlinear quasi-static mechanics consists in charging in traction-shearing a square plate.
One thus validates the relation of nonlinear behavior of viscoelasticity of Lemaître in plane deformations for a nonradial loading.

The plate is modelled by an element 2D (QUAD4).

The results obtained by Code_Aster are very close to the reference solution.

---

1 Problem of reference

1.1 Geometry

Square plate

C

B

D

D
D
D
D
D
With
y
The problem is independent
X
dimensions of the plate

1.2

Material properties

E = 178.600 MPa
= 0.3
Viscoelastic relation of behavior of Lemaître
1
-
1
N = 11
= 328410 4
.
(*K* =
)
3045
= 017857
.
(*m* = 5.)
6
K
m

1.3

Boundary conditions and loadings

In a: ux = uy = 0
On side AB: ux = 0
Loading below:
Ways OA and AB, of duration 30 seconds,
Time of maintenance in A and 3600 second old B.
3D MPa
(
)
B

420
With (210, 210)
D MPa
(
)
0

---

2 Reference solution

2.1 Method of calculation used for the reference solution

Calculation 3D Aster carried out with an element HEXA8 of which all the nodes have a displacement imposed no one
according to OZ. That makes it possible to constitute a reference for the case of the plane deformations (in the plan
(OX, OY)), where one does not have an analytical solution or results of other computer codes.
Operation in 3D of the non-linear viscoelasticity of Lemaître itself was validated with the assistance test SSNP05A.

2.2 Results of reference

v and at the moment T = 30 S, T = 3630 S, T = 3660 S and T = 3720 S
xx
vxy

2.3 Uncertainty on the solution

Uncertainty lower than 0.5%.

---

3 Modeling
With
3.1
Characteristics of modeling

y
N02
N03
N01
N04
X

The loading and the boundary conditions are modelled by:

DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N03, DX: 0.)
1
1
FORCE_NODALE: (NODE; (N01 N02), FX: -
( )
T, FY: -

)
D ()
T
D
2
2
1
FORCE_NODALE: (NODE; (N01 N04), FX: -
( )
T)

D
2
1
FORCE_NODALE: (NODE; (N03 N04), FY:
( )
T)
D
2
1
FORCE_NODALE: (NODE; (N02 N03), FX:
( )
T)
D
2
where ()

D T and
( )
D T are the higher definite positive functions [§1.3].

3.2
Characteristics of the grid

A number of nodes:
4
A number of meshs and types:
1 QUAD4

3.3 Functionalities
tested

Orders
Key
AFFE_MODELE
AFFE
MODELING
D_PLAN
[U4.22.01]
DEFI_MATERIAU
LEMAITRE
NR
[U4.23.01]
UN_SUR_K
UN_SUR_M
AFFE_CHAR_MECA
FORCE_NODALE
NODE

[U4.25.01]
STAT_NON_LINE
COMP_INCR
RELATION
LEMAITRE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/96/043 - Ind A

4
Results of modeling A
4.1 Values
tested
Variables
Moments (S)
Reference
Aster
% difference
v
30
1.7620 104
1.7623 104
0.017%
xx
v
30

1.81585 104
1.81582 104
-0.002%
xy
v
3630
1.9030 103
1.9033 103
0.018%
xx
v
3630
2.0789 103
2.0791 103
0.012%
xy
v
3660
1.9130 103
1.9125 103
-0.024%
xx
v
3660
2.1906 103
2.1904 103
-0.011%
xy
v
3720
1.8740 103
1.8741 103
0.004%
xx
v
3720
3.1813 103
3.1814 103
0.005%
xy

4.2 Parameters of execution

Version: 3.02.11

Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
39.07 seconds
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/96/043 - Ind A

5
Summary of the results

One cannot use the viscoelastic model of LEMAITRE (nor those of Zircaloy: ZIRC_CYRA2, and ZIRC_EPRI) in 2D forced plane (C_PLAN).

Organization (S): EDF/IMA/MMN

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.102 document

SSNP102 - Rate of refund of energy for a plate notched in elastoplasticity

Summary:

This test makes it possible to validate the calculation of the rate of refund of energy G for an elastoplastic problem in
plane deformations [R7.02.06].

This test contains a modeling in plane deformations and the results are compared with values numerical obtained by WATANABE by another method of calculation of G in elastoplasticity. Variations
are considered to be satisfactory.

Caution:

The defect is modelled by a notch and not by a crack like usually in breaking process (cf [R7.02.07]).

1
Problem of reference

1.1 Geometry

y
With
F
30
B
C
0.25
E
4 D
X
10

1.2
Material properties

The law of behavior of material constituting the notched plate is a law of plasticity with criterion of von Mises and isotropic linear work hardening. It is described in order DEFI_MATERIAU [U4.23.01].

E

T
y
E = 205800 MPa
= 0.3

E
y = 480.2 MPa

AND = 20.58 MPa

1.3
Boundary conditions and loadings

The plate is blocked:

.
according to OX along side AB
.
according to OY along the side OF

It is subjected to a cyclic traction on side AF.

F
F
196 NR
0
1.0
2.0
3.0
T (S)

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The reference solution results from an article of K. WATANABE [bib1]. To calculate the rate of restitution of energy in elastoplasticity K. WATANABE uses an integral J which is detailed in [bib1] and [bib2].

The reference solution is numerical:

T (S)	0.	0.5	1.0	1.5	2.0	2.5	3.0
G	0.	2.769	3.183	4.276	4.651	5.691	6.052

It should be noted that:

- *the theoretical method used in the reference is different from the method established in Code_Aster,*
- *the geometry of the test and the reference are identical, but the grid of the Aster test is more refined that that of the reference.*

2.2 References bibliographical

[1] K. WATANABE: Application of J - integral to elasto-plastic Ace, Bulletion of JSME, Flight. 28, n°242, August 1985

[2] G. DEBRUYNE: Proposal for an energy parameter of ductile rupture in thermoplasticity HI-74/95/027/0

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/01/010/A

3 Modeling
With

The plate is modelled by 243 TRIA6 and 39 SEG3.

3.1
Characteristics of the grid

A number of nodes: 527

A number of meshs and types: 243 TRIA6

3.2 Functionalities
tested

Orders

Keys
DEFI_MATERIAU TRACTION
SIGM

[U4.23.01]
STAT_NON_LINE COMP_INCR RELATION
VMIS_ISOT_TRAC

[U4.32.01]
CALC_THETA THETA_2D

[U4.63.02]
CALC_G_THETA_T COMP_INCR
RELATION
VMIS_ISOT_TRAC
[U4.63.03]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/01/010/A

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
Tolerance
T = 0.5 S

G (crown A)
2.769

2.863 3.39
3.5
G (crown B)
2.769

2.860 3.29
3.5
G (crown C)
2.769
2.859 3.27
3.5
G (crown D)
2.769
2.858 3.25
3.5
T = 1.0 S

G (A)
3.183
3.208 0.81
1.0
G (B)
3.183
3.212 0.93
1.0
G (C)
3.183
3.212 0.93
1.0
G (D)
3.183
3.212 0.93
1.0
T = 1.5 S

G (A)
4.2760
4.204 1.66
2.0

G (B)
4.2760
4.201 1.75
2.0
G (C)
4.2760
4.199 1.78
2.0
G (D)
4.2760
4.199 1.80
2.0
T = 2.0 S

G (A)
4.6510
4.640 0.22
1.0
G (B)
4.6510
4.645 0.13
1.0
G (C)
4.6510
4.645 0.13
1.0
G (D)
4.6510
4.645 0.13
1.0
T = 2.5 S

G (A)
5.691
5.570 2.12
3.0
G (B)
5.691

5.565 2.20
3.0
G (C)
5.691
5.564 2.22
3.0
G (D)
5.691
5.563 2.25
3.0
T = 3.0 S

G (A)
6.052
6.048 0.06
1.0
G (B)
6.052
6.052 0.01
1.0
G (C)
6.052
6.052 0.01
1.0
G (D)
6.052
6.052 0.01
1.0

4.2 Remarks

WITH B C D
Rinf 0.55 1.0
1.5
2.0
Rsup
1.0 1.5 2.0 3.0

4.3 Parameters of execution

Version: 4.03

Machine: CRAY C90

Obstruction memory:
8 MW
Time CPU To use:
175 seconds
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/01/010/A

5
Summary of the results

The comparison of the results resulting from the test Aster and those obtained numerically by another method by WATANABE are satisfactory (the maximum change is 3.4%).

It should be noted that the numerical results are sensitive to the grid in the vicinity of the notch and to form this notch. In particular if one models a crack the values obtained are false. In revenge, starting from a sufficient smoothness of the grid and ray of the notch, results numerical are stable. For more information, it is advised to consult the document [R7.02.07] and bibliographical references.

Code_Aster ®
Version
7.2

Titrate:
SSNP108 - Concrete element prestressed in compression

Date:
18/12/03
Author (S):
C. CHAVANT, X. DESROCHES, L. VIVAN Key
:
V6.03.108-B Page:
1/10

Organization (S): EDF-R & D /AMA, CS

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.108

SSNP108 - Prestressed concrete element
in compression

Summary:

One considers an elementary structure made up of a square concrete plate crossed by a cable of prestressed whose neutral fibre is confused with the horizontal axis of symmetry of the plate. The vertical edge left of the plate is fixed. The cable is put in traction at its two ends in order to prestress toggle plate. The losses of tension along the cable are neglected.

The goal of this case-test is to validate, on a simple configuration, the method of calculation of the state of balance of a prestressed structure of concrete. The results are validated by comparison with an analytical solution.

1
Problem of reference

1.1 Geometry

The concrete plate is square; the sides have even length L = H = 2 Mr.
The thickness of the plate is worth E = 0,6 Mr.
The cable crosses the plate horizontally, with middle height, without eccentricity in the thickness. The surface of the cross-section of the cable is worth Its = 1,5.104 m2.

y
2 m
With
B
1 m
H = 2 m
0
X
L = 2 m

1.2
Properties of materials

Material concrete constituting the plate:
Young modulus Eb = 3.1010 Pa
Material steel constituting the cable:
Young modulus Ea = 2,1.1011 Pa

The Poisson's ratio is taken equal to 0 for two materials; the direction thus is privileged of normal load application (direction X).

The losses of tension being neglected, the various parameters being used for their estimate are fixed at 0.

1.3
Boundary conditions and loadings

The lower top of the left edge of the plate, i.e. the node origin (0; 0), are embedded: all DDLs of translation and rotation are blocked.
The higher top of this same left edge, i.e. the node (0; 2), is supported bi-laterally: DDLs of translation blocked are DX and DZ.

One applies at the two ends of the cable (which are fixed on the concrete in A and B) a normal effort of traction: (F0; 0) with node A (0; 1) and (F0; 0) with the node B (2; 1), with F0 = 2.105 NR.

2
Reference solution

2.1 Solution
formal

Displacements in the cable and the concrete are continuous and homogeneous. Thus displacement
uL
horizontal on the interval [0; L] is worth U (X) =
X
L
The normal constraints in the concrete plate and the steel wire rope are written respectively (assumption of elasticity):

U
=
B
Eb
=
uL

E
X
B L

U
uL
=
has
E
+
has
= E
+
0
has

0
X
L

F0
where 0 =
is initial prestressing in the cable
Its
and uL is horizontal displacement with the X-coordinate L.

- LF
The balance of the unit plates and cables is written:
0
B Sb + has Its = 0 uL =

Eb eH + Ea Its
uL
EbeH
The normal effort in the cable is worth: NR has = Ea Its
+ F0 = F
L
0

EbeH + Ea Its
The total effort on the vertical section of the concrete plate is worth:

uL
EbeH
Nb = Eb eH
= - F0

L
EbeH + Ea Its

One deduces from it the linear density of normal effort on the concrete plate

Ebb
NR xx = - F0

EbeH + Ea Its

2.2
Numerical values of reference

The numerical values of reference are:

uL
= 1,11013974.105 m
Na = 1,99825153.105 NR
Nb = 1,99825153.105 NR
NR xx = 9,99125765.104 N/m
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---

3 Modeling With

3.1 Characteristics of modeling

The figure below gives a simplified representation of the grid.

NB002001
NB002002
Y
NC001001
NC001005
X
NB001001
NB001002

The concrete plate is represented by an element DKT, supported by a mesh quadrangle to 4 nodes.

A thickness E = 0,6 m is affected for him, as well as a material concrete for which are defined them behaviors ELAS (Young modulus Eb = 3.1010 Pa) and BPEL_BETON: parameters characteristics of this relation are fixed at 0 bus one neglects the losses of tension along the cable of prestressed.

Node NB001001 is embedded: DX, DY, DZ, DRX, DRY and DRZ are blocked. Node NB002001 is supported bilaterally: DX and DZ are blocked.

The cable is represented by 4 elements MECA_BARRE, supported by 4 meshs segments with 2 nodes.

A surface of cross-section Its = 1,5.104 m2 their is affected, as well as a material steel for which are defined behaviors ELAS (Young modulus Ea = 2,1.1011 Pa) and BPEL_ACIER: parameters characteristics of this relation are fixed at 0 (neglected losses of tension), except for stress ultimate elastic for which a zero value is illicit (fprg = 1,77.109 Pa).

The F0 tension = 2.105 NR is applied to nodes NC001001 and NC001005. This value of tension is coherent with the values of section and yield stress, for a cable of prestressed of type strand.

The calculation of the state of balance of the unit plates and cable is carried out in only one step, it behavior being elastic.

3.2 Stages of calculation and functionalities tested

The principal stages of calculation correspond to the functionalities which one wishes to validate:

- *operator DEFI_MATERIAU: definition of the relations of behavior BPEL_BETON and BPEL_ACIER, in the particular case where losses of tension along the cable of prestressed are neglected (default values of the parameters);*
- *operator DEFI_CABLE_BP: determination of a constant profile of tension along the cable of prestressed, losses being neglected; calculation of the coefficients of the relations kinematics between the DDL of the nodes of the cable and the DDL of the nodes “close” to the concrete plate;*
- *operator AFFE_CHAR_MECA: definition of a loading of the type RELA_CINE_BP;*
- *operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account loading of the type RELA_CINE_BP.*

4
Results of modeling A

4.1 Values tested

4.1.1 Linear density of normal effort on the vertical section of the concrete plate

One compares the values extracted field SIEF_ELNO_ELGA resulting from STAT_NON_LINE with the values theoretical of reference. The extraction is done on mesh QD001001 representing the concrete plate. The component to which the tests relate is NXX.
The tolerance of relative variation compared to the reference is worth 10 6%.

Node	***Value of reference***	***Computed value***	***Relative variation***
NB001001	***9,99125765.104 N/m***	***9,9912576495569.104 N/m***	*-4,43.10-11 %*
NB001002	***9,99125765.104 N/m***	***9,9912576495569.104 N/m***	*-4,43.10-11 %*
NB002001	***9,99125765.104 N/m***	***9,9912576495569.104 N/m***	*-4,43.10-11 %*
NB002002	*9,99125765.104 N/m*	*9,9912576495569.104 N/m*	*-4,43.10-11 %*

4.1.2 Horizontal displacement of the nodes of the concrete plate

One compares the values extracted field DEPL resulting from STAT_NON_LINE with the theoretical values from
reference.
The component to which the tests relate is DX.
The tolerance of relative variation compared to the reference is worth 10 6%.

Node
Value of reference
Computed value
Relative variation
NB001002
1,11013974.105 m
1,1101397388397.105 m
-1,05.10-9 %
NB002002
1,11013974.105 m
1,1101397388397.105 m
-1,05.10-9 %

4.1.3 Normal effort in the cable

One compares the values extracted field SIEF_ELNO_ELGA resulting from STAT_NON_LINE with the values
theoretical of reference. The extraction is done on meshs SG001001 for node NC001001,
SG001002 for node NC001002, SG001003 for node NC001003, and SG001004 for
nodes NC001004 and NC001005.
The component to which the tests relate is NR.
The tolerance of relative variation compared to the reference is worth 10 6%.

Node
Value of reference
Computed value
Relative variation
NC001001
1,99825153.105 NR
1,9982515299113.105 NR
-4,44.10-11 %
NC001002
1,99825153.105 NR
1,9982515299113.105 NR
-4,44.10-11 %

NC001003
1,99825153.105 NR
1,9982515299113.105 NR
-4,44.10-11 %
NC001004
1,99825153.105 NR
1,9982515299113.105 NR
-4,44.10-11 %
NC001005
1,99825153.105 NR
1,9982515299113.105 NR
-4,44.10-11 %

4.1.4 Horizontal displacement of the nodes of the cable

One compares the values extracted field DEPL resulting from STAT_NON_LINE with the theoretical values from
reference.
The component to which the tests relate is DX.
The tolerance of relative variation compared to the reference is worth 10 6%.

Node
Value of reference
Computed value

Relative variation
NC001002
2,77534935.106 m
2,7753493470988.106 m
-1,05.10-9 %
NC001003
5,55069869.106 m
5,5506986941982.106 m
7,56.10-10 %
NC001004
8,32604804.106 m
8,3260480412974.106 m
1,56.10-10 %
NC001005
1,11013974.105 m
1,1101397388389.105 m
-1,05.10-9 %

4.2 Remarks

The computed values correspond indeed to those theoretically awaited. One obtains well a compactness for the concrete plate.

One observes an infinitesimal difference between horizontal displacement with node NC001005 belonging to the cable and horizontal displacement to nodes NB001002 and NB002002 of the plate of concrete. The recorded values should be identical, but the rounding errors appearing in the coefficients of the relations kinematics explain this infinitesimal difference.

---

5 Modeling B

5.1 Characteristics of modeling

For this modeling, the nodes "cables" and "concrete" are confused.
The figure below gives a simplified representation of the grid.

N3
N4
Y
N5
N6
X
N1
N2

The concrete plate is represented by 10 elements DKT, supported by 10 meshs QUAD4.

A thickness E = 0,6 m is affected for him, as well as a material concrete for which are defined them behaviors ELAS (Young modulus Eb = 3.1010 Pa) and BPEL_BETON: parameters characteristics of this relation are fixed at 0 bus one neglects the losses of tension along the cable of prestressed.

The nodes N1, N5 and N3 are embedded: DX, DY, DZ, DRX, DRY and DRZ are blocked.

The cable is represented by 5 elements MECA_BARRE, supported by 5 meshs SEG2.

A surface of cross-section Its = 1,5.104 m2 their is affected, as well as a material steel for which are defined behaviors ELAS (Young modulus Ea = 2,1.1011 Pa) and BPEL_ACIER: parameters characteristics of this relation are fixed at 0 (neglected losses of tension), except for stress ultimate elastic for which a zero value is illicit (fprg = 1,77.109 Pa).

The F0 tension = 2.105 NR is applied to the nodes N5 and N6. This value of tension is coherent with values of section and yield stress, for a cable of prestressed of strand type.

The calculation of the state of balance of the unit plates and cable is carried out in only one step, it behavior being elastic.

5.2
Stages of calculation and functionalities tested

The principal stages of calculation correspond to the functionalities which one wishes to validate:

- *operator DEFI_MATERIAU: definition of the relations of behavior BPEL_BETON and BPEL_ACIER, in the particular case where losses of tension along the cable of prestressed are neglected (default values of the parameters);*
- *operator DEFI_CABLE_BP: determination of a constant profile of tension along the cable of prestressed, losses being neglected; calculation of the coefficients of the relations kinematics between the DDL of the nodes of the cable and the DDL of the nodes "close" to the concrete plate;*
- *operator AFFE_CHAR_MECA: definition of a loading of the type RELA_CINE_BP;*
- *operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account loading of the type RELA_CINE_BP.*
- *operator POST_RELEVE_T, NOM_CMP= `on all field SIEF_ELNO_ELGA.*

6
Results of modeling B

6.1 Values tested

6.1.1 Linear density of normal effort on the vertical section of the concrete plate

Node	Value of reference	Computed value	Relative variation
N1	***9,99125765.104 N/m***	***9,8387753336725.104 N/m***	*1.526 %*
N3	***9,99125765.104 N/m***	***9,8387753336725.104 N/m***	*1.526 %*

6.1.2 Normal effort in the cable

Node	Value of reference	Computed value	Relative variation
N5	***1,99825153.105 NR***	***1,9982248921222.105 NR***	*-0.001 %*
N6	***1,99825153.105 NR***	***1,9943932520206.105 NR***	*-0.193 %*

6.1.3 Normal effort in the cable via order POST_RELEVE_T

Node
Value of reference
Computed value

N5
1,998224892.105 NR
1,9982248921222.105 NR

N6
1,994393252.105 NR
1,9943932520206.105 NR

6.2 Remarks

The computed values correspond indeed to those theoretically awaited. One obtains well a compactness for the concrete plate.

7
Summary of the results

The results obtained are validated by comparison with an analytical solution of reference with one very good precision.

The particular functionalities tested are as follows:

.
operator DEFI_MATERIAU: definition of the parameters characteristic of the materials steel

and concrete allowing the calculation of the tension along the cable of prestressing, following the rules BPEL;

- *operator DEFI_CABLE_BP: calculation of the tension along the cable and the coefficients of relations kinematics between the DDL of the nodes of the cable and the DDL of the "close" nodes concrete plate;*
- *operator AFFE_CHAR_MECA: definition of a loading of the type RELA_CINE_BP;*
- *operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account loading of the type RELA_CINE_BP.*

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Titrate:
SSNP109 Cables of prestressing excentré in beam a right Date concrete:
21/02/02
Author (S):
C. CHAVANT, Key Mr. LAINET
:
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Organization (S): EDF/AMA, CS IF

SSNP109 - Cable of excentré prestressing in a right concrete beam

Summary

One considers a right concrete beam, of rectangular section, crossed over his length by a cable of prestressed out of steel. The cable is right, parallel to average fibre of the beam, and passes to middle height of section of the beam, while being excentré compared to the average plan. The left section of the beam and the end left of the cable are fixed. The cable is put in traction at its right end, in order to prestress the beam in inflection-compression. The losses of tension along the cable are neglected.

The goal of this case-test is to validate the method of calculation of the state of balance of a structure of concrete prestressed by comparison with an analytical reference solution.

1

Problem of reference

1.1 Geometry

The concrete beam is right, of rectangular section.
Its dimensions are: L × H × p = 10 m × 0,4 m × 0,2 m (y= h/2).
The cable crosses the beam parallel with average fibre of the beam, with middle height. Its eccentricity by
report/ratio in the average plan is E = 0,05 m (z= E).
The surface of the cross-section of the cable is worth Its = 1,5.104 m2.

y
H
X
With
p
Z
L
p
E
X
F0
L
Z

1.2
Properties of materials

Material concrete constituting the beam: Young modulus Eb = 3.1010 Pa
Material steel constituting the cable:
Young modulus Ea = 2,1.1011 Pa

The Poisson's ratio is taken equal to 0 for two materials. One thus cancels the effects of Poisson in directions y and Z. Displacements have components only in the plan (X, Z).

Losses of tension in the cable being neglected, the various parameters being used for their estimate are fixed at 0.

1.3
Boundary conditions and loadings

Point A located in bottom of the left edge of the beam, co-ordinates (0; h/2; 0), are blocked in translation according to the three directions and in rotation around axis Y.
The blocking of the DDL of rotation DRY implies a null slope of the deformation of average fibre in

X = 0.

The left end of the cable, co-ordinates (0; 0; E), is blocked in translation according to the three directions.

One applies at the right end of the cable, of co-ordinates (L; 0; E), a normal effort of traction (F0; 0; 0) where F0 = 2.105 NR.

2
Reference solution

The analytical solution of reference is determined by the theory of the beams.
A embed-free beam is considered. The geometrical characteristics are those defined in paragraph [§2.1]. The prestressed cable applies at the loose lead a normal effort of compression (- F; 0; 0) and a bending moment (0; eF; 0).

The solution of this problem is as follows:

xx 0
0
F
12ez
***Tensor of the constraints**: = 0*
0
0 with xx = -

1+

2

HP
p
0
0
0

(
F
12ez
U X, y, Z) = -
1+
X

E
2
B HP
p

12
B F
ez
H
Displacements: *v*
(X, y, Z) =
1 +
y +

E
2

2

B HP
p

(
F
E
6

2
2
H

W X, y, Z) =

2
2
B Z +
X -
y

2
B
-
- *Z*
E

B HP
p

4

U
= v = W = 0
H
with the ***boundary conditions****:*
X = 0 y = -
Z = 0

in
,
,

y = 0
2

When the effects Poisson are neglected (B = 0), the solution in displacements is simplified as follows:

12
(
F
ez
U X, y, Z) = -
1+
X
E

2
B HP
p
v
(X, y, Z) = 0

(
F
ex
6 2
W X, y, Z) =
×

E
2
B HP
p

The numerical values of reference are calculated using the analytical expressions above, by using for F the value with the overall balance of the normal effort in the cable:

E HP
F = - F
B
0

12e2
E HP + E S
B

has has 1 +

p2
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3 Modeling
With

3.1
Characteristics of modeling

The figure below gives a simplified representation of the grid of the beam.

NB002001
NB002021
NC002001
NC002021
NB001001
NB001021

The concrete beam is represented by 20 elements of the type DKT, supported per as many meshs quadrangles with 4 nodes.

A thickness p = 0,2 m their is affected, as well as a material concrete for which are defined them behaviors ELAS (Young modulus Eb = 3.1010 Pa) and BPEL_BETON: parameters characteristics of this relation are fixed at 0 bus one neglects the losses of tension along the cable of prestressed.

DDL DX, DY, DZ and DRY of node NB001001 are blocked.

The cable is represented by 20 elements MECA_BARRE, supported per as many meshs segments to 2 nodes. The ends left and right-hand side are respectively nodes NC001001 and NC001021.

A surface of cross-section Its = 1,5.104 m2 is assigned to the elements, as well as a material steel for which are defined behaviors ELAS (Young modulus Ea = 2,1.1011 Pa) and BPEL_ACIER:

parameters characteristic of this relation are fixed at 0 (neglected losses of tension), except stress ultimate elastic for which the value of fprg = 1,77.109 Pa is selected.

The DDL DX, DY, and DZ of node NC001001 are blocked.

The F0 tension = 2.105 NR is applied to node NC001021. This value of tension is coherent with values of section and yield stress, for a cable of prestressed of strand type.

The calculation of the state of balance of the beam unit and cable is carried out in only one step, it behavior being elastic. One carries out then two complementary calculations allowing of to determine the constraints in skins lower and higher (z= ±p/2) of the beam.

3.2
Stages of calculation and functionalities tested

The principal stages of calculation correspond to the functionalities which one wishes to validate:

·
operator DEFI_MATERIAU: definition of the relations of behavior BPEL_BETON and BPEL_ACIER, in the particular case where losses of tension along the cable of prestressed are neglected (default values of the parameters);
·
operator DEFI_CABLE_BP: determination of a constant profile of tension along the cable of prestressed, losses being neglected; calculation of the coefficients of the relations kinematics between the DDL of the nodes of the cable and the DDL of the nodes "close" to the concrete beam, in the case of a excentré cable;
·
operator AFFE_CHAR_MECA: definition of a loading of the type RELA_CINE_BP;
·
operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account loading of the type RELA_CINE_BP.

One uses finally operator CALC_ELEM option SIGM_ELNO_DEPL in order to calculate the constraints in lower skin then in higher skin of the beam.

4
Results of modeling A

The value with the balance of the normal effort in the cable is F = 1,95509 105 NR. This value is used to calculate the numerical results of reference using the analytical expressions clarified in paragraph [§3].

4.1 Values tested

4.1.1 Displacements of the nodes of the concrete part

One compares the values extracted field DEPL resulting from STAT_NON_LINE with the theoretical values from reference corresponding to the plan Z= 0.
The tolerance of relative variation compared to the reference is worth 0,1%.

Node	Component	Value of reference	Computed value	Relative variation
NB001006	DX	2,036552.104 m	2,0365561834835.104 m	2,05.10-6 %
NB002006	DX	2,036552.104 m	2,0365561835042.104 m	2,05.10-6 %
NB001011	DX	4,073104.104 m	4,0731123669671.104 m	2,05.10-6 %
NB002011	DX	4,073104.104 m	4,0731123670073.104 m	2,05.10-6 %
NB001016	DX	6,109656.104 m	6,1096685504506.104 m	

2,05.10-6 %
NB002016 DX 6,109656.104 m
6,1096685505104.104 m
2,05.10-6 %
NB001021 DX 8,146208.104 m
8,1462247339343.104 m
2,05.10-6 %
NB002021 DX 8,146208.104 m
8,1462247340137.104 m
2,05.10-6 %

NB001006 DZ
3,818535.103 m
3,8185428440476.103 m
2,05.10-6 %
NB002006 DZ
3,818535.103 m
3,8185428440475.103 m
2,05.10-6 %
NB001011 DZ
1,527414.102 m
1,5274171376197.102 m
2,05.10-6 %
NB002011 DZ
1,527414.102 m
1,5274171376197.102 m
2,05.10-6 %
NB001016 DZ
3,436682.102 m
3,4366885596448.102 m
1,91.10-6 %
NB002016 DZ
3,436682.102 m
3,4366885596448.102 m
1,91.10-6 %
NB001021 DZ
6,109656.102 m
6,1096695504804.102 m
2,05.10-6 %
NB002021 DZ

6,109656.102 m
6,1096695504804.102 m
2,05.10-6 %

4.1.2 Linear density of normal effort on the average level of the concrete part (analyzes with the model of plate)

One compares the values extracted field SIEF_ELNO_ELGA resulting from STAT_NON_LINE with the values
theoretical of reference.
The component to which the tests relate is NR (NR = S p).
XX
XX
xx
The tolerance of relative variation compared to the reference is worth 0,1%.

Node
Net
Value of reference
Computed value
Relative variation
NB001001 QD001001 4,887725.105 N/m
4,8877348399136.105 N/m
2,01.10-6 %
NB002001 QD001001 4,887725.105 N/m
4,8877348399728.105 N/m
2,01.10-6 %
NB001011 QD001011 4,887725.105 N/m
4,8877348402090.105 N/m
2,01.10-6 %
NB002011 QD001011 4,887725.105 N/m
4,8877348402511.105 N/m
2,01.10-6 %
NB001021 QD001020 4,887725.105 N/m
4,8877348403607.105 N/m
2,01.10-6 %
NB002021 QD001020 4,887725.105 N/m
4,8877348404039.105 N/m
2,01.10-6 %

4.1.3 Normal constraint on the lower skin (Z = -0.1 m) of the concrete part

One compares the values extracted field SIGM_ELNO_DEPL resulting from CALC_ELEM with the values

theoretical of reference.
The component to which the tests relate is SIXX.
The tolerance of relative variation compared to the reference is worth 0,1%.
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Node
Net
Value of reference
Computed value
Relative variation
NB001001 QD001001
1,221931.106 Pa
1,2219337100849.106 Pa
2,22.10-6 %
NB002001 QD001001
1,221931.106 Pa
1,2219337101082.106 Pa
2,22.10-6 %
NB001011 QD001011
1,221931.106 Pa
1,2219337101212.106 Pa
2,22.10-6 %
NB002011 QD001011
1,221931.106 Pa
1,2219337100924.106 Pa
2,22.10-6 %
NB001021 QD001020
1,221931.106 Pa

1,2219337100302.106 Pa
2,22.10-6 %
NB002021 QD001020
1,221931.106 Pa
1,2219337101559.106 Pa
2,22.10-6 %

4.1.4 Normal constraint on the higher skin (z= 0.1 m) of the concrete part

One compares the values extracted field SIGM_ELNO_DEPL resulting from CALC_ELEM with the values
theoretical of reference.
The component to which the tests relate is SIXX.
The tolerance of relative variation compared to the reference is worth 0,1%.

Node	Net	Value of reference	Computed value	Relative variation
NB001001	QD001001	6,109656.106 Pa	6,1096685504454.106 Pa	2,05.10-6 %
NB002001	QD001001	6,109656.106 Pa	6,1096685505156.106 Pa	2,05.10-6 %
NB001011	QD001011	6,109656.106 Pa	6,1096685504816.106 Pa	2,05.10-6 %
NB002011	QD001011	6,109656.106 Pa	6,1096685504999.106 Pa	2,05.10-6 %
NB001021	QD001020	6,109656.106 Pa	6,1096685503914.106 Pa	2,05.10-6 %
NB002021	QD001020	6,109656.106 Pa	6,1096685505642.106 Pa	2,05.10-6 %

4.2 Remarks

The computed values correspond indeed to those theoretically awaited. One obtains well a state of inflection-compression for the concrete beam.

5
Summary of the results

The results obtained are validated by comparison with an analytical solution of reference with one very good precision.

The particular functionalities tested are as follows:

·
operator DEFI_MATERIAU: definition of the parameters characteristic of the materials steel and concrete allowing the calculation of the tension along the cable of prestressing, following the rules BPEL;
·
operator DEFI_CABLE_BP: calculation of the tension along the cable and the coefficients of relations kinematics between the DDL of the nodes of the cable and the DDL of the "close" nodes concrete beam;
·
operator AFFE_CHAR_MECA: definition of a loading of the type RELA_CINE_BP;
·
operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account loading of the type RELA_CINE_BP.

Organization (S): EDF-R & D /AMA

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Document: V6.03.110

SSNP110 - Fissure edge in a plate rectangular finished in elastoplasticity

Summary:

This test is a case test in nonlinear breaking process.

One calculates the rate of refund of energy G in a rectangular plate finished, fissured and subjected to one loading of traction. The law of behavior used is an elastoplastic law of Von Mises without work hardening.

This case test includes/understands two plane modelings in 2D forced in order to study the influence of the catch in count or not terms of second order of the deformations (DEFORMATION = "SMALL" or "GREEN" in

operator STAT_NON_LINE). The stability of the result of the calculation of G by the method théta (CALC_G_THETA_T)
is also checked.

1
Problem of reference

1.1 Geometry

L
C
B
Uy =
W
Uy = -
With
X
has
y

D

Length
L = 50 mm

Width
W = 16 mm
Depth of crack
= 6 mm have

1.2 Properties of material

The material is rubber band-perfectly plastic of Von Mises type. Its properties are them following:

Young modulus
E = 2,0601 105 MPa
Poisson's ratio = 0.3
Yield stress
Y = 808,34 MPa
Modulate work hardening
= 0

1.3 Boundary conditions and loading

The model will be limited to half of the structure, the plan of the vertical crack being a plan of symmetry.

Boundary conditions
They are thus defined for the half spaces y 0.
Vertical displacement UX = 0 at the point B
Horizontal displacement UY = 0 in ligament AB

Loading
Horizontal displacement imposed on the segment CD: UY =

2 Reference solution

No the reference solution. This is a test of not-regression.
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HT-62/06/005/A

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3 Modeling
With

3.1
Characteristics of modeling

It is about a calculation in elastoplasticity under the assumption of small displacements.

3.2
Characteristics of the grid

The grid, built with an automatic procedure gibi, consists of 400 elements
quadratic (1000 nodes). Tori are defined in bottom of crack in order to improve the precision of
calculation in breaking process, cf [Figure 3.2-a] below. The ray of the largest torus is of
1,5 Misters.

Appear 3.2-a: Grid of the fissured rectangular plate

3.3
Functionalities tested

Calculation of the rate of refund of energy by the method THETA in elastoplasticity.

Orders

STAT_NON_LINE COMP_ELAS
RELATION
ELAS_VMIS_LINE

DEFORMATION
SMALL
CALC_THETA

CALC_G_THETA OPTION
CALC_G

COMP_ELAS
RELATION
ELAS_VMIS_LINE

4
Results of modeling A

4.1 Values tested

The values of the rate of refund are tested for five values of imposed horizontal displacement.
One compares the results obtained for three different crowns of integration:

· crown 1: Rinf = 0,15 mm; Rsup = 0,6 mm
· crown 2: Rinf = 0,3 mm; Rsup = 0,9 mm
· crown 3: Rinf = 0,9 mm; Rsup = 1,5 mm

Displacement
***G** (N/mm)*
***G** (N/mm)*
***G** (N/mm)*
imposed (mm)
crown 1
crown 2
crown 3
0,02 3.29 3.20 3.20
0,04 13.60 13.24 13.24
0,06 31.97 31.22 31.24
0,08 58.99 57.74 57.76
0,1 91.42
89.64 89.71

The results are satisfactory: the maximum variation enters the values of G obtained on the three crowns of integration is lower than 2%.
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HT-62/06/005/A

Code_Aster ®
Version
8.1

Titrate:
SSNP110 - Fissure edge in a plate in elastoplasticity
Date:
15/02/06
Author (S):
***E. GALENNE** Key*
:
V6.03.110-A Page:
5/6

5 Modeling B

5.1 Characteristics of modeling

It is about a calculation in elastoplasticity under the assumption of great displacements.

5.2
Characteristics of the grid

The grid is identical to that of modeling A.

5.3
Functionalities tested

Calculation of the rate of refund of energy by the method THETA in elastoplasticity.

Orders

STAT_NON_LINE COMP_ELAS
RELATION
ELAS_VMIS_LINE
DEFORMATION
GREEN
CALC_THETA

CALC_G_THETA OPTION
CALC_G

COMP_ELAS
RELATION
ELAS_VMIS_LINE

6
Results of modeling B

6.1 Values
tested

The values of the rate of refund are tested for the same crowns of integration as in modeling A.

Displacement
***G** (N/mm)*
***G** (N/mm)*

G *(N/mm)*
imposed (mm)
crown 1
crown 2
crown 3
0,02 3.26 3.17 3.18
0,04 13.36 13.03 13.07
0,06 31.02 30.50 30.67
0,08 56.33 55.90 56.51
0,1 85.84
85.91 87.47

The results are satisfactory: the maximum variation enters the values of G obtained on the three crowns of integration is lower than 2%.

The effect of the terms of second order in the deformation is relatively weak: the variation enters them results of two modelings is increasing with imposed displacement and is worth to the maximum 6%, cf [Figure 6.1-a].

100
90
MODELING A
80
MODELING B

70
***)** 60*
m
/
***m** 50*
NR
***G (**40*
30
20
10
0
0
0,02
0,04
0,06
0,08
0,1
0,12
Imposed displacement (mm)

Appear 6.1-a: Comparison of the rates of refund of energy of two modelings

7
Summary of the results

This case test makes it possible to be ensured of the invariance of the calculation of the rate of refund of energy by
method théta according to the crowns of integration for laws of behavior of the type
plastic rubber band-perfectly.
The weak contribution of the terms of second order in the deformation is highlighted.

21/02/02
Author (S):
***X.DESROCHES**, NR. RAHNI Key*
:
V6.03.111-A Page:
1/6

Organization (S): EDF/AMA, CS IF

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.111 document

SSNP111 - Passage of the points of Gauss with the nodes on quadratic elements

Summary:

It is about a test of static mechanics nonlinear.

The goal is to test, in the order CALC_ELEM, the matrices making it possible to place from the points of integration to the nodes tops. The treated case relates to a plane plate subjected on one of its faces to
a pressure varying linearly.

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V6.03 booklet: Nonlinear statics of the plane systems
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

Plane rectangular plate.

N4
N3
N1N2 = 40 mm
N1N4 = 30 mm
y

X
N1
N2

1.2
Properties of materials

E = 200.000 MPa
= 0

Slope of the traction diagram C = 1930 Mpa

Elastic limit
y
= 181 Mpa

1.3
Boundary conditions and loadings mechanical

Face NR NR: blocked according to OX
1
2
Node NR: blocked according to OY
1
Node NR: blocked according to OY
2

Pressure varying linearly:

P (N2)
LMBO
= 0

P (NR)
LMBO
3 = 300 MPa

2
Reference solution

2.1
Method of calculation used for the reference solution

The cumulated plastic deformation P is equal to:
y
-
P
L
=

C
with: : constraint with the node considered
L
y
: elastic limit
C: slope of the traction diagram

The constraints are given by:
(NR) = - P (NR)
xx
I
LMBO
I

The plastic deformation is given by:
p
(NR) = P (NR)
xx
I
I

2.2
Results of reference

One calculates in the nodes N2 and N3 the uniaxial constraint, the plastic deformation, as well as cumulated plastic deformation.
Maybe for the problem considered:

N2
N3

0 -300
xx

0 -6.1658
10-2
xx
p

0 6.1658
10-2
xx

2.3 Uncertainty on the solution

Analytical solution.

2.4 References bibliographical

[1]
LORENTZ E., PROIX J.M., VAUTIER I., VOLDOIRE F., WAECKEL F.: Initiation with thermoplasticity in the code Aster. Handbook of Reference of the course. EDF-DER, SCE IMA, Dept. Mechanics and digital Models, HI-74/96/013/0

---

3 Modeling
With

3.1
Characteristics of modeling

N4
N3
TRI6
5 elements
y
QUA8
5 elements
X
QUA9
5 elements
N1
20 elements
N2

3.2
Characteristics of the grid

A number of nodes: 1072
A number of meshs and types:
100 QUAD9
100
QUAD8
200
TRIA6

3.3 Functionalities

tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
VMIS_ISOT_LINE
CALC_ELEM OPTIONS
"SIEF_ELNO_ELGA"

"VARI_ELNO_ELGA"
"EPSP_ELNO"

4
Results of modeling A

4.1 Values
tested

Identification Increment
Reference
Aster Difference

Cumulated plastic deformation

Node N2
10
0
0
0
N3 node
6.1658 102
6.1230 10-2
0.6%
Plastic deformation

Node N2
10
0
-1.46 10-5
-1.46 10-5
N3 node
6.1658 102
-6.1230 10-2
-0.6%
Constraints

Node N2
10
0
-1.34
-1.34
N3 node
-300
-300.65
0.22%

Handbook of Validation

5
Summary of the results

The results coincide with the reference solution. They thus make it possible to rule on the validity of matrices of passage of the points of gauss to the nodes tops.

Titrate:
SSNP113 - Rotation of the principal constraints (law of MAZARS)
Date:
19/02/04

Author (S):
S. MICHEL-PONNELLE, F. LEBOUVIER Key
:
V6.03.113-B Page:
1/6

Organization (S): EDF-R & D /AMA, DeltaCAD

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.113

SSNP113 - Rotation of the principal constraints
(law of MAZARS)

Summary:

This case test of mechanics is inspired by work of Willam [bib1] and was used in the benchmark EDF/Division R & D "Model three-dimensional of non-linear behaviors of the material concrete in cracking" [bib2] to evaluate the models of behavior dedicated to the concrete. It is characterized by a way of specific loading which creates a continuous rotation of the principal constraints. It is used here to test establishment of the model of Mazars in its local version (modeling 3D) and in its delocalized version (modeling 3D_GRAD_EPSI). The validation is carried out by comparison with the results obtained with code CASTEM 2000 with the LGCNSN (Central School of Nantes).

1
Problem of reference

1.1
Geometry and boundary conditions

P4
P3

y
length of the edges: has = 0.56 m, thickness 0.1 m

X

P
P

1
2

Appear 1.1-a: Geometry and boundary conditions

The loading is such as one obtains a homogeneous state of plane forced constraint and type even if modeling in Aster were carried out in 3D. The loading is imposed in the form of displacements imposed in two stages:

1) direction

(xx, yy, xy) = (1, -, 0)
until the maximum constraint
(initiation of the lenitive phase)
2) direction
(xx, yy, xy) = (1, 1.5, 1) up to xx = 0.0015

-
xx: displacement on the side delimited by side 2
P - 3
P in direction OX
-
yy: displacement on the side delimited by side 3
P - 4
P in direction OY
-
xy: displacement on the side delimited by side 2
P - 3
P in direction OY

That is to say P5P6P7P8 the plan of the cube in z=0.1.
Practically, the following conditions are imposed

· during all the loading: P1P4P8P5: dx = 0
P1: Dy = dz = 0
P5: Dy = 0

· during phase 1:
P2, P6: Dy = 0
P2P3P7P6: dx = 1
P3P4P8P7: Dy = - 0.2

· during phase 2:
P2P3P7P6: dx = 1
P4, P8: Dy = 1.5
P3, P7: Dy = 3.5
P2, P6: Dy = 2.

1.2
Properties of material

For the model of Mazars, the following parameters were used:

Elastic behavior:
E = 32.000 MPa, = 2

.
0
Damaging behavior:

=
10
.
375
.
9
4
-; Ac = 15
.
1
; At = 8
.
0; Bc =
3
.
1391; LT = 10.000;
06
.
1
D 0
=

---

2 Reference solution

It is about a comparison code-code. The reference used is the code Castem2000 (version 2001). The results were obtained by the LGCNSN (Central School of Nantes) with the same parameters materials and same discretization in time. Contrary to the calculation carried out with Code_Aster, it Castem calculation was carried out in 2D under the assumption of plane constraints. The delocalized version of the model of Mazars was tested with a null length characteristic of way to check that one finds the same results as with the local version.

3 References bibliographical

[1] Willam K., Pramono E. and Sture S. - Fundamental exits of smeared ace models, Proc. of the Int. Conf. one fractures and concrete and rock'n'roll, Huston Texas, 1987, pp 17-19
[2] CR-99-232, concrete tests Evaluation one models of non-linear behaviour of cracking using three dimensional modelling, Benchmark EDF/Division R & D S. Ghavamian

---

4 Modeling With

4.1

Characteristics of modeling

Modeling 3D
Element MECA_HEXA8

4.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and type: 1 HEXA8

4.3 Functionalities
tested

The law of behavior MAZARS local version in 3D.

5
Results of modeling A

One compares with 3 steps times different (at the end from stage 1, during the phase of growth of the damage and at the end of the loading) strains, stresses as well as the value of the damage.

Identification Reference
Aster %
difference
N°10 xx
9.375 10-5
9.375 10-5 5.8
10-14
xx
3.00 106
3.00 106 4.7
10-14
yy
-1.875 10-5
-1.875 10-5 9.0
10-14
yy
0.
-2.83 10-10
-2.83 10-10
xy
0. 0.

-
xy
0.
0. -
D
0. 2.22
10-16 2.22
10-16

Identification Reference
Aster %
difference
N°25 xx
1.64 10-4
1.64 10-4 0.065
xx
2.04 106
2.04 106 -0.048
yy
8.67 10-5
8.68 10-5
0.099
yy
1.35 106
1.35 106
-0.016
xy
7.03 10-5
7.04 10-5
0.081
xy
6.34 105
6.33 105
-0.016
D
0.66211 0.66238
0.040

Identification Reference
Aster
%
difference
N°310 xx

1.50 10-3
1.50 10-3
0.06
xx
3.69 105
3.69 105
-0.002
yy
2.09 10-3
2.09 10-3
0.064
yy
4.59 105
4.59 105
5.22 10-4
xy
1.41 10-3
1.41 10-3
0.063
xy
2.16 105
2.16 105
6.85 10-4
D
0.99423 0.99424 8.07
10-4

---

6 Modeling
B

6.1
Characteristics of modeling

The use of the delocalized version of the model of Mazars passes by the use of modeling 3D_GRAD_EPSI and implies the use of quadratic elements.
The test is carried out with a null characteristic length.

Modeling: 3D_GRAD_EPSI
Element: MGCA_HEXA20

6.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and type: 1 HEXA20

6.3 Functionalities
tested

The law of behavior of Mazars in delocalized.

7
Results of modeling B

One compares with 3 steps times different (at the end from stage 1, during the phase of growth of the damage and at the end of the loading) strains, stresses as well as the value of the damage.

Identification Reference
Aster %
difference
N°10 xx
9.375 10-5
9.375 10-5 2.02
10-13
xx
3.00 106
3.00 106 -2.33
10-13

yy
-1.875 10-5
-1.875 10-5 5.42
10-14
yy
0.
5.98 10-10
5.98 10-10
xy
0. 6.88
10-21
6.88 10-21
xy
0.
0. -
D
0. 3.88
10-15 3.88
10-15

Identification Reference
Aster %
difference
N°25 xx
1.64 10-4
1.64 10-4 0.038
xx
2.04 106
2.04 106 -1.89
10-4
yy
8.67 10-5
8.67 10-5
0.022
yy
1.35 106
1.35 106
-3.39 10-4
xy
7.03 10-5
7.03 10-5
0.018
xy

6.34 105
6.34 105
1.4 10-5
D
0.66211 0.66211
-1.88
10-4

Identification Reference
Aster %
difference
N°310 xx
1.50 10-3
1.50 10-3
2.02 10-13
xx
3.69 105
3.69 105
9.02 10-5
yy
2.09 10-3
2.09 10-3
-2.39 10-4
yy
4.59 105
4.59 105
-8.66 10-5
xy
1.41 10-3
1.41 10-3
1.23 10-13
xy
2.16 105
2.16 105
7.66 10-5
D
0.99423 0.99423
4.42
10-4
Handbook of Validation
V6.03 booklet: Non-linear statics of the plane systems
HT-66/04/005/A

8
Summary of the results

With very weak variations of about 0.05% to the maximum on the constraints in the phase non-linear and about 0.002% after complete damage on a test where loadings are not radial, one can consider that the establishment of the model of Mazars too well in local version that not-local, is faithful to the original model.

Titrate:
FORMA03 - Nonlinear TP2 static formation

Date:
16/07/03
Author (S):
Key ***J.M. PROIX***
:
V6.03.114-B Page:
1/12

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.114 document

FORMA03 - Work Practise formation
nonlinear statics: charge limit of a plate
perforated

Summary:

This test 2D in plane constraints quasi-static makes it possible to illustrate on a simple case the questions relative to elastoplastic modeling; it highlights the effects of structure, of stress concentration, of charge limit.

It is about a homogeneous rectangular plate, perforated in its center, consisted of an elastoplastic material with isotropic work hardening, whose initial state is nonconstrained, which is subjected to a traction at its ends.
One is interested in the elastoplastic solution in load. More precisely, the analytical methods allow to know a lower limit of the limiting load. By an elastoplastic calculation, one would like to find one limit higher.

The objective of the test is to show the possibilities of modeling and postprocessing with STAT_NON_LINE.

Modeling A corresponds to the first loading, and comprises the orders of examination

useful for the TP

Modeling B clarifies the procedure to carry out calculation until the limiting load, and for to model the discharge.

1
Problem of reference

1.1 Geometry

One models only one quarter of the plate because of symmetries.

P
G
F

G
F

H=150

With

a=10

With

B
D

B
D

L=100

1.2
Material properties

Elastoplastic behaviour with isotropic work hardening given by the traction diagram.

Young modulus E = 1000 Mpa
NAKED Poisson's ratio = 0.3
Traction diagram (prolongation constant right)

Epsilon 0.004 0.006 0.009
0.02
Sigma 4.
5. 5.5 6.

1.3
Boundary conditions and loadings

Conditions of symmetry
The plate is blocked according to OX along the side AG and following OY along side data base

Loading in imposed constraint
It is subjected to a traction P following OY distributed on side FG.

Way of loading
One considers a monotonous way of loading, such as traction P grows since 1 MPa (
solution is then elastic) and until complete plasticization of the structure.

2
Reference solution

2.1 Solution
rubber band

In elasticity, for an ***infinite*** *plate****,*** *comprising a hole of diameter, subjected to a loading P according to y ad infinitum, the analytical solution in plane constraints and polar co-ordinates (R,) are [bib1]:*

P
2
has

2
4
has
has

rr =

1

1 4
3

- - - + *cos*
2
2

R
R
R

2
4

P
has
has
=

1+
+ 1+
3
cos
2
2
R

R

2
4

P
has
has
R =

1+
2
-
3
sin
2
2
R
R

In particular, at the edge of the hole (R = has): = P ([1+ 2cos
2)]

2
4
P
has
has
And along axis X: = yy =

1+

+ 1+
3

2
R

R

Numerically, for P = 1 Mpa, and an infinite plate

Not CMP
MPa
WITH SIGXX
-1
B SIGYY
3

For a plate of ***finished*** *size, the abacuses [bib3] make it possible to obtain the coefficients of stress concentration, and it is found that SIGYY are worth approximately 3.03 MPa.*

2.2
Elastoplastic solution (load limits)

In elastoplasticity, by a static approach in plane constraints, one can obtain a terminal lower of the load limits [bib2] for a band of width 2L finished and infinite length, comprising a hole of width 2a and subjected to an ad infinitum imposed constraint P:

P
lim = y [L - has]/L
Here one obtains as limits lower limiting load: -
lim
P = 5.4 MPa.
(One takes = 6 MPa, because the limiting load is identical between a perfect elastoplastic material and
y
a material, whose traction diagram presents a horizontal asymptote at 6 MPa).

2.3 References
bibliographical

[1]

Guide Validation of the Software packages of Structural analysis SFM. Technical AFNOR.
[2]
Analyze limit of the fissured structures and criteria of resistance.
[3]
F. VOLDOIRE: Note EDF/DER/HI/74/95/26 1995
[4]
Stress concentration factors. R.E. PETERSON ED. J. WILEY p150
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HT-66/03/008/A

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3 Modeling With

3.1 Characteristics of modeling

Modeling C_PLAN. A quarter of the plate is modelled.

3.2 Characteristics of the grid

G
F
With
B
D

One uses a grid in QUAD8 (grid GIBI: forma03a.mgib). It comprises 186 QUAD8 and 617 nodes. The file forma03a.datg contains data GIBI to build this grid and also (in end of file) orders GIBI for the examination of the results.

Note:

This grid is sufficiently fine to have a good approximation of the solution in elasticity: for example if one compares on the edge of the hole compared to the solution analytical, one obtains:

3.3 Functionalities tested

Orders

AFFE_CHAR_MECA FACE_IMPO

AFFE_CHAR_MECA FORCE_CONTOUR

DEFI_MATERIAU TRACTION

STAT_NON_LINE COMP_INCR
RELATION
“VMIS_ISOT_TRAC”
STAT_NON_LINE NEWTON
REAC_ITER
1
STAT_NON_LINE INCREMENT
SUBD_PAS
4
CALC_ELEM
OPTION
SIEF_ELNO_ELGA
VARI_ELNO_ELGA
EQUI_ELGA_SIGM
RECU_FONCTION
NOM_CHAM
DEPL,
SIEF_ELNO_ELGA
CURVED IMPR_COURBE
FUNCTION

IMPR_RESU RESU
FORMAT
CASTEM,
GMSH
IMPR_RESU RESU
VALE_MAX
YES
POST_RELEVE_T ACTION
LOCATE
POLAR
INTE_MAIL_2D

FORMULATE

CALC_FONC_INTERP

3.4
Unfolding of the TP

This modeling (command files forma03a.com m) corresponds to a calculation in elastoplasticity for P going up to 5.4 MPa. It also contains (in the command file forma03a.com 1, to use in continuation) the orders necessary to the examination (traced graphic curves and postprocessing).

3.4.1 Results of calculation

Before the throw calculation itself, it is necessary to define a base, on the machine of execution, which will contain all the results. One can launch provided calculation, to P = 5.4 MPa in the goal post-to treat it. In card-indexing it result, one can observe how the maximum evolves/moves (on all elements) of component VMIS of field EQUI_ELGA_SIGM, as well as the maximum of internal variables.

One will be able to note on this level on the internal variables that:

· at moments 1 and 1.2, it does not have there plasticization,
· until moment 5.4, one is constantly in load.

and on the constraints:

· the maximum value of the criterion of Von Mises at the points of Gauss is always limited to 6 Mpa, what shows that the solution checks the law of behavior well.

3.4.2 Use of the tools for examination

One will be able to use in continuation the command file forma03a.com 1, on the basis previously created.
It is necessary to define the files following results:

- ***a file of the type "cast" if one wants effector a graphic examination with GIBI,***
- ***a file of the type "pos" if one wants effector a graphic examination using GMSH,***
- ***of other files specific to the layouts of curves, (extension .dat for layout with xmgrace).***

The orders necessary to the layout of curves are defined in the file forma03a.com 1.
One finds there:

- ***evolution of the component Sigma-Theta at moment 1 at the edge of the hole, and the curve definite by the analytical solution = P ([1+ 2cos*** *2)],*
- ***evolution of the Syy component at the point G according to displacement at the same point, for every calculated moment,***
- ***evolution of the resultant of the nodal forces on edge FG, according to displacement with not G.***

These three calls to IMPR_COURBE make it possible to generate three files, which can be traced via one spreadsheet, or a software of layout of curve like xmgrace.

To plot a curve using xmgrace, "grace should be launched", then "dated/ASCII importation/" and to select the file to be traced. For the moment, the file produced by Aster is not directly readable: it is necessary to comment on the lines of text (character #) before the reading by xmgrace.

One can visualize with GIBI, or GMSH the deformation, the isovaleurs of constraints SYY and of *cumulated equivalent plastic deformation p. One will be able to note at moment 1. (elasticity) stress concentration at the point B.A moment 5.4, one can notice on the isovaleurs of cumulated plastic deformation, localization of the deformations in the vicinity of B.*

One will be able to finally use interactive postprocessing Stanley to visualize fields or curves. It is enough for that to oter the character comment (# in front of the order to launching to Stanley.

3.4.3 Continuation of the TP

Then, to continue calculation, it is necessary to modify the way of applying the loading. This been the

subject of
modeling B.

4
Results of modeling A

4.1 Values
tested

Value of the limiting loading. The value of reference corresponds on the lower terminal. Difficulties of convergence occur as soon as one seeks to increase the loading beyond 5.4Mpa.

Moment
GROUP_NO
Identification Reference
Aster Difference
(%)
1. B
Constraint
SIYY
3.
3.023 0.8
1. With
Constraint
SIXX
-1. -1.02 2.1
5.4 G
Constraint
SIYY
5.4
5.4026 0.5

---

5 Modeling B

5.1 Characteristics of modeling

This modeling allows, within the framework of Practical Work, to conclude calculation until charge limit of the structure, thanks to the piloting of the loading and the discharge. The behavior is elastoplastic with isotropic work hardening given by a traction diagram such as the constraint uniaxial tends towards a constant value (6 MPa). There is thus a limiting load for this structure whose lower limit is known: Plim > 5.4 MPa [bib2].

The plate is subjected to a traction P following OY on side FG. Therefore, if P largely exceeds 5.4 MPa, it has there no more solution. Numerically, there are thus concern! It is what is observed: for P=5.4 Mpa, convergence is very slow. If calculation were continued, there would be no more convergence with beyond 5.41 Mpa.

The best solution if one wishes to calculate the load limits (by the resolution of a problem elastoplastic incremental - other methods exist like the use of material incompressible with direct methods of analysis limits) is to use the piloting of the constraint imposed by the displacement of a point.

5.2 Characteristics of the grid

The grid is identical to that of modeling A.

5.3 Functionalities tested

Orders

AFFE_CHAR_MECA FACE_IMPO

AFFE_CHAR_MECA FORCE_CONTOUR

DEFI_MATERIAU TRACTION

STAT_NON_LINE COMP_INCR
RELATION
"VMIS_ISOT_TRAC"
STAT_NON_LINE NEWTON
REAC_ITER
1
STAT_NON_LINE INCREMENT
SUBD_PAS
4
STAT_NON_LINE PILOTING
TYPE
DDL_IMPO
CALC_ELEM
OPTION
SIEF_ELNO_ELGA
VARI_ELNO_ELGA
EQUI_ELGA_SIGM
EPSI_ELNO_DEPL
CALC_NO
OPTION
SIEF_NOEU_ELGA
RECU_FONCTION
NOM_CHAM
DEPL
CURVED IMPR_COURBE
FUNCTION

IMPR_RESU RESU
FORMAT
CASTEM
IMPR_RESU RESU
VALE_MAX
YES
STAT_NON_LINE NEWTON

PREDICTION
RUBBER BAND
CREA_MAILLAGE ECLA_PG

CREA_RESU ECLA_PG

RECU_FONCTION
NOM_PARA_RESU
ETA_PILOTAGE
CALC_NO
OPTION
FORC_NODA
POST_RELEVE_T ACTION
RESULTANT
DY

5.4
Calculation until the limiting load

5.4.1 Test of increase in the loading to P = 5.4 MPa

One wishes to continue calculation with an aim of considering a limit upper of the limiting load, in *trying to go beyond 5.4 MPa (limits lower analytical), without modification of the loading. One note whereas:*

· calculation is possible up to 5.41 Mpa, beyond that, it does not converge more, even by subdividing it no time,
· convergence is increasingly slow.

The cause of difficult convergence is well the proximity of the limiting load. This is why it is necessary to subdivide the step of time. One can realize it by the value of the loading (5.4 Mpa = theoretical value of the lower limit) and by the curve constraint-displacement in top of the structure : one can note that for P=5.4 MPa the limiting load is not completely reached (not of horizontal asymptote) but that one approaches some.

The isovaleurs of p show a zone of concentration of plastic deformation (comparable to one line of slip) tilted of 53° approximately compared to the vertical, energy of the point B at the flat rim This corresponds rather well to the theory which says that the lines of slip are tilted of 54,44° [bib2]. There is here of course an approximation of the line of slip which is in theory of null thickness.

5.4.2 Calculation with loading controlled by a displacement

A good way of carrying out this type of calculation is to use the piloting of the loading imposed by value of a displacement. It is thus proposed to modify the command file to use it piloting. One will be able to use for example displacement UY of point A to control constraint YY imposed on FG.
One will increase it up to 2 mm for example. One will take a coefficient equal to 1. One will thus be used
*fictitious time T such as t= UY (A)*1. Thus time varies here between 0 and 2s (to represent one displacement between 0 and 2mm).*

One treats all the rise charges some in a new STAT_NON_LINE. One can cut out the interval (0. 2.) in 10 or 20 increment for example.

The syntax of the key word factor PILOTING is:

PILOTING: _F (GROUP_NO = A, STANDARD = “DDL_IMPO”, NOM_CMP = “DY”, COEF_MULT = 1.))
Attention with the type of loading CH2 (force distributed): to use “FIXE_PILO”.

Note:

One could have controlled by the displacement of other points, e.g. Uy of the point G or UX of the point D.

To observe in the file "message" the value of the parameter: "ETA_PILOTAGE".
One obtains in theory a good approximation of the limiting load (by higher value) than one
will be able to compare on the analytical lower terminal (5.4).

One will be able to plot, in continuation, the curve forces resultant-displacement in G according to time. (them
orders necessary are in the file forma03a.com 1). One should find on this curve
value of the load limits given by "ETA_PILOTAGE".

One can visualize with GIBI, or GMSH the deformation, the isovaleurs of constraints SYY and of
cumulated equivalent plastic deformation p. A moment 2, one can notice on the isovaleurs of
cumulated plastic deformation, localization of the deformations in the vicinity of B.

One will be able to finally use interactive postprocessing Stanley to visualize fields or
curves. It is enough for that to remove the character comment (# in front of the order of lancerment of
Stanley.

5.4.3 Discharge: use of the elastic prediction and the elastic matrix

One will use initial calculation without piloting, in continuation since P = 5.4 MPa. Several solutions are
possible:

· Essayer to discharge with tangent matrix. Conclusion?

· Essayer the elastic prediction for the phase of discharge.
· Essayer MATRIX = “ELASTIC” (by increasing the iteration count total of Newton allowed).

To analyze the residual state: deformation, isovaleurs of constraints and variables internal.

5.4.4 Use of linear research

If one wants to calculate all the way of loading (P growing up to 5.4 MPa, then decreasing up to 0) in same order STAT_NON_LINE, (without piloting), it is possible, with research linear and subdivision of the step of time (and stamps tangent reactualized).

One will be able to put 10 iterations of linear research, and to facilitate the phase of discharge, one will be able to put PREDICTION = “ELASTIC”.

One will be able to compare the solution obtained with that obtained previously (they must be identical!) and to compare time CPU and the iteration count of each solution.

6 Results of modeling B

6.1 Values tested

Value of the limiting loading. The value of reference corresponds on the lower terminal. Grace is obtained with piloting a value higher than this value of reference.

Moment	Identification	Reference	Aster	Difference (%)
0.1	ETA_PILOTAGE	3.11	3.11	0
0.4	ETA_PILOTAGE	5.05	5.05	0
1.	ETA_PILOTAGE	5.39	5.39	0
1.5	ETA_PILOTAGE	5.401	5.401	

0
2. ETA_PILOTAGE 5.405
5.405
0
5.4 SIYY 5.4 5.4026 0.5

Examination: one notes in the file RESULT that the limiting load is almost reached:
parameter ETA_PILOTAGE tends towards a constant value: 5.405, which is very close to the terminal
lower theoretical (5.4): This load pattern thus makes it possible to correctly treat this case which could be treated by a loading in conventional force.
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Discharge:

The way of loading goes up to 5.4 MPa then totals 0. One discretizes in 27 steps to go until P = 5.4 MPa, and 6 steps to total 0. The consistent tangent matrix (FULL_MECA) does not allow to converge at the time of the discharge. To treat the discharge, two methods can be used:

1) to calculate the discharge with elastic prediction (but reactualization of the tangent matrix with run of the iterations). One can note that that makes it possible to cross the phase of beginning of discharge. But that does not make it possible to calculate all the discharge (until a loading no one).
2) to use the elastic matrix. This method functions but convergence is slow. It is necessary simply to think of increasing the maximum iteration count (ITER_GLOB_MAXI).

Curve forces resulting - displacement: there is a state of residual stresses no one everywhere safe in some areas (around the point B in particular), but of the nonnull residual deformations.

6.1.1 Use of linear research

With 10 iterations of linear research, and PREDICTION = "ELASTIC", one treats indeed all calculation in 100s approximately (instead of 85s without linear research, by cumulating all the stages the preceding ones, except piloting). One can in particular note that during the phase of discharge, the number

iterations is definitely weaker with piloting.

7
Summary of the results

This test makes it possible to go up how to carry out the calculation of an elastoplastic structure and sound
examination, and in particular to highlight the benefit to use piloting for one
problem of limiting load.

One can retain of this test some ideas:

· even apart from a perfect elastoplastic behavior, it can exist a limiting load:
it is the case with all the real traction diagrams. It is then necessary to adapt the method of
resolution with the mechanical solution and for example to use piloting,
· cutting in small increments of load is often necessary to integrate
correctly the relation of behavior. That can also contribute to convergence, it is thus
advised to use the automatic recutting of the step of time,
· linear research can be used to contribute to convergence, as well as the subdivision
automatic of the steps of time.

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Version
7.4

Titrate:
SSNP115 Validation of LIRE_RESU and DEPL_CALCULE

Date:
02/11/05
Author (S):
Key J.M. PROIX
:
V6.03.115-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.115 document

SSNP115 Validation of LIRE_RESU and DEPL_CALCULE on the elastoplastic calculation of one plate perforated

Summary:

This test 2D in plane constraints quasi-static makes it possible to illustrate on a simple case (treated in

addition in
[V6.03.114] reading and exploitation of results via LIRE_RESU and the continuation in
STAT_NON_LINE
(DEPL_CALCULE).

It is about a homogeneous rectangular plate, perforated in its center, consisted of an elastoplastic material
with isotropic work hardening, whose initial state is nonconstrained, which is subjected to a traction at its ends.
One is interested in the elastoplastic solution in load. More precisely, the analytical methods allow
to know a lower limit of the limiting load. By an elastoplastic calculation, one would like to find one limit higher.

Modeling B makes it possible to read the result with format MED (via LIRE_RESU) and comprises orders of
examination on the fields read.

Modeling C makes it possible to validate the procedure to carry out the calculation of the constraints and variables
interns starting from the displacements read by LIRE_RESU (PREDICTION=' DEPL_CALCULE').

1
Problem of reference

1.1 Geometry

The problem is identical to that treated in [V6.03.114]. One models only one quarter of plate because of symmetries.

P
G
F

G
F

H=150

With

a=10

With

B
D

B
D

L=100

1.2
Properties of materials

Elastoplastic behaviour with isotropic work hardening given by the traction diagram.

Young modulus E = 1000 Mpa (modeling C)
Young modulus E = 200000 Mpa (modeling B)
NAKED Poisson's ratio = 0.3
Traction diagram (prolongation constant right)

Epsilon 0.004 0.006 0.009
0.02

Sigma 4.
5. 5.5 6.

These values are to be multiplied per 1000 for modeling B.

1.3
Boundary conditions and loadings

Loading
In this case (second reading partial or total of the solution) no loading is used.

2
Reference solution

2.1 Solution
elastoplastic

The reference solution is that of test FORMA03A [V6.03.114].

---

3 Modeling
B

3.1
Characteristics of modeling

Modeling C_PLAN. A quarter of the plate is modelled. Reading of the fields of displacements and constraints with format MED.

3.2
Characteristics of the grid

One uses a grid with format MED [SSNP115]. It comprises 186 QUAD8 and 617 nodes.

3.3 Functionalities
tested

Orders

LIRE_MAILLAGE FORMAT
MED

LIRE_RESU FORMAT_MED NOM_CHAM
DEPL
LIRE_RESU FORMAT_MED NOM_CHAM
SIEF_ELNO_ELGA
CALC_NO OPTION SIEF_NOEU_ELGA

MACR_LIGN_COUP NOM_CHAM
SIEF_NOEU_ELGA
POST_RELEVE_T ACTION
LOCATE
POLAR

4
Results of modeling B

4.1 Values
tested

It is checked that the values read are correct: one tests for that the value of displacement following Y at the point G as well as component SIYY at the same point.

Moment
GROUP_NO

Identification Reference
Aster Difference
(%)

1.4 G
Displacement
DY
1.4. 1.4
0.

1.4 G
Constraint
SIXX
541.57 541.57
0

---

5 Modeling
C

5.1
Characteristics of modeling

Modeling C_PLAN. A quarter of the plate is modelled. Reading of the fields of displacements with format IDEAS.

5.2

Characteristics of the grid

The grid is identical to that of modeling A.

5.3 Functionalities tested

Orders

LIRE_RESU FORMAT_MED
NOM_CHAM
DEPL
DEFI_MATERIAU TRACTION

STAT_NON_LINE COMP_INCR
RELATION
"VMIS_ISOT_TRAC"
STAT_NON_LINE NEWTON
PREDICTION
DEPL_CALCULE
CALC_ELEM
OPTION
SIEF_ELNO_ELGA
VARI_ELNO_ELGA
EQUI_ELGA_SIGM
EPSI_ELNO_DEPL
CALC_NO
OPTION
SIEF_NOEU_ELGA
RECU_FONCTION
NOM_CHAM
DEPL
CURVED IMPR_FONCTION
FUNCTION

6 Results of modeling C

6.1 Values tested

Constraint SIYY at the point G for a force distributed of 5.2 Mpa. The value of reference results from test FORMA03A.

Moment	Identification	Reference	Aster	Difference (%)
5.2	SIYY	5.202	5.202	0.

7 Summary of the results

This test makes it possible to check the correct operation of LIRE_RESU on a result of STAT_NON_LINE (fields of displacements and constraints).

It also makes it possible to validate operation "DEPL_CALCULE" allowing starting from the only field solution displacement, to quickly find (without iteration of Newton) the solutions in constraints and internal variables. This can be useful to save place of storage for calculations bulky.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.116 document

SSNP116 - Coupling creep/cracking - Traction uniaxial

Summary:

This case of validation is intended to check the model of coupling of the laws of creep of Granger with the laws of plasticity/cracking. Coupling, initially restricted with some laws of the environment not linear of Code_Aster, could be wide thereafter with more laws. Parameters of the models of plasticity/cracking is selected in a particular way to model an elastoplastic behavior quasi perfect, and to bring back itself to a problem presenting a relatively simple analytical solution.

The geometry consists of three linear elements (cubic and prisms in 3D, squares and triangles in 2D), and three quadratic elements, connected to the precedents by linear relations. Modelings tested here are modelings 3D, C_PLAN, and D_PLAN.

The loading is a uniaxial traction in imposed displacement.

One tests the coupling of the model of creep of Granger with BETON_DOUBLE_DP (or NADAI_B in C_PLAN),
VMIS_ISOT_LINE and CHABOCHE. One has the analytical solution in 3D and C_PLAN, when there is not
variation in the temperature and drying. In cases 3D and D_PLAN, one also tests the solutions
obtained when there is variation in the temperature and the drying and activation of the corresponding withdrawals (with
opposite effect). They are then tests of not-regression.

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Code_Aster ®
Version
7.3

Titrate:
SSNP116 - Coupling creep/cracking - uniaxial Traction
Date
:
30/09/04
Author (S):
Key ***S. MICHEL-PONNELLE***
:
V6.03.116-B Page:
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1
Problem of reference

1.1 Geometry

y
A1
B1
C1

D1
E1
F1 Ux

Relations

linear

X

1.2
Material properties

The parameters of the laws of behavior are as follows:

For the mechanical characteristics in linear elasticity (ELAS):

Young modulus:
E = 31.000 MPa

Poisson's ratio:
= 0.2

Thermal dilation coefficient:
= 10-5

Coefficient of withdrawal of desiccation: = 10-5

For the nonlinear mechanical characteristics of model BETON_DOUBLE_DP:

Resistance in uniaxial pressing:
f' C = 40 N/mm ^{2}

Resistance in uniaxial traction:
f' T = 4 N/mm ^{2}

Report/ratio of resistances in compression = 1.16

biaxial/uniaxial pressing:
Energy of rupture in compression:
Gc =10 Nmm/mm ²

Energy of rupture in traction:
WP =10000 Nmm/mm ² to simulate a work hardening
quasi no one
Report/ratio of the limit elastic to resistance 33.33%

in uniaxial pressing:

For the nonlinear mechanical characteristics of model NADAI_B:

Resistance in uniaxial pressing:
f' C = 40 N/mm ²
Resistance in uniaxial traction:
f' T = 4 N/mm ²
Initial threshold of elasticity:
= 1
Plastic deformation with the peak in compression:
Epsp_p_c = 9.64705
Plastic deformation with rupture in compression: Epsp_r_c = 5
Deformation with rupture in traction:
Epsi_r_t =5000 to simulate a work hardening quasi
no one

For the mechanical characteristics of the model with linear work hardening VMIS_ISOT_LINE:

Yield stress:
Sy = 4 N/mm ²

Slope of work hardening:
D_sigm_epsi =0.1 N/mm ²

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For the mechanical characteristics of the model of CHABOCHE:

Initial ray of plasticity:
R_0 = 4.0 N/mm ²
Ray of plasticity ad infinitum:
R_I = 4.1 N/mm ²
Coefficient of evolution of the ray of plasticity:
Gc =0.1 N/mm ²
The parameters characterizing kinematic work hardening are null to simulate a work hardening quasi
no one: A1 = A2 = C1 = C2 = W = 0 and K = 1.

For the mechanical characteristics of the model of creep of GRANGER:

J1 coefficient:
J1 = 0.2 MPa-1
Coefficient 1:
1 = 4.320.000 S
Coefficient Q/R:
QsR_K = 0. K
The curve of desorption is worth 1 for all values of the hygroscopy, to simplify the solution analytical.

1.3
Boundary conditions and loadings mechanical

For calculations in 3D:

.
Face in X = 0 of the first cube (its):
blocked according to OX,
.

Nodes of the faces in y = 0:
blocked according to OY,
·
Nodes of the faces in Z = 0:
blocked according to OZ,
·
Linear relation (LIAISON_DDL) between the nodes end of the faces confused of
linear and quadratic elements adjacent (dependent nodes c1, c2, c3, c4 with the nodes d1, d2, d3, d4),
·
Linear relation (LIAISON_UNIF) on the face sd to bind displacements according to X of quadratic nodes of this vis-a-vis those of the nodes top,
·
Face in X = xmax of the last cube (sf):
Traction exerted according to OX.

For calculations in 2D:

· *Ligne in X = 0 of the first square (it):*
blocked according to OX,
· *Noeuds of the lines in y = 0:*
blocked according to OY,
·
Linear relation (LIAISON_DDL) between the nodes end of the lines confused of
linear and quadratic elements adjacent (dependent nodes c1, c2 with the nodes d1, d2),
·
Linear relation (LIAISON_UNIF) on the line ld to bind displacements according to X of quadratic nodes of this line to those of the nodes top,
· *Ligne in X = xmax of the last square (lf):*
Traction exerted according to OX.

The field of temperature is either constant (the first calculation), or crescent of 0°C with 20°C for all them
other calculations. If the temperature varies, it is supposed that the field of drying varies from 1 to 0. The characteristics material are constant. Moreover, one applies a coefficient of withdrawal of desiccation not no one, in such way that the withdrawal of desiccation compensates for thermal dilation,
to check that these 2 phenomena are well taken into account.
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2
Reference solution

2.1
Method of calculation used for the reference solution

To be able to calculate a simple analytical solution, the following choices were carried out, the objective being
to validate the coupling and not the laws of plasticity/cracking or creep:

- *a law of creep of Granger with only one model of Kelvin in series,*
- *a law of plasticity/cracking modelling a perfect elastoplastic law,*
- *a loading of uniaxial traction.*

The reference solution is calculated in an analytical way, knowing that in traction, only the criterion of traction is activated. The equations of the model are brought back to scalar equations allowing to calculate the analytical solution. The only difficulty comes from the determination of the beginning of plasticity (moment and deformation of creep) which requires to solve by a numerical method an equation nonlinear with an unknown factor.

If the temperature is not constant, creep is more complex to solve, the solution analytical was not calculated. They are thus tests of not-regression. However, in the cases 3D and D_PLAN, one can check that one obtains the same results with the 3 models.

The imposed deformation (displacement of an end of the structure) is a linear function of *time allowing to bring into play creep and plasticity.*

2.2
Calculation of the reference solution

One notes, component xx of the total deflection, E component xx of the deformation rubber band, fl component xx of the deformation of creep of Granger, and pl component xx of plastic deformation, component xx of the constraint, and E the Young modulus.
The model of creep selected comprises one model of Kelvin in series and the model of plasticity/cracking is a nearly perfect law elastoplastic (quasi null slope of work hardening), which allows to easily calculate the analytical solution of the coupling creep/plasticity, in the case of one uniaxial simple traction. The nearly perfect elastoplastic law can be obtained starting from the laws of Code_Aster BETON_DOUBLE_DP or NADAI_B, VMIS_ISOT_LINE or CHABOCHE, by choosing it set of parameters which is appropriate (work hardening quasi no one).

The loading is a uniaxial traction in imposed displacement. A deformation is thus imposed total proportional to passed time, of the form
= T
xx
.
0
. Like there is no exerted effort
in the other directions, the stress field is uniaxial. One can thus bring back oneself to one problem 1D for the resolution, which makes it possible to calculate in the second time of the deformations
in the transverse directions with the loading (yy and zz).
= (
0
,
0
,
0
,
0
,
0
,
xx
) and = (,
0
,
0
,

0
,
xx
yy
zz
)
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The equations of the model of creep and the model of plasticity merge with the equations scalars following, by omitting index xx correspondent with the first component of the tensors:

= 0.t (imposed traction)
= + +
E
fl
pl

1
=
µ & fl + K fl with µ = S and K =

Js
Js
=
E E
= E [- -

pl
fl]

Resolution in linear elasticity
Before reaching the threshold of plasticity, the plastic deformation is null, which leads to:

= 0.t (imposed traction)
=
pl
0
= +
E
fl

1
= μ& fl + K fl with μ = S and K =

Js
Js
=
E E
= E [- fl]

One obtains the differential equation allowing to calculate the deformation of creep:

= E [-] = μ& +
K
=
fl
fl
fl with
0.t
The deformation of creep is thus expressed as the sum of a linear function of time and one exponential function, of the type:

(T) a.t B T.
=
+ +
-
fl
E

who gives in the differential equation:
0 = μ.& (T) + K. (T) + E. (T) - E.0.

fl
fl
fl
T
That is to say:
0 = [(+) +
]+ ([+) -
T + K + E
-
-
K E B
has
K E has E 0] [(
)
] E T
µ

µ

.
.
. .
.
from where:
E.
µ
E.
K + E
has =
0 B = -
0 =

K + E
K + E K + E
µ
At the initial moment, one starts from a null deformation of creep, which leads to:
µ
E.
=
0
K + E K + E
One obtains finally the expression of the deformation of creep according to time:
K + E

-
T
xx
. E
μ

(T) =
0

μ
=
-
1 -

fl
fl (T)
T
E

K + E
K + E

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Component xx of the elastic strain is worth: E = - fl
That is to say:

K +
-
E T
xx
. K
. E μ
.
0
0

μ

T
() = T
( ) =
T +
1-
E
E
E

K + E
(K + E) 2

The components yy and zz of the elastic strain and creep are obtained by multiplication of component xx by the Poisson's ratio.
Component xx of the constraint is worth: = E
. E = E (- fl)
That is to say:
2

K +
-

E T
. K.E
. E μ
.
0
0

μ

T
() = T
( ) =
T +
1-
xx
E

K + E
(K + E) 2

Threshold of elasticity

The behavior remains elastic until one reaches limited of elasticity. In the case of one uniaxial traction, the equivalent constraint is equal to the nonnull component of the constraint. plasticity thus intervenes when xx T
() = eq = ft (resistance in traction), is:
K +E
2

-
T
. K.E
. E μ
.
0
0

μ

T +
1-
=

K + E
(K + E)
E
ft
2

This equation, solved by a numerical method, makes it possible to obtain the moment of the beginning of plasticization tplas and deformation of creep at this moment:

K +
-
E T

plas
. E
0

μ
plas
μ

= T (
) =
fl
fl
plas
T
1 E

K + E
-
-
plas
K + E

Resolution in plasticity

The model of plasticity was selected in order to obtain a simple analytical resolution. It is about a law of nearly perfect plasticity, obtained by taking a particular play of parameters for the model of behavior leading to a quasi null slope of work hardening. Therefore, in plastic phase, constraint (component xx), equal to the equivalent constraint is worth resistance in traction. equations of the model are then:

= 0.t (imposed traction)

= + +

E

fl

pl

1

= μ& +

K

= μ

= S

=

fl

fl

& +

fl

K [- -

E

pl] with μ

and K

Js

Js

=

E E

= E [- -] = F

pl

fl

T

with like initial conditions:

T = T plas

plas

fl T (plas) = fl

what leads to the differential equation making it possible to calculate the deformation of creep:

= ft =
μ & fl + K fl

The deformation of creep is thus expressed in the form:

(T) T has.
= +
-
fl
E

who gives in the differential equation:
0 =
T + K
T - F = [K has - F] + [K -
] -
μ

μ

. & ()
.
( )
.

.
. .
.t
fl
fl
T
T
E
from where:
F
K
has
T
=
=

K
μ
At the moment T
plas
plas, the deformation of creep is worth fl
, which leads to:
plas
ft
=
-
T

fl
E.
K
One obtains finally the expression of the deformation of creep according to time:
K
F

F - (t-t)
xx
T
T
plas
T
μ
fl

fl
E
plas
( ) =
+
-

K

K

with = 0.t

F
Component xx of the elastic strain is worth:
T
=
=
E

E
E
Component xx of the plastic deformation is worth: = - - *= T* - -
pl
E
fl
0.
E
fl
That is to say:
K
F
F

F - *(t-t)*
xx T =
T
T
T -
-
- *plas*
T
µ

-
plas
0
fl
E
plas
( )
.

E
K

K
The components yy and zz of the elastic strain and creep are obtained by multiplication of component xx by the Poisson's ratio.
Component xx of the constraint is worth: = ft

Numerical application:
One imposes a deformation of 103 in 100 seconds, which gives 0 = 105
The only difficulty consists in calculating the moment of plasticization T plas, and the deformation of creep
plas
fl
who corresponds to him, by dichotomy for example.
One obtains finally the parameters:
tplas = 13.024296
plas
fl
= 1.20969985.10-6
= 1.2903226.10-4
who allow to obtain the values of reference after plasticization of the concrete.

At 10 seconds, the behavior is a coupling creep/elasticity. At 100 seconds, the behavior is a coupling creep/plasticity:

time 10 100

3.0778607 4.0

1.10-4 1.10-3
fl
7.1417140.10-7 1.7316168.10-5

E

9.9285829.10-5 1.2903226.10-4

0.0
pl
8.5365157.10-4

2.3
Uncertainty on the solution

It is negligible, about the precision machine.

2.4 References
bibliographical

The model was defined in the document of specification:

[1] CS
SI/311-1/420AL0/RAP/00.019
Version 1.1, “
Development of the coupling
creep/cracking in Code_Aster - Specifications”

3 Modeling With

3.1 Characteristics of modeling

3D (1 HEXA8, 2 PENTA6, 1 HEXA20, 2 PENTA15)

They are a cube with 8 nodes and two prisms with 6 nodes bound by linear relations to a cube with 20 nodes and of two prisms with 15 nodes. The unit is subjected to a uniaxial traction according to direction X. Dimensions following y and Z are unit. Dimensions according to direction X are chosen so that all the elements have the same characteristic length (this one is worth cubic root of volume for the quadratic elements, and the cubic root of volume multiplied by 2 for the linear elements).

The stress fields and deformations are uniform.
In 3D, one validates the coupling of law BETON_DOUBLE_DP with law GRANGER_FP. One tests also it coupling of laws VMIS_ISOT_LINE and CHABOCHE with law GRANGER_FP.

Z
B1

E1

y
C1
D1
Ux
A1

Elements
Relations
Elements
F1

X
linear
linear
quadratic

3.2
Characteristics of the grid

A number of nodes: 46
A number of meshs and type: 1 HEXA8, 2 PENTA6, 1 HEXA20, 2 PENTA15

3.3
Functionalities tested

Orders Options

"MECHANICAL" AFFE_MODELE
"3D"

DEFI_MATERIAU "BETON_DOUBLE_DP"

DEFI_MATERIAU "VMIS_ISOT_LINE"

DEFI_MATERIAU "CHABOCHE"

AFFE_CHAR_MECA "SECH_CALCULEE"

STAT_NON_LINE "RELATION" "KIT_DDI"
CALC_ELEM "OPTION" "EPSP_ELNO"

CALC_ELEM "OPTION" "EPGR_ELNO"

4
Results of modeling A

4.1 Values tested

One tests components xx of the stress field SIEF_ELNO_ELGA, the field of deformations of creep EPGR_ELNO, and field of plastic deformation EPSP_ELNO.
For the coupling with law BETON_DOUBLE_DP, if the temperature and drying are constant and the solution analytical known, these values were tested at the C1 point located at the interface between the linear elements and the quadratic elements, and at the F1 point located at the end of structure, where is applied imposed displacement (in xmax).
When the temperature and drying vary, the analytical solution was not calculated: one tests thus same components as previously but only at the F1 point located at the end of the structure. The solution obtained with BETON_DOUBLE_DP is tested as a not-regression, but the values obtained are used then as reference for other models (VMIS_ISOT_LINE and

CHABOCHE).

The tests are carried out at moment 10, when plasticity did not start, only creep is present, and at moment 100, after the beginning of the plasticization of the concrete.

4.2
Calculation with law BETON_DOUBLE_DP at a constant temperature (Reference)

Coupling GRANGER_FP/BETON_DOUBLE_DP

.
at the C1 point

Identification Reference
Aster
% difference

-4
xx per xx 104
3.07786 3.07787
1.9.10
fl
xx per xx 104
7.14171 10-7
7.140035 10-7
-0.023

-5
xx per xx 103
4.0 3.999999
-2.0.10
fl
xx per xx 103
1.73162 10-5
1.731596 10-5
-0.001
p
xx per xx 103
8.53652 10-4
8.536546 10-4
3.1 10-4

.

at the F1 point

Identification Reference
Aster
% difference

-4
xx per xx 104
3.07786 3.07787
1.9.10
fl
xx per xx 104
7.14171 10-7
7.140035 10-7
-0.023

-5
xx per xx 103
4.0 3.999998
-6.0.10
fl
xx per xx 103
1.73162 10-5
1.731596 10-5
-0.001
p
xx per xx 103
8.53652 10-4
8.536023 10-4
-0.006

4.3 Calculation with law BETON_DOUBLE_DP in nonisotherm (Not regression)

.

at the F1 point

Identification
Aster
xx per xx 104
3.077193
fl
xx per xx 104
7.357178 10-7
xx per xx 103
3.999998
fl
xx per xx 103
2.140534 10-5
p
xx per xx 103
8.495132 10-4

4.4
Calculation with law VMIS_ISOT_LINE in nonisotherm

.

at the F1 point

Identification
Aster
xx per xx 104
3.077193
fl
xx per xx 104
7.357178 10-7
xx per xx 103

4.000009
fl
xx per xx 103
2.140537 10-5
p
xx per xx 103
8.495621 10-4

4.5
Calculation with law CHABOCHE in nonisotherm

.
at the F1 point

Identification
Aster
xx per xx 104
3.077193
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.
fl
xx per xx 103
2.140535 10-5
p
xx per xx 103
8.495624 10-4

---

5 Modeling B

5.1 Characteristics of modeling

D_PLAN (1 QUAD4, 2 TRI3, 1 QUAD8, 2 TRI6)

They are a square with 4 nodes and two triangles with 3 nodes bound by linear relations to a square with 8 nodes and of two triangles with 6 nodes. The unit is subjected to a uniaxial traction according to direction X. Dimensions following there are unit. Dimensions according to direction X are chosen so that all the elements have the same characteristic length (root of surface for the quadratic elements, and root of the surface multiplied by 2 for the elements linear).

The stress fields and deformations are uniform.
In 2D plane deformations (D_PLAN), one tests the coupling between law BETON_DOUBLE_DP with law GRANGER_FP. One tests also the coupling of laws VMIS_ISOT_LINE with law CHABOCHE and GRANGER_FP. The analytical solution was not calculated in D_PLAN.

E1
y
B1
C1
D1

A1
F1 Ux
Elements
Relations

Elements

linear
linear
quadratic

X

5.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and type: 1 QUAD4, 2 TRI3, 1 QUAD8, 2 TRI6

5.3
Functionalities tested

Orders Options

“MECHANICAL” AFFE_MODELE “D_PLAN”

DEFI_MATERIAU “BETON_DOUBLE_DP”

DEFI_MATERIAU “VMIS_ISOT_LINE”

DEFI_MATERIAU “CHABOCHE”

AFFE_CHAR_MECA “SECH_CALCULEE”

STAT_NON_LINE “RELATION”
“KIT_DDI”
CALC_ELEM “OPTION” “EPSP_ELNO”

CALC_ELEM “OPTION” “EPGR_ELNO”

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V6.03 booklet: Nonlinear statics of the plane systems

6
Results of modeling B

6.1 Values tested

One tests components xx of the stress field SIEF_ELNO_ELGA and the field of deformations of creep EPGR_ELNO, and the field of plastic deformation EPSP_ELNO at the F1 point located at the end of the structure, where is applied imposed displacement (in xmax).

The analytical solution was not calculated in plane deformation. One thus carries out only the same one calculation with the 3 models of cracking at temperature and variable drying. The tests are of type not regression.

The tests are carried out at moment 10, when plasticity did not start, only creep is present, and at moment 100, after the beginning of the plasticization of the concrete.

6.2 Calculation with law BETON_DOUBLE_DP in nonisotherm (Not regression)

At the C1 point

Identification
Aster
xx per xx 104

3.205409
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.382555
fl
xx per xx 103
2.307822 10-5
p
xx per xx 103
8.217046 10-4

At the F1 point

Identification
Aster
xx per xx 104
3.205409
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.382555
fl
xx per xx 103
2.307822 10-5
p
xx per xx 103
8.217039 10-4

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HT-66/04/005/A

6.3 Calculation with law VMIS_ISOT_LINE in nonisotherm (Not regression)

At the F1 point

Identification
Aster
xx per xx 104
3.205409
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.614209
fl
xx per xx 103
2.195353 10-5
p
xx per xx 103
8.429335 10-4

6.4
Calculation with law CHABOCHE in nonisotherm (Not regression)

At the F1 point

Identification

Aster
xx per xx 104
3.205409
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.614199
fl
xx per xx 103
2.195350 10-5
p
xx per xx 103
8.429339 10-4

---

7 Modeling C

7.1 Characteristics of modeling

C_PLAN (1 QUAD4, 2 TRI3, 1 QUAD8, 2 TRI6)

The stress fields and deformations are uniform.

In 2D C_PLAN, one validates the coupling of law NADAI_B with law GRANGER_FP (bus BETON_DOUBLE_DP is not available in plane constraints). One tests also the coupling of the laws VMIS_ISOT_LINE and CHABOCHE with law GRANGER_FP.

E1
B1

y
C1
D1
A1
F1 Ux

Elements
Relations
Elements

linear
linear
quadratic
X

7.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and type: 1 QUAD4, 2 TRI3, 1 QUAD8, 2 TRI6

7.3
Functionalities tested

Orders Options

"MECHANICAL" AFFE_MODELE "D_PLAN"

DEFI_MATERIAU "BETON_DOUBLE_DP"

DEFI_MATERIAU "VMIS_ISOT_LINE"

DEFI_MATERIAU "CHABOCHE"

AFFE_CHAR_MECA "SECH_CALCULEE"

STAT_NON_LINE "RELATION"
"KIT_DDI"
CALC_ELEM "OPTION" "EPSP_ELNO"

CALC_ELEM "OPTION" "EPGR_ELNO"

8
Results of modeling C

8.1 Values tested

Were tested components xx of the field and stress field SIEF_ELNO_ELGA of
deformations of creep EPGR_ELNO. For the coupling with law NADAI_B, these values were tested at the C1 point located at the interface enters the linear elements and the quadratic elements, and at the F1 point
located at the end of the structure, where is applied imposed displacement (in xmax).

For the coupling with the other laws, (VMIS_ISOT_LINE and CHABOCHE), the fields were tested only at the F1 point located at the end of the structure.

As for the case 3D, one carries out the first calculation with temperature and constant drying, which allows
to validate NADAI_B in plane constraints. All the models are then tested with temperature and drying variables and activation of the corresponding withdrawals. It is checked that the same ones well are found
results with VMIS_ISOT_LINE and CHABOCHE that with NADAI_B.

The tests are carried out at moment 10, when plasticity did not start, only creep is present, and at moment 100, after the beginning of the plasticization of the concrete.

8.2
Calculation with law NADAI_B at a constant temperature (Reference)

.
at the C1 point

Identification Reference
Aster
% difference

-4
xx per xx 104
3.07786 3.07787
1.9.10
fl
xx per xx 104
7.14171 10-7
7.140035 10-7
-0.023

-5
xx per xx 103
4.0 3.999999
-2.0.10

fl
xx per xx 103
1.73162 10-5
1.731597 10-5
-0.001

.
at the F1 point

Identification Reference
Aster
% difference

-4
xx per xx 104
3.07786 3.07787
1.9.10
fl
xx per xx 104
7.14171 10-7
7.140035 10-7
-0.023

-5
xx per xx 103
4.0 3.999999
-2.3.10
fl
xx per xx 103
1.73162 10-5
1.731597 10-5
-0.001

8.3
Calculation with law NADAI_B in nonisotherm (Not regression)

At the F1 point

Identification
Aster
xx per xx 104
3.077192
fl
xx per xx 104
7.357178 10-7
xx per xx 103
3.999942
fl
xx per xx 103
2.140718 10-5

8.4
Calculation with law VMIS_ISOT_LINE in nonisotherm

At the F1 point

Identification
Aster
xx per xx 104
3.077193
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.000009
fl

xx per xx 103
2.140745 10-5

8.5
Calculation with law CHABOCHE in nonisotherm

At the F1 point

Identification
Aster
xx per xx 104
3.077192
fl
xx per xx 104
7.357178 10-7
xx per xx 103
4.000001
fl
xx per xx 103
2.140743 10-5

9
Summary of the results

If one knows the analytical solution (not-variation of the temperature and drying), it case test offers very satisfactory results with a lower deviation than 0.02% for all the cases of calculation. The iteration count for the plastic phase is generally about ten; for the model of CHABOCHE, convergence are better with an elastic matrix. This is explained by the choice of the law of nearly perfect plasticity, obtained with models VMIS_ISOT_LINE and CHABOCHE, and with particular plays of parameters. In fact, these same models used without coupling creep/cracking, under the same conditions of loading and with the same ones parameters, present the same difficulties of convergence.

It is checked that under the effect of the increase in the temperature the deformations of creep are increased (+ approximately 3% in the elastic phase, +23% in the plastic phase).
Lastly, in 3D and C_PLAN, one checks that the 3 models which were degenerated give many quasi-similar results. On the other hand, in D_PLAN, model BETON_DOUBLE_DP is not equivalent with the two other models because of writing of the criterion which depends on the trace of the tensor
deformations and is thus not equivalent to the perfectly plastic model.

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V6.03 booklet: Nonlinear statics of the plane systems
HT-66/04/005/A

Code_Aster ®
Version
6.2

Titrate:
SSNP117 - Model of ROUSSELIER in 2D - DP

Date:
09/09/03
Author (S):
R. Key MASSON, M.BONNAMY
:
V6.03.117-A Page:
1/4

Organization (S): EDF-R & D /MMC, AUSY

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.117

SSNP117 - Model of Rousselier in 2D - DP

Summary:

This test of nonlinear quasi-static mechanics makes it possible to validate the model of Rousselier in 2D
plane deformations for the following configurations: elastoplastic basic model, model germination and
viscoplastic model with theta-method for integration of the law of behavior.

Modeling is carried out with a quadratic element 2D, in plane deformation.

---

1 Problem of reference

1.1 Geometry

One considers a mesh square 2D:

Y

P1
L32
P2

L21

L43

X

P3
P4
L14

The sides L21, L32, L43, L14 measure each one 10 Misters.

1.2 Properties of material

One takes: E=200 GPa, and = 0,3.

The traction diagram employed is given in the following table:

0.0001 0.00338 0.03
0.04
0.05 0.07 0.10 0.15 0.2 0.3 0.4

27.30 222.72 519.58 580.94 633.48 721.82 828.96 970.19 1084.75 1269.57 1419.48

0.5 0.7 1.0 1.5 2.0

1547.86 1763.72 2025.50
2370.59 2650.53

The model of Rousselier is employed in three configurations with the following parameters:

Elastoplastic basic model
Elastoplastic model
Viscoplastic model
(ROUSS_PR)
(ROUSS_PR) with germination
(VISCOROUSS) and theta-method
· D = 2.
· D = 2.
· D = 2.
· 1 = 600 MPa
· 1 = 600 MPa
· 1 = 600 MPa
· = 1.
· = 1.
· = 1.
· f0 = 1.e-4 (initial porosity)
· f0 = 1.e-4
· f0 = 1.e-4
· FC = 1. (porosity criticizes)
· FC = 1.
· FC = 1.

· A = 1.
· A = 1.
· A = 1.
· An = 0.6
· 0 = 27 MPa
· 0 = 1.e-2
· = 0.57
· m = 2

1.3
Boundary conditions and loadings

While referring to the figure [§1.1] boundary conditions are as follows:

· on the edge L32 displacement L imposed following direction OY (monotonous traction),
· blocked displacements of L21 following X,
· blocked displacements of L14 following Y.

The evolution temporal of lengthening L are deferred in the following table:

Time [S]
0.
10.

Displacement L [mm]
0. 10.

The evolution is linear between the two moments.

1.4 Conditions
initial

Null constraints and deformations.

2
Reference solutions

2.1
Method of calculation

Without object.

2.2
Sizes and results of reference

Values of porosity at the final moment at the points of Gauss.

2.3
Uncertainties on the solution

Without object.

3 Modeling
With

3.1
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 (QUA8)

3.2
Characteristics of modeling

3.3 Functionalities
tested

Orders

DEFI_MATERIAU ROUSSELIER PORO_INIT

D_SIGM_EPSI_NORM

PORO_CRIT

D

SIGM_1

PORO_ACCE
VISCOROUSS
SIGM_1

SIGM_0

M

EPSI_0
ELAS
TRACTION
STAT_NON_LINE COMP_INCR RELATION
ROUSS_PR

DEFORMATION
PETIT_REAC
STAT_NON_LINE COMP_INCR RELATION
VISCOROUSS

DEFORMATION
PETIT_REAC

3.4
Sizes tested and results

Model
Code_Aster

porosity F (t=10s.)
Basic model
0,03257572
Model with nucleation
0,39058042
Viscoplastic model (= 0,57)
0,03352194

4
Summary of the results

The results obtained by Code_Aster show that the model of Rousselier functions and gives coherent results with the awaited theoretical results.

Version
8.1

Titrate:
SSNP118 - Validation of the element of joint

Date:
29/06/05
Author (S):
J. LAVERNE Key
:
V6.03.118-B Page:
1/4

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.118

SSNP118 - Validation of the element of joint in 2D
plan

Summary:

Validation of the element of joint plane 2D with a cohesive law of behavior: CZM_EXP_REG and a piloting of elastic prediction type. Comparison between the results and the analytical solution.

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HT-66/05/005/A

1
Problem of reference

1.1 Geometry

cubic on L=1mm side
element of joint

U = (2.167302, 1.251293)

T
y

N

= 30°

X

1.2
Properties of material

***Cubic**: rubber band*
E = 0.5 MPa,
= 0

***Element of joint**: cohesive law of behavior: CZM_EXP_REG with:*

tenacity:
Gc = 1 N/mm
(key word: GC)

critical stress:
C =1 MPa
(key word: SIGM_C)

penalization of adherence PENA_ADHERENCE = 10-3 mm
(key word: PENA_ADHERENCE)
(small parameter of regularization of energy in 0, to see [R7.02.11])
penalization of the contact
PENA_CONTACT = 1 (default value) (key word: PENA_CONTACT)

1.3
Boundary conditions and loadings

Null displacements imposed on the left face of the element of joint.
Displacements imposed on the right face of the cube.

2
Reference solution

2.1
Method of calculation

The cohesive law of behavior: CZM_EXP_REG gives the relations between the normal constraint and tangential in the element of joint and the jump in the element:

[U] [loc
U
loc
] N
the jump in the element is noted:

=

[loc
U
] T

[loc
U
] - C [locu]
N
G

C
C
E
loc

[loc
U
]

loc
N
the constraint in the element:

=
=

loc

T
[loc
U
] - C [locu]

T
C
G

E
C [loc
U
]

loc
U

[loc
U
]
[loc
U
] = [loc

U
]
[loc
U
]
a normal loading is carried out: N

thus
= 0
>
T
and
N (if
0
N
)
0

- *C [loc*
U]

N
loc
G

From where:
=
C
it

0

loc
U N = [loc
U
]
And like
+
N
L elast

One has
U loc
N
= - (Gc/C) ln (loc
N/c)
loc
+
L/E
N
éq
2.1-1

This last relation is used to compare the analytical values with the numerical results.

2.2
Sizes and results of reference

In the local reference mark of the element one a:

U loc = RtU
loc

= Rt R
cos - sin
with R =

and = 30°
sin
cos

One checks that for a loading U = (2.
,
167302 1.251293) there is a constraint
= 0.075
XX

loc
01. 0
knowing that
loc
U
= (2.
,
502585 0) and

=

check [éq 2.1-1].
0 0

3 Modeling
With

3.1
Characteristics of modeling

Modeling in plane deformations for the cube on side 1.
Modeling plan fissures (key word PLAN_JOINT) for the element of joint.

The cube is a QUAD4.
The element of joint is a degenerated QUAD4 (confused nodes).

3.2
Characteristics of the grid

A number of nodes: 6
Numbers and type of meshs: 2 QUAD4.

3.3 Functionalities

tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
CZM_EXP_REG
PILOTING
PRED_ELAS

AFFE_MODELE MODELING PLAN_JOINT
DEFI_MATERIAU RUPT_FRAG
SIGM_C

PENA_ADHERENCE

4 Results of modeling A

4.1 Sizes tested and results

Size tested	***Theory***	***Code_Aster***	***Difference (%)***
in the element			
7.5E-02	*7.49999794404E-02*	*2.74E-05*	
XX			

4.2 Remarks

.

The law of behavior of the element of joint is given locally (reference mark (N, T)), calculations system are carried out in the total reference mark (X, y). The basic change was taken in count in calculations. The case test was developed with a rotation of 30° with an aim of to validate this basic change.

.

Piloting was tested, one arrives has to follow the unstable branch of the total curve (force, imposed displacement).

5
Summary of the results

The numerical results are in agreement with the theory.

FORMA04 - Mechanical adaptive grid on one beam in inflection

Summary:

In this case-test, it is a question of making sure of the not-regression of the TP n°1 associated Indicating courses the "
of error and adaptation of grid; State of the art and establishment in Code_Aster" of the formation "Non-linear static Analysis with Code_Aster".

In fact, one "abuses" an elastic design on a metal beam in inflection in forced modeling plane. One makes it converge uniformly via the tool of refinement-déraffinement HOMARD® encapsulated in
MACR_ADAP_MAIL, then freely by coupling the process with a chart of space errors (exhumed via CALC_ELEM "ERRE_ELGA_NORE" or "ERRE_ELEM_NOZ1") localised on each finite element.

From a data-processing validation point of view, this case test of course makes it possible to test the not-regression of
different coupling calculations from chart of errors/procedure of refinement-déraffinement in mechanics, but
also options the "pre one and postprocessings" of these calculations (smoothing of the constraints to the nodes, passage
of an error by element with an error with the nodes by element).

Each modeling is associated a question of the TP and one retranscribed "substantial" marrow of it elements of correction. Entirety of the text of the TP being available on Internet site http://www.code-aster.com/utilisation/formations.
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HI-23/02/017/A

Code_Aster ®
Version
6.3

Titrate:
FORMA04 - Mechanical adaptive grid on a beam in inflection
Date:

1
Problem of reference

1.1 Geometry

Appear 1.1-a: Deformation of the grid

GM12
PRES_REP=0.1 NR
Y
10
1 1
GM14
GM13
GM10
X
DX=0
DY=0
100

Appear 1.1-b: Diagram of the thermal loadings and the geometry

It is about a metal beam (steel 16MND5, E = 210.103 Mpa, = 0.2) in inflection. Calculation rubber band (MECA_STATIQUE or STAT_NON_LINE) in modeling forced plane (C_PLAN). Grids in TRIA3/SEG2 (modeling A) and TRIA6/SEG3 (modelings B and C).

The various key zones of calculation are indicated: GM14 for all the voluminal part SORTED some, GM13 for embedding (DDL_IMPO DX=DY=0 for all the points (X=0, Y=0… 10)), GM12 for pressure distributed (PRES_REP=0.1N for all the points (X=50… 100, Y=10)) and GM10 (mesh-point
M1=N2 at the point (X=100, Y=0) on the level of which one will measure the arrow).

1.2
Material properties

To all structure (GROUP_MA GM14), one applies the characteristics material

E = 210000 Mpa

= 2
.
0

1.3
Boundary conditions and loadings

One can synthesize the decomposition of the loadings by zone in the shape of the following table:

Geometrical zones
Loadings
(GROUP_NO/GROUP_MA)
GM13
DDL_IMPO

DX = 0, DY = 0
GM12
PRES_REP = 0.1 NR

2

Reference solution

2.1
Method of calculation used for the reference solutions

On such a case of figure, it is not possible to exhume an analytical solution! The solution of reference used for error analyses on the arrow and the potential energy of deformation is in fact an approximate solution obtained after a series of four uniform refinements (on even grid but in TRIA6).
This procedure of uniform refinement can be controlled by a loop PYTHON and the operator UNIFORM MACR_ADAP_MAIL option. The first two modelings are precisely one illustration of this functionality.

2.2
Result of reference

Potential energy of deformation = 0.102242 J
Arrow
= 0.0614777 m

2.3
Uncertainty on the solutions

They acts only of approximate solutions obtained on a "quasi-converged" grid.

2.4 References
bibliographical

[1]
X. DESROCHES "Estimators of error of Zhu-Zienkiewicz in elasticity 2D". [R4.10.01], 1994.
[2]
X. DESROCHES "Estimator of error in residue". [R4.10.02], 2000.
[3]
O. BOITEAU "Run and TP Indicateurs of error & Adaptation of grid; State of the art and establishment in Code_Aster".
http://www.code-aster.com/utilisation/formations, 2002.
[4]
O. BOITEAU "FORMA05: Thermomechanical adaptive grid on a fissured cylinder head". [V6.03.120], 2002.
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems

3 Modeling
With

3.1
Characteristics of modeling

The grid is carried out with elements of the type TRIA3. Calculation is made in linear elasticity with operator STAT_NON_LINE.

One calculates the charts of space errors of the indicator of Zhu-Zienkiewicz version 1 (ERRE_ELEM_NOZ1) and of the indicator in pure residue (ERRE_ELGA_NORE). Beforehand it is necessary to have
smoothed the stress field of the points of Gauss to nodes (SIEF_ELNO_ELGA) and, for post-
to treat the chart of error (via GIBI), it is necessary to transform it of a CHAM_ELEM by element with a CHAM_ELEM
with the nodes by element. One determines also the value of the arrow (POST_RELEVE_T) and energy
potential of deformation (POST_ELEM).
The whole is placed in a loop PYTHON allowing the installation of a procedure of
uniform refinement in nb_calc=4 levels (via MACR_ADAP_MAIL option
UNIFORME=' RAFFINEMENT').

One can thus note the convergence of the values of arrow and energy, the increase of theirs
errors relative compared to the errors provided by the indicators (they same into relative and on
all the structure), variations of the indices of effectiveness of the indicators and their good checking of
the assumption of saturation.

In order to illustrate councils of "good practice" for the quality of the studies, on the aspects geometry with a grid, grid itself and standard of finite elements, one uses the options adhoc LIRE_MAILLAGE, MACR_ADAP_MAIL and MACR_INFO_MAIL.

Appear 3.1-a: Isovaleurs of the error in residue (component absolute ERREST) on the initial grid.

Appear 3.1-b: Decreases of the relative errors of the deformation energy and of the arrow compared with those of the relative total component of the indicators.

3.2
Characteristics of the grid

Initially: 61 TRIA3, 15 SEG2, 48 nodes
After a uniform refinement: 244 TRIA3, 30 SEG2, 156 nodes
After two uniform refinements: 976 TRIA3, 60 SEG2, 555 nodes
After three uniform refinements: 3904 TRIA3, 120 SEG2, 2085 nodes
After four uniform refinements: 15616 TRIA3, 240 SEG2, 8073 nodes

3.3 Functionalities
tested

Orders

DEFI_MATERIAU ELAS

LIRE_MAILLAGE INFORMATION
VERI_MAIL

MACR_INFO_MAIL QUALITY
INTERPENETRATION
CUT
CONNEXITY

DEFI_GROUP CREA_GROUP_NO

MECHANICAL AFFE_MODELE C_PLAN

AFFE_MATERIAU

AFFE_CHAR_MECA DDL_IMPO
PRES_REP

STAT_NON_LINE COMP_INCR=' ELAS'

CALC_ELEM "SIEF_ELNO_ELGA"
"ERRE_ELEM_NOZ1"
"ERRE_ELGA_NORE"
"ERRE_ELNO_ELGA"

IMPR_RESU FORMAT=' CASTEM'

POST_ELEM ENER_POT

POST_RELEVE_T OPERATION=

"EXTRACTION"
IMPR_TABLE

MACR_ADAP_MAIL UNIFORME=

INTERPENETRATION QUALITY
"REFINEMENT"
CUT
CONNEXITY

Various PYTHON
Buckle
Structure of control
Passage SD
ASTER - > PYTHON
Passage
SD

PYTHON - > ASTER

4
Results of modeling A

4.1 Values
tested

One tests the values of the relative errors out of arrow and potential energy of deformation by report/ratio with the reference solutions (cf [§2.2]). And this, on the initial grid and after four refinements
uniforms. Tests having to be multi-platforms, the relative tolerance, which is on the errors initial fixed at 10 6%, is voluntarily slackened on the errors after four refinements: 104%.

These tests are carried out on variables PYTHON (via TEST_FONCTION) inserted beforehand in functions ASTER (via FORMULA).

Identification Values Values Tolerance relative Variation
Variable
Variable
Code_Aster
of
(in %)
ASTER
PYTHON
reference
Ep (0)
39.406851 %
idem
10-6% -1.26
10-12
ERREEN0 eren0
~ 0%
Ep (4)
0.274116 %
idem
10-4% 1.5
10-12
ERREEN4 eren4
~ 0%

Arrow (0)
39.244715 %
idem
10-6% 1.09
10-13
ERREFL0 erfl0
~ 0%
Arrow (4)
0.270896 %
idem
10-4% -2.25

10-13
ERREFL4 erfl4
~ 0%

4.2
What it was necessary to retain of this part of the TP…

MACR_INFO_MAIL is thus complementary to LIRE_MAILLAGE (VERI_MAIL and INFORMATION) and
POST_ELEM. Their combined "efforts" can thus allow:

· to check the agreement of the grid with the initial geometry (in mass, dimension, in surface and in volume),
· to list the GROUP_MA and GROUP_NO, paramount for a good modeling of CLs,
· to diagnose possible problems (symmetrization or connexity, elements of outline still present in the model, taken into CL account on surfaces or lines of bad dimensions, interpenetration of elements),
· to strictly evaluate the quality of the grid from a point of view finite element.

HK
K
T =
the possible close relation of 1
H
K
K

For example, an empirical criterion could be:

· at least 50% of EFs with a quality standard in lower part of 1.5,
· at least 90%, in lower part of 2.

The sequence "operators thermo-mécaniques/MACR_ADAP_MAIL "UNIFORM" OPTION" allows to make converge properly, automatically and easily a grid. It is necessary however to take guard with the number of generated DDL which can quickly become prohibitory!

---

5 Modeling B

5.1 Characteristics of modeling

Identical to modeling A, but in TRIA6.

5.2 Characteristics of the grid

Initially: 61 TRIA6, 15 SEG3, 156 nodes
After a uniform refinement: 244 TRIA6, 30 SEG3, 555 nodes
After two uniform refinements: 976 TRIA6, 60 SEG3, 2085 nodes
After three uniform refinements: 3904 TRIA6, 120 SEG3, 8073 nodes
After four uniform refinements: 15616 TRIA6, 240 SEG3, 31761 nodes

5.3 Functionalities tested

Identical to modeling A.

6 Results of modeling B

6.1 Values tested

One tests the values of the relative errors out of arrow and potential energy of deformation by report/ratio with the reference solutions (cf [§2.2]). And this, on the initial grid and after four refinements uniforms. Tests having to be multi-platforms, the relative tolerance, which is on the errors initial fixed at 10 6%, is voluntarily slackened on the errors after four refinements: 104%.

These tests are carried out on variables PYTHON (via TEST_FONCTION) inserted beforehand in functions ASTER (via FORMULA).

Identification Values Values Variable Tolerance Variable relative Variation
Code_Aster
of
(in %)
ASTER PYTHON
référenc
E
Ep (0)
0.125637 %
idem
10-6% -2.65
1012 ERREEN0 eren0
~ 0%
Ep (4)
7.015631 10-4 %
idem 104% 4.71
10-13
ERREEN4 eren4
~ 0%

Arrow (0)
0.106929 %
idem
10-6% 1.6
10-12
ERREFL0 erfl0
~ 0%
Arrow (4) 1.546674 10 4%
idem
10-4% -3.33
1013 ERREFL4 erfl4
~ 0%

6.2
What it was necessary to retain of this part of the TP…

The P1 elements are disadvised in mechanics. The good practice is rather: P1 lumpé in thermics and P2 (possibly under-integrated) in mechanics (not artificially not to privilege the thermal component of the field of deformation and to try to avoid oscillations spatio-temporal of the field of temperature and its violation of the principle of the maximum).

The choice of the type of finite element premium on the quality of the meshs on which are pressed this element.
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7 Modeling C

7.1 Characteristics of modeling

Identical to modeling A with the following modifications:

· grid in TRIA6,
· free refinement-déraffinement (MACR_ADAP_MAIL option LIBRE=' RAFF_DERA') controlled by component NUEST of ERRE_ELGA_NORE (component relative of the indicator in residue).
With as criteria CRIT_RAFF_PE=CRIT_DERA_PE=0.2 (one refines 20% of the elements them worse and one déraffine 20% of best).

7.2 Characteristics of the grid

Initially: 61 TRIA6, 15 SEG3, 156 nodes
After a free refinement: 107 TRIA6, 19 SEG3, 256 nodes
After two free refinements: 212 TRIA6, 26 SEG3, 479 nodes
After three free refinements: 404 TRIA6, 33 SEG3, 879 nodes
After four free refinements: 786 TRIA6, 39 SEG3, 1671 nodes

7.3 Functionalities tested

Identical to modeling A with like only different line

MACR_ADAP_MAIL LIBRE=
INTERPENETRATION QUALITY
“RAFF_DERA”
CUT
CONNEXITY

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HI-23/02/017/A

Code_Aster ®
Version
6.3

Titrate:
FORMA04 - Mechanical adaptive grid on a beam in inflection
Date:
22/11/02
Author (S):
O. BOITEAU *Key*
:
V6.03.119-A Page:
9/10

8
Results of modeling C

8.1 Values
tested

One tests the values of the relative errors out of arrow and potential energy of deformation by report/ratio with the reference solutions (cf [§2.2]). And this, on the initial grid and after four refinements
uniforms. Tests having to be multi-platforms, the relative tolerance, which is on the errors initial fixed at 10 6%, is voluntarily slackened on the errors after four refinements: 104%.
These tests are carried out on variables PYTHON (via TEST_FONCTION) inserted beforehand in functions ASTER (via FORMULA).

Identification Values Values Variable Tolérance Variable relative Variation
Code_Aster
of
E
(in %)

ASTER PYTHON
référenc
E
Ep (0)
0.125637 %
idem
10-6% -2.65
1012 ERREEN0 eren0
~ 0%
Ep (4)
1.245370 10-2 %
idem 104% 2.27
1012 ERREEN4 eren4
~ 0%

Arrow (0)
0.106929 %
idem
10-6% 1.6
10-12
ERREFL0 erfl0
~ 0%
Arrow (4) 1.074923 10 2%
idem
10-4% -2.34
1012 ERREFL4 erfl4
~ 0%

8.2
What it was necessary to retain of this part of the TP…

The sequence “
operators thermo-mécaniques/MACR_ADAP_MAIL “FREE” OPTION
»
converge optimalement the grid makes it possible to make.

The quality of the elements is impacted little by the process of refinement/déraffinement. Count held of the choices operated in HOMARD®, it can even improve in 3D!

The type of indicator and its mode of standardization affect great the final grid.
Taking into account the type of standardization adopted for the indicators in mechanics,
(K)
(K) =100×
(in %)
rel
2
2
(K) + H 0, K
On problems with singularities (embedding, discontinuity of curve, returning corner,
fissure….), it is to better use the absolute component of these indicators. Because as for "our
good old woman fixed beam":
(K)
% when
(close to embedding)
H

rel
0
0, K
(K)
% when
(close to the arrow)
H
0
rel
100
0, K
and this, independently of the true values of the absolute indicator (K)!

This does not call at all into question the great utility of these indicators. It is just necessary to take account of
these elements to refine its diagnosis and "to possibly juggle" with these two components
to refine in the zones of interest.

The problem does not arise in thermics*, because the indicator in residue for the thermal problem*
is standardized differently. One can however "juggle" with the components of the indicator
thermics and of the limiting, "fictitious" conditions or not, to direct the construction of a grid
refined or déraffiné by zones (cf [§6.3] [R4.10.03] and modeling A, _ TP21 _, of [V6.03.120]).

9
Summary of the results

*In this case-test, it is a question of making sure of the not-**regression of the TP n°1 associated the courses***
***"Indicating of error and adaptation of grid; State of the art and establishment in Code_Aster"** of the formation "Analyzes static non-linear with Code_Aster".*

*In fact, one "abuses" an **elastic design on a metal beam in inflection** in modeling plane constraint. One makes it **converge uniformly** via the tool of refinement-déraffinement HOMARD® encapsulated in MACR_ADAP_MAIL, then **freely** by coupling the process with a chart errors space (exhumed via CALC_ELEM + "ERRE_ELGA_NORE" or "ERRE_ELEM_NOZ1") located on each finite element.*

The objectives of this TP are multiple, it acts:

· to familiarize and put into practice the two dual problems: calculation of chart of indicator of error and strategies of adaptation of grid. On standard cases, but also on pathological cases…,
· to detail the various parameter settings of accused operators (CALC_ELEM, MACR_ADAP_MAIL) and related operators who can appear particularly interesting for these problems (INFO_MAILLAGE, MACR_INFO_MAIL, PROJ_CHAMP…),
· to hammer councils of "good practice" for the quality of the studies and the use of tools already available on the subject. One is interested only in the aspects geometry with a grid, grid itself and standard of finite elements. One is not delayed here on the problems of no time, of calibration of numerical parameters and on the aspects sensitivity opposite data,
· to illustrate the formidable potentialities and facilitated which allows the coupling "language

ASTER/PYTHON" in the command file of a study (test, buckles, posting, calculation, personal macro-order, interactivity…). Official case-tests being gauged for to function in batch, some of these aspects "were thus commentarisés" in the file of order.

From a ***data-processing validation*** *point of view, this case test of course makes it possible to test the not-regression of various couplings calculations of chart of errors/procedure of refinement-déraffinement in mechanics, but also options the "pre one and postprocessings" of these calculations (smoothing of the constraints with nodes, passage of an error per element with an error with the nodes by element).*

Each modeling is associated a question of the TP and one ***retranscribed the "substantial one" marrow of the elements of correction****. Entirety of the text of the TP being available on Internet site http://www.code-aster.com/utilisation/formations.*

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V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.120

FORMA05 - Thermomechanical adaptive grid on a fissured cylinder head

Summary:

In this case-test, it is a question of making sure of the not-regression of the TP n°2 associated Indicating courses the "
of error and adaptation of grid; State of the art and establishment in Code_Aster" of the formation "Non-linear static Analysis with Code_Aster".

One "abuses" a thermoelastic calculation on a metal cylinder head fissured in forced modeling plane (for the mechanical part) and lumpée (for the thermal part). In accordance with the "good practices"
of quality type of the studies, one uses two distinct grids: linear in thermics and quadratic in mechanics.
One first of all carries out (modeling A) the thermal calculation on which one makes converge freely the grid
P1 with a coupling chart of indicator of space errors (CALC_ELEM + "ERTH_ELEM_TEMP") / raffinement-
déraffinement (MACR_ADAP_MAIL + "RAFF_DERA").
In the second modeling (B), the two grids are adapted jointly according to the same process during a chained thermomechanical calculation. For the free adaptation of the mechanical grid, one A resorts to
the indicator in pure residue "ERRE_ELGA_NORE".

This case test makes it possible to test the not-regression of different coupling calculations from chart of errors/procedure of
refinement-déraffinement into thermomechanical, and options the "pre one and postprocessings" of these calculations.

The entirety of the text of the TP is available on Internet site http://www.code-aster.com/utilisation/formations.

Handbook of Validation

1
Problem of reference

1.1 Geometry

GM36
GM33
Y
ECHANGE= (1000 W/m2°C, 350°C)
OUTGOING FLOW
=-400 W/m2
8
4
GM34
20
10
GM35
3
6
3
X

GM37
55
ECHANGE= (5000 W/m2°C, 150°C)
Appear 1.1-a: Diagram of the thermal loadings and the geometry (modelings A and B)

Appear 1.1-b: Isovaleurs of the thermal field on the initial thermal grid (modelings A and B)

It is about one "
cylinder head
" metal fissured (steel 16MND5, E= 210.103 Mpa, v= 0.2,
C = 526.104 J/m3 C
°, =
5
,
33 W/m C
°).
p
In two modelings (A and B), one carries out an isotropic transitory linear calculation thermal (THER_LINEAIRE or THER_NON_LINE) in modeling lumpée (PLAN_DIAG) on a grid thermics TRIA3/SEG2.
In the second modeling, this calculation is chained with an elastic design (MECA_STATIQUE or STAT_NON_LINE) in modeling forced plane (C_PLAN) on a mechanical grid in TRIA6/SEG3.

GM36
GM33
ECHANGE= (1000 W/m2°C, 350°C)
OUTGOING FLOW

=-400 W/m2
GM34
GM35
PRES_REP= -0.1N
GM39/GM40
DX=DY=0

GM37
ECHANGE= (5000 W/m2°C, 150°C)
Appear 1.1-c: Diagram of the thermomechanical loadings and the geometry (modeling B)

Appear 1.1-d: Decrease of the potential energy of deformation
during the process of adjustment free of the grids (modeling B)

Appear 1.1-e: Deformation of the mechanical grid (modeling B)

The various key zones of calculation are indicated: GM38 for all the voluminal part SORTED some, GM33 for the outgoing heat flux, GM36/37 for the conditions of exchange, GM39/40 for embedding, GM34 for the pressure distributed and GM35 on the level of which one will measure the integral
temperature.

1.2 Material properties

To all structure (GROUP_MA GM38), one applies the characteristics material

E = 210000 Mpa
= 2
.
0
C = 526.104 J/m3 C
°
p

=
5
.
33
W/m C
°

1.3 Boundary conditions and loadings

One can synthesize the decomposition of the loadings by zone in the shape of the following table:

Geometrical zones
Loadings
(GROUP_NO/GROUP_MA)
GM33
FLUX_REP

FLUN = -400 W/m2
GM36 EXCHANGE
COEF_H = 1000 W/m2°C
TEMP_EXT = 350 °C
GM37 EXCHANGE
COEF_H = 5000 W/m2°C
TEMP_EXT = 150 °C
GM39/40 DDL_IMPO
DX = DY = 0.
GM34 PRES_REP
CLOSE = -0.1 NR

2
Reference solution

2.1
Method of calculation used for the reference solutions

On such a case of figure, it is not possible to exhume an analytical solution! The solution of reference used for error analyses on the integral of the temperature of GM35 (modeling A) and on the potential energy of deformation (modeling A and B), is in fact an approximate solution obtained after a series of three uniform refinements. This procedure of uniform refinement can be controlled by a loop PYTHON and UNIFORM operator MACR_ADAP_MAIL option.

2.2
Result of reference

Modeling a:
Potential energy of deformation (purely thermal) = 2016.80291 J
Integral of the temperature on GM35 = 4080 °Cm

Modeling b:
Potential energy of deformation (thermomechanical) = 6.75073756. 105 J

2.3
Uncertainty on the solutions

They acts only of approximate solutions obtained on a "quasi-converged" grid.

2.4 References
bibliographical

[1]
X.DESROCHES. "Estimators of error of Zhu-Zienkiewicz in elasticity 2D". [R4.10.01], 1994.
[2]
X.DESROCHES. "Estimator of error in residue". [R4.10.02], 2000.
[3]
O.BOITEAU. "Indicating of space error in residue for transitory thermics". [R4.10.03], 2001.
[4]
O.BOITEAU. "Course and TP Indicateurs of error & Adaptation of grid; State of the art and establishment in Code_Aster". http://www.code-aster.com/utilisation/formations, 2002.
[5]
O.BOITEAU. "FORMA04: Mechanical adaptive grid on a beam in inflection". [V6.03.119], 2002.

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3 Modeling
With

3.1
Characteristics of modeling

The grid is carried out with elements of the type TRIA3. Calculation is made in linear thermics stationary isotropic with operator THER_LINEAIRE in lumpé (modeling PLAN_DIAG).

One calculates the charts of space errors of the indicator in pure residue (ERTH_ELEM_TEMP). Beforehand it is necessary to have smoothed the heat flux of the points of Gauss to the nodes (FLUX_ELNO_TEMP) and, post-to treat the chart of error (via GIBI), it should be transformed of one
CHAM_ELEM by element with a CHAM_ELEM with the nodes by element. One determines also the value of
the integral of the temperature on GM35 (POST_RELEVE_T) and that of the potential energy of deformation (POST_ELEM).
The whole is placed in a loop PYTHON allowing the installation of a procedure of
free refinement in nb_calc=4 levels (via MACR_ADAP_MAIL option LIBRE=' RAFF_DERA') coupled on the chart of error exhumed beforehand. One controls this process by the component ERTREL of ERTH_ELEM_TEMP (component relative of the indicator in residue). With like criteria CRIT_RAFF_PE=0.2 and CRIT_DERA_PE=0.1 (one refines 20% of the worst elements and one déraffine
10% of best).

One can thus note the convergence of the values of the temperature and energy, the increase of their errors relative compared to the errors provided by the indicator (they same into relative and on all the structure), variations of the indices of effectiveness of the indicator and its good checking of the assumption of saturation.

In order to illustrate councils of "good practice" for the quality of the studies, on the aspects geometry with a grid, grid itself and standard of finite elements, one uses the options adhoc LIRE_MAILLAGE, MACR_ADAP_MAIL and MACR_INFO_MAIL.

Appear 3.1-a: Isovaleurs of the component of exchange (TERME2) of the indicator of error

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Appear 3.1-b: Decreases of the relative errors of the deformation energy and of the average temperature compared with that of the total component relative of indicator (ERTREL)

3.2 Characteristics of the grid

Initially: 1619 TRIA3, 102 SEG2, 911 nodes
After a free refinement: 3088 TRIA3, 134 SEG2, 1681 nodes
After two free refinements: 6105 TRIA3, 180 SEG2, 3253 nodes
After three free refinements: 12345 TRIA3, 245 SEG2, 6462 nodes
After four free refinements: 25063 TRIA3, 347 SEG2, 12962 nodes

3.3 Functionalities tested

Orders

DEFI_MATERIAU THER

LIRE_MAILLAGE INFORMATION
VERI_MAIL

MACR_INFO_MAIL QUALITY
INTERPENETRATION
CUT

CONNEXITY

DEFI_GROUP CREA_GROUP_NO

THERMAL AFFE_MODELE
PLAN_DIAG
AFFE_MATERIAU

AFFE_CHAR_THER EXCHANGE
FLUX_REP

STATIONARY THER_LINEAIRE

CALC_ELEM “FLUX_ELNO_TEMP”
“ERTH_ELEM_TEMP”
ERTH ELNO ELEM'
IMPR_RESU FORMAT=' CASTEM'

POST_ELEM ENER_POT

POST_RELEVE_T OPERATION=' MOYENNE'

IMPR_TABLE

MACR_ADAP_MAIL LIBRE=' RAFF_DERA'
QUALITY
NTERPENETRATION
CUT
CONNEXITY
Various PYTHON
Buckle
Structure of control
Passage SD
ASTER - > PYTHON
Passage
SD

PYTHON - > ASTER

4
Results of modeling A

4.1 Values tested

One tests the values of the relative errors in integral of the temperature and potential energy of deformation compared to the reference solutions (cf [§2.2]). And this, on the initial grid and afterwards four free refinements. Tests having to be multi-platforms, the relative tolerance, which is on the initial errors fixed at 10 6%, is voluntarily slackened on the errors after four refinements: 104%.
These tests are carried out on variables PYTHON (via TEST_FONCTION) inserted beforehand in functions ASTER (via FORMULA).

Identification Values Values Tolerance relative Variation
Variable
Variable
Code_Aster
of
(in %)
ASTER
PYTHON
reference
Ep (0)
0.491819 %
idem

10-6% 1.1010-11
ERREEN0 eren0
~ 0%
Ep (4)
0.016287 %
idem
10-4% 3.05
10-12
ERREEN4 eren4
~ 0%

T (0)
0.921819 %
idem
10-6% 2.42
10-12
ERRETM0 ertm0
~ 0%
T (4)
0.208827 %
idem
10-4% -6.65
10-13
ERRETM4 ertm4
~ 0%

4.2
What it was necessary to retain of this part of the TP…

It is necessary well to keep in mind, that as a "simple postprocessing" of the problem thermomechanical, the ***indicator cannot unfortunately provide more reliable diagnosis in the zones where the resolution of the initial problem stumbles*** *(crack, corners, multi-material, embedding, shock…). It is thus necessary to begin a process of adjustment (UNIFORM or FREE), with a grid refined already a little "with the hand" close to the zones of discontinuities (materials, geometrical…).*

MACR_ADAP_MAIL does not have process of regularization, therefore a bad initial grid will produce, even coupled to an indicator, probably a bad adapted grid!

As in mechanics, the ***sequence "operators thermique/MACR_ADAP_MAIL OPTION "FREE"" converge optimalement the grid makes it possible to make****.*

One can, moreover, ***"to juggle" with the components of the thermal indicator*** *and the conditions limits, "fictitious" or not,* ***to direct the construction of a grid refined or déraffiné by zones*** *(cf [§6.3] [R4.10.03]).*

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5 Modeling B

5.1 Characteristics of modeling

Thermal grid (resp. mechanics) is carried out with elements of the type TRIA3 (resp. TRIA6). One chains a calculation of stationary linear thermics isotropic (via THER_LINEAIRE in modeling PLAN_DIAG) and a calculation in linear elasticity (via STAT_NON_LINE in modeling C_PLAN).

One calculates the charts of space errors of the indicators in thermal and mechanical pure residue (ERTH_ELEM_TEMP and ERRE_ELGA_NORE). Beforehand it is necessary to have smoothed the heat flux and it stress field of the points of Gauss to nodes (FLUX_ELNO_TEMP and SIEF_ELNO_ELGA) and, post-to treat the chart of error (via GIBI), it should be transformed of a CHAM_ELEM by element with one CHAM_ELEM with the nodes by element. One determines also the value of the potential energy of deformation (POST_ELEM).
The whole is placed in a loop PYTHON allowing the installation of a procedure of

*free refinement in nb_calc=2 levels (via MACR_ADAP_MAIL option LIBRE=' RAFF_DERA')
coupled on the chart of error exhumed beforehand. This process is controlled:*

*· by component ERTREL of ERTH_ELEM_TEMP (component relative of the indicator in
residue) for the thermal grid,
· by component NUEST of ERRE_ELGA_NORE (component relative of the indicator in
residue) for the mechanical grid.*

*With like criteria CRIT_RAFF_PE=0.2 and CRIT_DERA_PE=0.1 (one refines 20% of the elements
them
worse and one déraffine 10% of best).*

*After each thermal calculation one of course projects the field of temperature of the thermal grid
on the mechanical grid (via PROJ_CHAMP).*

*One can thus note the convergence of energy, the increase of his relative error per report/ratio
with the errors provided by the indicators (they same into relative and on all the structure), the
variations
indices of effectiveness of the indicators and their good checking of the assumption of saturation.*

5.2 Characteristics of the grid

Thermal grid

*Initially: 1619 TRIA3, 102 SEG2, 911 nodes
After a free refinement: 3088 TRIA3, 134 SEG2, 1681 nodes
After two free refinements: 6105 TRIA3, 180 SEG2, 3253 nodes*

Mechanical grid

*Initially: 1619 TRIA6, 102 SEG3, 3443 nodes
After a free refinement: 2881 TRIA6, 152 SEG3, 6065 nodes
After two free refinements: 5319 TRIA6, 180 SEG3, 11097 nodes*

5.3 Functionalities tested

Orders

DEFI_MATERIAU THER
ELAS

LIRE_MAILLAGE

DEFI_GROUP CREA_GROUP_NO

THERMAL AFFE_MODELE
PLAN_DIAG

MECHANICS
C_PLAN

AFFE_MATERIAU

AFFE_CHAR_THER EXCHANGE
FLUX_REP

AFFE_CHAR_MECA TEMP_CALCULEE
DDL_IMPO
PRES_REP
STATIONARY THER_LINEAIRE

STAT_NON_LINE COMPR_INCR=' ELAS'

CALC_ELEM "FLUX_ELNO_TEMP"

“ERTH_ELEM_TEMP”
“ERTH_ELNO_ELEM”
“SIEF_ELNO_ELGA”
`ERRE_ELGA_NORE4
“ERRE_ELNO_ELGA”
IMPR_RESU FORMAT=' CASTEM'

POST_ELEM ENER_POT

IMPR_TABLE

MACR_ADAP_MAIL LIBRE=' RAFF_DERA'
QUALITY
INTERPENETRATION
CUT
CONNEXITY

Various PYTHON
Buckle
Structure of control
Passage SD
ASTER - > PYTHON
Passage
SD

PYTHON - > ASTER

12/14

6
Results of modeling B

6.1 Values
tested

One tests the relative error values in potential energy of deformation compared to the solution of reference (cf [§2.2]). And this, on the initial grid and after two free refinements. Tests in front of being multi-platforms, the relative tolerance, which on the initial errors is fixed at 10 6%, is voluntarily slackened on the errors after two refinements: 104%.
These tests are carried out on variables PYTHON (via TEST_FONCTION) inserted beforehand in functions ASTER (via FORMULA).

Identification Values Values Tolerance relative Variation
Variable
Variable
Code_Aster
of
(in %)
ASTER
PYTHON
reference
Ep (0)
10.077761% idem 106% 4.7912
ERREEN0 eren0
~ 0%
Ep (2)
0.459330 %
idem
10-4% -1.03
10-12
ERREEN2 eren2
~ 0%

6.2
What it was necessary to retain of this part of the TP…

Into **thermomechanical, various strategies of adaptation of grid** *are offered to the user:*

· to adapt the grid only according to one thermal criterion,
· idem according to a mechanical criterion,

· to adapt initially according to a thermal criterion, then according to a mechanical criterion (two separate loops of adaptation).
· to adapt jointly according to a thermal criterion then mechanical (a loop as in this TP),
· to adapt according to a thermomechanical criterion.

In Code_Aster, one does not have access to explicitly thermomechanical indicators, although the mechanical indicators can comprise incidentally a thermal dependence via loading TEMP_CALCULEE.
According to the needs for the study (rather thermal or rather mechanics, to make converge a grid broadly, better taken into account of certain CLs…) one can set up in the code, one of the first four strategies.

Good practice during a thermomechanical calculation being to use the P1 elements lumpés in thermics and P2 in mechanics, that resulted in using two grids (as in this TP) and to interpolate the thermal field linear solution on the quadratic mechanical network (via PROJ_CHAMP).

Nevertheless, if one wishes to work only with one grid, one can easily decline one of quatres first strategies via option MAJ_CHAMP of MACR_ADAP_MAIL. That allows, all in adapting the grid according to a thermal criterion (resp. mechanics), to update the field complementary, mechanical (resp. thermics), on the new adapted grid.

---

7 Summary of the results

*In this case-test, it is a question of making sure of the not-**regression of the TP n°2 associated the courses***
***"Indicating of error and adaptation of grid; State of the art and establishment in Code_Aster"** of the formation "Analyzes static non-linear with Code_Aster".*

*In fact, one "abuses" a **thermoelastic calculation on a metal cylinder head fissured** in plane forced modeling (for the mechanical part) and lumpé (for the thermal part).*
In accordance with the "good practices" of quality type of the studies, one uses two grids distinct: linear in thermics and quadratic in mechanics.
One first of all carries out (modeling A) the thermal calculation on which one makes converge freely it P1 grid with a coupling chart of indicator of space errors (CALC_ELEM + "ERTH_ELEM_TEMP") /RAFFINEMENT-DÉRAFFINEMENT (MACR_ADAP_MAIL "RAFF_DERA").
In the second modeling (B), the two grids are adapted jointly according to the same one process during a chained thermomechanical calculation. For the free adaptation of the grid mechanics, one has recourse to the indicator in pure residue "ERRE_ELGA_NORE".

The objectives of this TP are multiple, it acts:

· to familiarize and put into practice the two dual problems: calculation of chart of indicator of error and strategies of adaptation of grid. On standard cases, but also on pathological cases and for chainings of calculations,
· to detail the various parameter settings of accused operators (CALC_ELEM, MACR_ADAP_MAIL) and related operators who can appear particularly interesting for these problems (INFO_MAILLAGE,
MACR_INFO_MAIL,
PROJ_CHAMP…),
· to hammer councils of "good practice" for the quality of the studies and the use of tools already available on the subject. One is interested only in the aspects geometry with a grid, grid itself and standard of finite elements. One is not delayed here on the problems of no time, of calibration of numerical parameters and on the aspects sensitivity opposite data,
· to illustrate the formidable potentialities and facilitated which allows the coupling "language ASTER/PYTHON" in the command file of a study (test, buckles, posting, calculation, personal macro-order, interactivity…). Official case-tests being gauged for to function in batch, some of these aspects "were thus commentarisés" in the file of order.

*From a **data-processing validation** point of view, this case test of course makes it possible to test the not-regression of various couplings calculations of chart of errors/procedure of refinement-déraffinement into thermo mechanics, but also options the "pre one and postprocessings" of these calculations (smoothing of constraints and of the heat fluxes to the nodes, passage of an error per element with an error with nodes by element).*

Each modeling is associated a question of the TP and one ***retranscribed the "substantial one" marrow of the elements of correction****. Entirety of the text of the TP being available on Internet site http://www.code-aster.com/utilisation/formations.*

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Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.121

SSNP121 Integration of the terms of contact in 2D and 3D

Summary:

This problem corresponds to a quasi-static analysis of a problem of mechanics with contact without friction. One is interested particularly here in integration of the terms of contact. It is a question of studying two
identical blocks subjected to symmetrical imposed displacements.
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This test comprises three modelings in 2D (linear elements SEG2):

· modeling a: METHODE= `CONTINUE'. Method of integration by subelements
also proposed by Bathe [bib1] is used with three subelements,
· modeling b: METHODE= `CONTRAINTE',
· modeling C: METHODE= `PENALISATION',

a modeling in 2D (linear elements SEG2 in with respect to quadratic elements SEG3):

· modeling H
: METHODE= `CONTINUE'. Surfaces of contact are made up
elements SEG2 in with respect to elements SEG3,

three modelings in 3D (quadratic elements):

· modeling D
: METHODE= `CONTINUE'. Surfaces of contact are made up
elements QUAD8 in with respect to elements QUAD8,

· modeling E: METHODE= `CONTINUE'. Surfaces of contact are made up of elements TRIA6 in with respect to elements TRIA6,
· modeling F: METHODE= `CONTINUE'. Surfaces of contact are made up of elements TRIA6 in with respect to elements QUAD8.
· modeling G: METHODE= `CONTINUE'. An alternative of modeling A where one tests the initial activation of the statute of contact.

and three modelings in 3D (linear elements in with respect to quadratic elements):

· modeling I: METHODE= `CONTINUE'. Surfaces of contact are made up of elements QUAD4 in with respect to elements QUAD8,
· modeling J: METHODE= `CONTINUE'. Surfaces of contact are made up of elements TRIA3 in with respect to elements TRIA6,
· modeling K: METHODE= `CONTINUE'. Surfaces of contact are made up of elements TRIA3 in with respect to elements QUAD8.

1
Problem of reference

1.1 Geometry

Length has = 2 Mr.
Width B = 1 Mr.
O not medium of segment AB.

1.2
Material properties

Plates 1 and 2:
Poisson's ratio: 0.0
Young modulus: 2. 106 N/m2

1.3
Boundary conditions and loadings

Plate 1 is blocked:
· On HG DX = 0 and DY = 0.

Plate 2 is subjected to an imposed displacement:
· On CD: DY = U0 = 0.1 m and DX = 0.

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2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution, analytical, can be deduced from a very simple calculation. Deformation = U0/HD = 0.1/2. The pressure is worth then E = 1.105 Pa.

2.2
Results of reference

The contact pressure is constant and equal to 1.105 Pa on all the surface of contact. In the same way it vertical displacement (according to y) is constant on the surface of contact and equal to U0/2 = 0.05 Misters.

2.3 Reference
bibliographical

[1]
NR. EL-ABBASI and K.J. BATHE: "Stability and Patch Test Performance of Contact Discretizations and has New Solution Algorithm ", Computers & Structures, 79, 1473-1486, 2001

3 Modeling With

3.1 Characteristics of modeling

One uses a modeling 2D_PLAN for the solid elements with the method CONTINUES for treatment of CONTACT with integration of the type "SIMPSON2".

12 finite elements SEG2 are laid out on the initial surface of contact of plate 1 and only 11 on the surface of contact of other surface. By activating key word "SIMPSON2" three subelements are used for the integration of the terms of contact. The grid comprises in all 265 elements QUAD4 for the two plates.

3.2 Characteristics of the grid

A number of nodes:
313
A number of meshs and types:
265 QUAD4 and 132 SEG2

3.3 Functionalities tested

AFFE_CHAR_MECA CONTACT
METHOD

“CONTINUES”
AFFE_CHAR_MECA CONTACT
INTEGRATION
“SIMPSON2”
AFFE_CHAR_MECA CONTACT
MODL_AXIS
“NOT”
AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
“ELAS”

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster
% difference
DY at point A
-0.05
-0.0499
-0.007 %
LAGR_C at point A
1.E+5
1.0008 E+5
0.08 %
DY at the point O
-0.05
-0.0499
-0.043 %
LAGR_C at the point O
1.E+5
1.0035 E+5

0.351 %
DY at the point B
-0.05
-0.0499
-0.007 %
LAGR_C at the point B
1.E+5
1.0008 E+5
0.08 %

One as checks by a IMPR_RESU as the vertical pressure and displacements are identical on all segment AB.

---

5 Modeling B

5.1 Characteristics of modeling

One uses a modeling 2D_PLAN for the solid elements with the method FORCED for treatment of CONTACT.

5.2 Characteristics of the grid

One uses the same grid as for preceding modeling.

A number of nodes:
313
A number of meshs and types:
265 QUAD4 and 132 SEG2

5.3 Functionalities tested

AFFE_CHAR_MECA CONTACT
METHOD
“FORCED”
AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”
STAT_NON_LINE COMP_ELAS
RELATION
“ELAS”

6 Results of modeling B

6.1 Values tested

Identification Reference
Aster
% difference
DY at point A
-0.05
-0.05017
0.347 %
SIYY at point A
1.E+5
9.9624 E+5
-0.376 %
DY at the point O
-0.05
-0.04916

-1.666 %
SIYY at the point O
1.E+5
1.0600 E+5
6.004 %
DY at the point B
-0.05
-0.04916
-1.666 %
SIYY at the point B
1.E+5
1.0600 E+5
6.004 %

---

7 Modeling C

7.1 Characteristics of modeling

One uses a modeling 2D_PLAN for the solid elements with the method PENALIZATION with a coefficient of penalization of 1.E7 for the treatment of the contact.

7.2

Characteristics of the grid

One uses the same grid as for preceding modeling.

A number of nodes:
313
A number of meshs and types:
265 QUAD4 and 132 SEG2

7.3 Functionalities
tested

AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”
AFFE_CHAR_MECA CONTACT
E_N

STAT_NON_LINE COMP_ELAS
RELATION
“ELAS”

8
Results of modeling C

8.1 Values
tested

Identification Reference
Aster
% difference
DY at point A
-0.05
-0.05060
2.121 %
SIYY at point A
1.E+5
9.7875 E+5

-2.125 %
DY at the point O
-0.05
-0.04965
-0.699 %
SIYY at the point O
1.E+5
1.0741 E+5
7.413 %
DY at the point B
-0.05
-0.04965
-0.699 %
SIYY at the point B
1.E+5
1.0741 E+5
7.413 %

---

9 Modeling D

9.1 Characteristics of modeling

One uses a modeling 3D for the solid elements with the method CONTINUES for treatment of CONTACT. Surfaces of contact in opposite consist of elements QUAD8.

9.2 Characteristics of the grid

One uses the same grid as for preceding modeling.

A number of nodes:
850
A number of meshs and types:
128 HEXA20 and 64 QUAD8

9.3 Functionalities tested

AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"
AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"
AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
"ELAS"

10 Results of modeling D

10.1 Values tested

Identification Reference
Aster
% difference

DZ at point A
-0.05
-0.05
0.0 %
SIYY at point A
1.E+5
1. E+5
0.0 %
Max SIYY on the surface of contact
1.E+5
1. E+5
0.0 %
Min SIYY on the surface of contact
1.E+5
1. E+5
0.0 %
DZ at the point B
-0.05
-0.05
0.0 %
SIYY at the point B
1.E+5
1. E+5
0.0 %

---

11 Modeling E

11.1 Characteristics of modeling

One uses a modeling 3D for the solid elements with the method CONTINUES for treatment of CONTACT. Surfaces of contact in opposite consist of elements TRIA6.

11.2 Characteristics of the grid

One uses the same grid as for preceding modeling.

A number of nodes:
1010
A number of meshs and types:
256 PENTA15 and 128 TRIA6

11.3 Functionalities tested

AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"
AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"
AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
"ELAS"

12 Results of modeling E

12.1 Values tested

Identification Reference
Aster
% difference
DZ at point A
-0.05
-0.050002
0.004 %
SIYY at point A
1.E+5
1.001 E+5
0.01 %
Max SIYY on the surface of contact
1.E+5
9.9992 E+4
-0.008 %
Min SIYY on the surface of contact
1.E+5
1.00015 E+5
0.015 %
DZ at the point B
-0.05
-0.05
0.0 %
SIYY at the point B
1.E+5
9.9996 E+4
-0.003 %

---

13 Modeling F

13.1 Characteristics of modeling

One uses a modeling 3D for the solid elements with the method CONTINUES for treatment of CONTACT. Surfaces of contact in opposite consist of elements TRIA6 in with respect to meshs QUAD8.

13.2 Characteristics of the grid

One uses the same grid as for preceding modeling.

A number of nodes:
930
A number of meshs and types:
64 HEXA20, 128 PENTA15, 32 QUAD8 and 64 TRIA6

13.3 Functionalities tested

AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"
AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"
AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
"ELAS"

14 Results of modeling F

14.1 Values tested

Identification	*Reference*	*Aster*	*% difference*
DZ at point A	*-0.05*	*-0.05*	*0.0 %*
SIYY at point A	***1.E+5***	***1. E+5***	*0.0 %*
Max SIYY on the surface of contact	***1.E+5***	***1. E+5***	*0.0 %*
Min SIYY on the surface of contact	***1.E+5***	***1. E+5***	*0.0 %*
DZ at the point B	*-0.05*	*-0.05*	*0.0 %*
SIYY at the point B	***1.E+5***	***1. E+5***	*0.0 %*

14.2 Notice

The surface of contact slave is with a grid in TRIA6 and the surface of main contact is with a grid in *QUAD8. A use with elements QUAD8 for surface slave and of the TRIA6 for surface main does not satisfy the conditions of compatibility necessary to the good integration of terms of contact [R5.03.52]. In a general way, if one does not apprehend correctly this concept of compatibility, one advises with the user not informed to use the same elements for main grid of surfaces and slave.*

---

15 Modeling G

15.1 Characteristics of modeling

One uses a modeling 2D_PLAN for the solid elements with the method CONTINUES for treatment of CONTACT with integration of the type “SIMPSON2”.

Plate 2 is subjected to a pressure E = 1.105 Pa on all surface CD. This pressure to a displacement imposed U0 = 0.1 m is equivalent on CD according to following formulas':

= U0/HD = - 0.1/2 and P0 = E = 1.105 Pa

Note:

It should be taken care of the orientation of the group of mesh of plate 2 in such way that the normal that is to say outgoing. One had to use key word ORIENT_PEAU_2D.

Note:

In this modeling, one imposes a pressure on plate 2. So that the problem is soluble, it is necessary CONTACT_INIT = “YES”. In the contrary case, with the first iteration of first step of time, plate 2 would have a rigid movement of body.

15.2 Characteristics of the grid

A number of nodes:
313
A number of meshs and types:
265 QUAD4 and 132 SEG2

15.3 Functionalities
tested

AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"
AFFE_CHAR_MECA CONTACT
INTEGRATION
"SIMPSON2"
AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"
AFFE_CHAR_MECA CONTACT
CONTACT_INIT
"YES"
AFFE_CHAR_MECA DDL_IMPO

AFFE_CHAR_MECA PRES_REP

AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
"ELAS"

Boundary conditions:
To avoid the rigid movements of body, the node D has a horizontal displacement no one.

16 Results of modeling G

16.1 Values tested

Identification	Reference	Aster	% difference
DY at point A	-0.05	-0.0499	-0.007 %
LAGR_C at point A	1.E+5	1.0008 E+5	0.08 %
DY at the point O	-0.05	-0.0499	-0.043 %
LAGR_C at the point O	1.E+5	1.0035 E+5	0.351 %
DY at the point B	-0.05	-0.0499	-0.007 %
LAGR_C at the point B			

1.E+5
1.0008 E+5
0.08 %

One as checks by a IMPR_RESU as the vertical pressure and displacements are identical on all segment AB.

---

17 Modeling H

17.1 Characteristics of modeling

One uses a modeling 2D_PLAN for the solid elements with the method CONTINUES for treatment of the CONTACT between linear mixed elements and quadratic elements with presence incompatibilities of grids.
12 finite elements SEG2 are laid out on the initial surface of contact of the plate slave and only 11 finite elements SEG3 on the surface of main contact. By activating the key word "NCOTES2", a diagram of the Newton-Dimensions type coupled to a technique of subdivision in under elements was used for the integration of the terms of contact. The grid comprises in all 144 elements QUAD4 for the plate slave opposite 121 elements QUAD8 for the plate Master.

17.2 Characteristics of the grid

A number of nodes:
721
A number of meshs and types:
144 QUAD4, 121 QUAD8, 48 SEG2 and 44 SEG3

17.3 Functionalities tested

AFFE_CHAR_MECA CONTACT METHOD "CONTINUES"
AFFE_CHAR_MECA CONTACT INTEGRATION "NCOTES2"
AFFE_CHAR_MECA CONTACT MODL_AXIS "NOT"
AFFE_CHAR_MECA CONTACT ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS RELATION "ELAS"

18 Results of modeling H

18.1 Values tested

Identification Reference
Aster
% difference
DY at point A
-0.05
-0.0499
-0.012 %
LAGR_C at point A
1.E+5

1.00034 E+5
0.034 %
DY at the point B
-0.05
-0.0499
-0.012 %
LAGR_C at the point B
1.E+5
1.00034 E+5
0.034 %

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19 Modeling
I

19.1 Characteristics of modeling

One uses a modeling 3D for the solid elements with the method CONTINUES for
treatment of the CONTACT between linear mixed elements and quadratic elements with presence
incompatibilities of grids. Surfaces of contact consist of 5 elements QUAD4 in
with respect to 4 elements QUAD8. The diagram of integration used is of Newton-Dimensions type
coupled to
a technique of subdivision in subelements.

19.2 Characteristics of the grid

A number of nodes:
227
A number of meshs and types:
16 HEXA20, 25 HEXA8, 32 QUAD8 and 50 QUAD8

19.3 Functionalities
tested

AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"
AFFE_CHAR_MECA CONTACT
INTEGRATION

"NCOTES2"
AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"
AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
"ELAS"

20 Results of modeling I

20.1 Values tested

Identification Reference
Aster
% difference
DZ at point A
-0.05
-0.0499996
0.000061 %
SIYY at point A
1.E+5
1.000045 E+5
0.005 %
Max SIYY on the surface of contact
1.E+5
9.9988 E+4
-0.012 %
Min SIYY on the surface of contact
1.E+5
1.000093 E+5
0.009 %
DZ at the point B
-0.05
-0.0499996

0.000061 %
SIYY at the point B
1.E+5
1.000045 E+5
0.005 %

21 Modeling
J

21.1 Characteristics of modeling

One uses a modeling 3D for the solid elements with the method CONTINUES for treatment of the CONTACT between linear mixed elements and quadratic elements. Surfaces of contact consist of elements TRIA3 in with respect to elements TRIA6. The grids are compatible. The diagram of integration used is of Newton-Dimensions type.

21.2 Characteristics of the grid

A number of nodes:
630
A number of meshs and types:
128 PENTA6, 128 PENTA15, 64 TRIA3 and 64 TRIA6

21.3 Functionalities tested

AFFE_CHAR_MECA CONTACT METHOD "CONTINUES"
AFFE_CHAR_MECA CONTACT INTEGRATION "NCOTES"
AFFE_CHAR_MECA CONTACT MODL_AXIS "NOT"
AFFE_CHAR_MECA CONTACT ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS RELATION "ELAS"

22 Results of modeling J

22.1 Values tested

Identification	***Reference***	***Aster***	***% difference***
DZ at point A	*-0.05*	*-0.05*	*0.0 %*
SIYY at point A	***1.E+5***	***1.E+5***	*0.0 %*
Max SIYY on the surface of contact	***1.E+5***	***1.E+5***	

0.0 %
Min SIYY on the surface of contact
1.E+5
1.E+5
0.0 %
DZ at the point B
-0.05
-0.05
0.0 %
SIYY at the point B
1.E+5
1.E+5
0.0 %

---

23 Modeling
K

23.1 Characteristics of modeling

One uses a modeling 3D for the solid elements with the method CONTINUES for treatment of the CONTACT for the linear/quadratic mixed elements. Surfaces of contact in opposite consist of elements TRIA3 in with respect to meshs QUAD8. The grids are compatible. The diagram of integration used is of Newton-Dimensions type.

23.2 Characteristics of the grid

A number of nodes:
550
A number of meshs and types:
64 HEXA20, 128 PENTA6, 32 QUAD8 and 64 TRIA3

23.3 Functionalities
tested

AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"
AFFE_CHAR_MECA CONTACT
INTEGRATION
"NCOTES"
AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"
AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
STAT_NON_LINE COMP_ELAS
RELATION
"ELAS"

24 Results of modeling K

24.1 Values
tested

Identification Reference
Aster
% difference
DZ at point A
-0.05
-0.05

0.0 %
SIYY at point A
1.E+5
1. E+5
0.0 %
Max SIYY on the surface of contact
1.E+5
1. E+5
0.0 %
Min SIYY on the surface of contact
1.E+5
1. E+5
0.0 %
DZ at the point B
-0.05
-0.05
0.0 %
SIYY at the point B
1.E+5
1. E+5
0.0 %

24.2 Notice

The surface of contact slave is with a grid in TRIA3 and the surface of main contact is with a grid in QUAD8. A use with elements QUAD4 for surface slave and of the TRIA6 for surface main does not satisfy the conditions of compatibility necessary to the good integration of terms of contact [R5.03.52].

25 Summary of the results

One seeks on this example very simple to test a new technique of integration of the terms of contact based on the subdivision by subelements available only for the method "CONTINUOUS". This technique aims to attenuate the amplitude of oscillation of the pressure of contact. In the case studied here, the pressure is constant on all the surface of contact (notice that the Poisson's ratio is null).

One also implemented a new diagram of integration of the Newton-Dimensions type allowing of to solve the problems of contact for Linear/Quadratic mixed elements with incompatibility of grids.

One notes thus that with the methods "FORCED" and "PENALIZATION" the solution present nonphysical oscillations of about 6 to 7%. By using the "CONTINUOUS" method, them oscillations disappear almost completely and the results obtained are very close to the solution of reference (<0,5%). Moreover, one notes that when this technique is used, the interpenetration (due to the use of master-slave modeling) decreases also significantly.
The "CONTINUOUS" method allows moreover a nonapproximate treatment of surfaces of contact with a grid with quadratic elements, whereas the "FORCED" method is used with one linearization of the elements on the surface of contact. One advises with the users not informed on *compatibility of the elements to be used for the main grid of surfaces and slave to use the same one type of meshs for two surfaces.*

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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.122

SSNP122 - Traction. Model of Rousselier in
versions local and nonlocal

Summary:

This quasi-static test consists in applying to a bar a loading of traction. Two versions are used
model of Rousselier with the kinematics of the great deformations of Simo and Miehe: the local version and
the nonlocal version (model with gradient of internal variables). For a test tensile, terms in
gradient are not activated: one thus finds the results of the local version, at least as long as the solution
local version remains homogeneous (not localization).
The bar is modelled by a quadrangular element (QUAD8) in plane deformation.

The results obtained are results of nonregression. The two models give identical results
as long as the solution of the local version does not locate. The solution of the model with gradient remains homogeneous all
with the length of the way of loading.

1
Problem of reference

1.1 Geometry

y
1 (mm)
1
4
2
3
Z
X
1 (mm)

1.2
Properties of material

Isotropic elasticity
Young modulus: E =
MPa

200000

Poisson's ratio: = 0.3
Coefficients of the model of Rousselier

Initial porosity: F
01
.
0
0 =

D = 2

MPa

500
1 =

Rational traction diagram
Deformation logarithmic curve
Rational constraint (MPa)
0.0
0.0
0.002
400.0
1.002
2400.0
Nonlocal model
Characteristic length: 0.1mm

1.3
Boundary conditions and loadings

The bar, blocked in the direction y
However on the face [1,2], is subjected to a displacement U (T) on the face
[3, 4].

U (T)
U (mm)
1.5
4
3
T (S)
1.5
1 2

1.4 Conditions
initial

Null constraints and deformations with T = 0.

2
Results of reference

We do not have reference solution.

· As long as the solution of the local model remains homogeneous for the various points of Gauss,
i.e. for t=0.93s, one will take as reference solution the results obtained with
Code_Aster for this model. For the results of the model with gradient, one must find
exactly results obtained with the local version. At this moment, one will thus test, for
two models, the constraint of Cauchy yy in the direction y, the constraint of Cauchy zz
in direction Z, cumulated plastic deformation p and the porosity F, calculated at the point of
Gauss n°1 of the mesh [1,2,3,4].
· For the model with gradient, the answer must remain homogeneous in the points of Gauss all with
length of the way of loading. To test this result, one will adopt as solution of
reference, the constraint of Cauchy yy in the direction y at the points of Gauss n°1, 2, 3 and 4
mesh [1,2,3,4] and at the final moment.

3 Modeling With

3.1 Characteristics of modeling

Modeling 2D: 1 quadrangle QUAD8

y
C
D
N4
N7
N3
N8
N6
N1
N5
N2
With
B

The imposed loading is as follows:

· the nodes N1, N5 and N2 are blocked according to the direction y,
· the N1 node is blocked according to direction X,
· the nodes N4, N7 and N3 undergo a displacement of 1.5mm in 1.5s distributed according to 50 increments.

3.2 Functionalities tested

For the model of Rousselier in local version, the functionalities tested are:

Order
Key word factor
Simple key word
Argument
AFFE_MODELE AFFE
MODELING
“D_PLAN_SI”
DEFI_MATERIAU ROUSSELIER

STAT_NON_LINE COMP_INCR
RELATION
“ROUSSELIER”
COMP_INCR
DEFORMATION
“SIMO_MIEHE”
RECH_LINEAIRE
ITER_LINE_MAXI
5
CONVERGENCE
ITER_INTE_MAXI
15

CONVERGENCE
RESI_INTE_RELA
10-06

For the model of Rousselier in nonlocal version, the functionalities tested are:

Order
Key word factor
Simple key word
Argument
AFFE_MODELE AFFE
MODELING
“D_PLAN_GRAD_VARI”
DEFI_MATERIAU ROUSSELIER

NON_LOCAL

STAT_NON_LINE COMP_INCR
RELATION
"ROUSSELIER"
COMP_INCR
DEFORMATION
"SIMO_MIEHE"
CONVERGENCE
ITER_INTE_MAXI
15

CONVERGENCE
RESI_INTE_RELA
10-06
LAGR_NON_LOCAL

4
Results of modeling A

4.1 Values

tested

The values are calculated at the point of Gauss.

At the moment of calculation T = 0.93s, one finds for the two models:
For the model of Rousselier in local version:

Identification Reference
Aster %
difference
At the point of Gauss n° 1

yy
1056.20 1056.27 0.007
zz
179.51 179.42 -0.048
p
0.6536 0.6538 0.04
F
0.2108 0.2110 0.097

For the model of Rousselier in nonlocal version:

Identification Reference
Aster %
difference
At the point of Gauss n° 1

yy
1056.20 1056.20 -1.37
10-04
zz
179.51 179.51
-5.17 10-05
p
0.6536 0.6536 6.93 10-04
F
0.2108 0.2107
-0.009

At the final moment T = 1.5s, one finds for the model with gradient:

Identification Reference
Aster %
difference
At the point of Gauss n° 1: yy
799.19100 799.19116 1.98
10-05
At the point of Gauss n° 2: yy
799.19100 799.19116 1.98
10-05
At the point of Gauss n° 3: yy
799.19100 799.19116 1.98
10-05
At the point of Gauss n° 4:
799.19100 799.19116 1.98
10-05
yy

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5
Summary of the results

As long as the solution of the local model remains homogeneous, values obtained with the two versions of
model of Rousselier are identical.
For the model with gradient, the solution remains homogeneous throughout the loading.

Titrate:
SSNP123 - Plate notched in elastoplasticity

Date:
06/05/04
Author (S):
***NR. TARDIEU**, J.M. PROIX Key*
:
V6.03.123-B Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.123 document

SSNP123 - Plate notched in elastoplasticity (test elements QUAD4 under integrated)

Summary:

This test 2D in plane deformations quasi-static makes it possible to illustrate the questions relating to the incompressibility
during the use of an elastoplastic law of behavior: when the rate of plasticity becomes important, of nonphysical oscillations of constraints can appear. It is shown that the use of elements QUAD4 under integrated can allow to mitigate this problem.

It is about a notched rectangular plate made up of an elastoplastic material with isotropic work hardening
who is subjected to a traction at his ends. One is interested in the elastoplastic solution in load.

Modeling A corresponds to the use of elements QUAD4 under integrated stabilized by the method "assumed strain".

Modeling B corresponds to the use of the incompressible elements QUAD8 which make it possible to obtain one
reference solution.

1
Problem of reference

1.1 Geometry

This calculation is based on the modeling of a notched sample requested by an imposed displacement.

Imposed displacement: DY = 0.1
F G
5
With
1
D
B
5

1.2
Material properties

Elastoplastic behaviour with isotropic work hardening:

E
E = 200 GPa
T
= 0.4999

y
y = 200 MPa
E
AND = 1000 MPa

1.3
Boundary conditions and loadings

On data base: DY=0.
On DF: DX=0.
On FG: DY=0.1

2
Reference solution

The reference solution is given by the modeling B carried out with elements
quasi-incompressible.
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---

3 Modeling
With

3.1

Characteristics of modeling

Modeling C_PLAN with elements QUAD4 under integrated stabilized by the method assumed strain.

3.2
Characteristics of the grid

A number of nodes: 527

A number of meshs: 582
SEG2: 102
QUAD4: 480

3.3 Functionalities
tested

Orders

AFFE_MODELE MODELING “D_PLAN_SI”
STAT_NON_LINE COMP_INCR
“VMIS_ISOT_LINE”

3.4
Sizes tested and results

One tests co-ordinate SIYY of the tensor of the constraints in various points of way IJ

I J

ABS. Curv.
Reference
Code_Aster

Difference (%)
0.0 234.174
234.930
0.323
1.54051 257.417 257.208 -0.081
3.26795 300.333 298.685 -0.549
3.83403 263.212 261.746 -0.557
4.37942 175.829 173.440 -1.359

One carries out also a test of nonregression on the values above.

---

4 Modeling
B

4.1
Characteristics of modeling

One takes again the preceding grid which one passes in quadratic elements with an aim of using modeling D_PLAN_INCO (elements adapted to the incompressible problems).

4.2
Characteristics of the grid

A number of nodes: 1533

A number of meshs: 582
SEG3: 102
QUAD8: 480

4.3 Functionalities tested

Orders

AFFE_MODELE MODELING "D_PLAN_INCO"

STAT_NON_LINE COMP_INCR "VMIS_ISOT_LINE"

4.4 Sizes tested and results

One tests co-ordinate SIYY of the tensor of the constraints in various points of way IJ in not regression.

ABS. Curv.	Reference	Code_Aster	Difference (%)
0.0	234.174	234.174	1.30E-04
1.54051	257.417	257.417	1.14E-04
3.26795	300.333	300.333	1.60E-04
3.83403	263.212	263.212	2.31E-05
4.37942	175.829	175.829	9.19E-05

5
Summary of the results

The result obtained using elements QUAD4 under integrated stabilized by the method assumed strain is very close to that provided by the incompressible quadratic elements, as it can to note on the graph below. This graph gathers the results for various elements:

QUAS4 elements QUAD4 under integrated
QUAD4 traditional elements QUAD4
QUAD8 traditional elements QUAD8
QUAS8 quasi incompressible elements QUAD8

One thus notes the good quality of the solution given by elements QUAD4 under integrated and disappearance of the oscillations of constraints given by traditional elements QUAD4.

350
300
250
200
150
[Mpa]
yy 100
50
0
-50
0
1

2
3
4
5
6
X-coordinate
QUAS4
QUAD4
QUAD8
QUAS8

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HT-66/04/005/A

Code_Aster ®
Version
8.1

Titrate:
SSNP126 - Test Validation of the law of behavior JOINT_BA
Date:
29/06/05
Author (S):
S. MICHEL-PONNELLE, NR. Key DOMINGUEZ
:
V6.03.126-B Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.126

SSNP126 - Validation of the law of behavior JOINT_BA (steel-concrete connection) in plane 2D

Summary:

Validation of the law of behavior JOINT_BA of the connection steel concrete by using the element of joint 2D
plan. This joined element is embedded in two nodes and bound to an element cubes with the characteristics of one
unspecified elastic material. By applying a monotonous loading in slip to the cubic element, one check the degradation of the interface, as well as the passage of the small deformations at the beginning of the experiment,
with the great observable slips starting from the peak of the resistance of the connection. In this case test, them
parameters used do not correspond to the data of a particular experimental case. However, validation is carried out by comparison with results obtained with code FEAP of Professor Taylor, from Berkeley, software in which this formulation was established.

1
Problem of reference

1.1 Geometry

cubic on L=1mm side
element of joint

U = (x=1.5, y=2.598076)

T
y

N

= 30°

X

Appear 1.1-a: Geometry and boundary conditions

1.2
Properties of material

Cubic: rubber band
E = 2.1x10+6 MPa, = 0

Element of joint:

.
law of behavior ELAS with the following parameters:
E = 2.1x10+6 MPa, = 0

.
law of behavior JOINT_BA with the following parameters:

- Initial Parameters:

coefficient of penetration:
Hpen = 0.64 mm
(key word: HPEN)

modulate rigidity:
G
(key word: GTT)
bound
= 6.65x10+3 MPa

- Parameters of tangential damage:

threshold of elastic strain:
0

(key word:

= 5x10-4
GAMD0)

coefficient of damage area 1:
AD
= 1.0
(key word: AD1)
1

coefficient of damage area 1:
Data base
= 0.5
(key word: BD1)
1

threshold of the great slips:
2

(key word:

= 9.6x10-1
GAMD2)

coefficient of damage area 2:
AD
= 6x10-5 MPa-1
(key word: AD2)
2

coefficient of damage area 2:
Data base
= 1.0
(key word: BD2)
2

- Parameters for the friction of the cracks and containment:

friction:

= 10.0 MPa
(key word: VIFROT)

kinematic work hardening:

= 4x10-1 MPa-1
(key word: F)

C

containment:

= 1.0
(key word: FC)

- Parameters of normal damage:

normal deformation criticizes (opening):
0

= 9x10-1
(key word: EPSTR0)
NR

coefficient of normal damage:
AD
(key word: ADN)
NR
= 1x10-9 MPa-1

coefficient of normal damage:
Data base
(key word: BDN)
NR
= 1.5

1.3
Boundary conditions and loadings

Null displacements imposed on the left face of the element of joint.
The mechanical loading is imposed in the form of displacements imposed on the right face of cubic in increments of 0.01*U to each step of time, 0 to 300.

1.4 Notice

.
The law of behavior of the element of joint is given locally (reference mark (N, T)), calculations system are carried out in the total reference mark (X, y). The basic change was taken in

count in calculations. The case test was developed with a rotation of 30° with an aim of to validate this basic change.

2
Reference solution

It is about a comparison code-code. The reference used is code FEAP version 7.4 of Professor R.L. Taylor, of the University of California, Berkeley. The results were obtained with same geometrical and material parameters, as well as the same discretization in time.

3 Bibliography

[1]
TAYLOR R.L. FEAP: In Finite Element Analysis Program version 7.4. To use, Theory, To program & Example Manuals - University Of California At Berkeley, the USA, December 2000.

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
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4 Modeling With

4.1 Characteristics of modeling

Modeling in plane deformations (key word D_PLAN) for the cube on side 1.
Modeling fissures planes (key word PLAN_JOINT) for the element of joint.

The cube is a QUAD4.
The element of joint is a degenerated QUAD4 (confused nodes).

4.2 Characteristics of the grid

A number of nodes: 6
Numbers and type of meshs: 2 QUAD4.

4.3 Functionalities tested

The law of behavior JOINT_BA local version in 2D.

Orders
Options

DEFI_MATERIAU JOINT_BA
HPEN

GTT

GAMD0

AD1

BD1

GAMD2

AD2

BD2

VIFROT

F

FC

EPSTR0

ADN

BDN

STAT_NON_LINE COMP_INCR
RELATION
JOINT_BA

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Code_Aster ®
Version
8.1

Titrate:
SSNP126 - Test Validation of the law of behavior JOINT_BA
Date:
29/06/05
Author (S):
***S. MICHEL-PONNELLE**, NR. Key DOMINGUEZ*
:

5
Results of modeling A

5.1
Sizes tested and results

One tests the components yy and xy of the element which correspond to the components normal and tangential of the local law of behavior in the interface, starting from the stress field SIEF_ELGA as well as the value of the damage T
D (which corresponds to the second variable of
field VARI_ELGA). The values are tested at the point of Gauss 1 of the element joint, with 4 steps of different times: at the beginning of loading, during the phase of growth of the damage,
after the peak of the maximum strength of the connection and to the end of the loading.

Component field SIEF_ELGA SIGN

Identification Reference
***Code_Aster** %*
difference
For an imposed displacement
U
-9.94080 E-02
-1.00976 E-01
1.577
TT = 0.2 mm
For an imposed displacement
U
-1.54560 E-01
-1.52328 E-01
-1.444
TT = 0.8 mm
For an imposed displacement
U
-1.44060 E-01
-1.47200 E-01
2.180
TT = 1.2 mm
For an imposed displacement
U
-1.06920 E-01

-1.06914 E-01
-0.006
TT = 3.0 mm

Component field SIEF_ELGA SITX

Identification Reference
***Code_Aster** %*
difference
For an imposed displacement
U
-7.58900 E+00
-7.65768 E+00
0.905
TT = 0.2 mm
For an imposed displacement
U
-1.17960 E+01
-1.15521 E+01
-2.068
TT = 0.8 mm
For an imposed displacement
U
-1.09950 E+01
-1.11632 E+01
1.530
TT = 1.2 mm
For an imposed displacement
U
-8.15940 E+00
-8.10802 E+00
-0.630
TT = 3.0 mm

Component field VARI_ELGA V2 (variable of tangential damage)

Identification Reference
***Code_Aster** %*
difference
For an imposed displacement
U
9.97203 E-01

9.97203 E-01
-2.19 E-05
TT = 0.2 mm
For an imposed displacement
U
9.98948 E-01
9.98915 E-01
-0.003
TT = 0.8 mm
For an imposed displacement
U
9.99369 E-01
9.99309 E-01
-0.006
TT = 1.2 mm
For an imposed displacement
U
9.99854 E-01
9.99821 E-01
-0.003
TT = 3.0 mm

6
Summary of the results

The comparison of the results resulting from Code_Aster and those obtained numerically by code FEAP of Professor Taylor of Berkeley are satisfactory (the maximum change is 2.18% on constraints).

The objective of modeling is to test the stability of the law of behavior by using them already existing elements joined in Code_Aster: one can consider that the establishment of the law is correct. However, since the maximum resistance of the connection between the steel reinforcements and the concrete is reached beyond the framework of the small deformations, it is necessary to pay attention to the choice of increments of time in particular when JOINT_BA is used in combination with other laws of behavior nonlinear (law MAZARS, for example).

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.128

SSNP128 Validation of the element with discontinuity on a plane plate

Summary:

The goal of this test is of exhiber an analytical solution in order to validate the quality of the element with discontinuity (see documentation [R7.02.12] for details on this element). The objective of this test is to check that this model conduit with a good prediction of the value of the jump of displacement along a crack. With this intention, one seek an analytical solution presenting a nonconstant jump along a discontinuity which one compares with the solution obtained numerically. In addition when one seeks to validate a numerical method it is preferable to ensure itself of the unicity of the required solution. We will see that it is the case for the solution analytical presented if a condition relating to the maximum size of the field studied according to parameters of the model is checked.

2/8

1
Problem of reference

1.1 Geometry

In the Cartesian frame of reference (X, y), let us consider a rectangular plane plate
rubber band noted =] 0, [
L ×] 0, H [(see [Figure 1.1-a]). Let us note = 0 × 0, H the left face of
0
{ }]
[
field and the 0 part complementary to the edge.

H
0

Y

X

L

Appear 1.1-a: Diagram of the plate

Dimensions of the field:

L = 1 mm, H=2 mm

1.2
Material properties

The material is elastic with a critical stress and a tenacity arbitrarily chosen:

-1
E = 10 MPa, = 0, = 1.1 MPa, G = 0.9 N.mm
C
C

1.3
Boundary conditions and loadings

The boundary conditions are determined by the analytical solution presented in the part following so that they lead to a crack having a nonconstant jump along 0. The loading corresponds to a displacement imposed on the edges of the plate: (see [Figure 1.3-a]).

U *=* ***U*** *(X, y) on 0*

U *=* ***U0*** *(y) - (y) on 0*

U *=* ***U***

0

U = ***U*** **-**

U = ***U***

0

Y

X

U = ***U***
Appear 1.3-a: Diagram of the loading

The values ***U****,* ***U0*** *and are defined during the construction of the reference solution in the part following.*

---

2 ***Reference solution***

In this part one exhibe an analytical solution with a nonconstant jump along 0, then one give a condition of unicity of the solution.

2.1 Solution analytical

The function of Airy (X, y) controlled by the equation = 0 on, if efforts outsides are null, leads to constraints satisfying the compatibility and equilibrium equations in elasticity (see Fung [bib1]). Components of the constraint, and derive from

xx

yy

xy

(X, y) in the following way:

2

2

2

=

, =

and = -

éq 2.1-1

xx

2

yy

2

xy

y

X

X

y

Let us choose a function Bi-harmonic (X, y) defined by:

3

2
(
y
y
X, y) =
+ (X +)
+ xy
6
2

with, and arbitrary real constants. One deduces some according to [éq 2.1-1] the field from constraint:

= X + y +
xx

= 0

éq
2.1-2
yy

=
- y -
xy

By integrating the elastic law, if one notes E the modulus Young and the Poisson's ratio (that one takes no one), one deduces the field from it from displacement in checking balance:

1
x2

- y2 + X (y +)
U (X, y)
E

2

U =^

éq
2.1-3
v (X, y) =

1 x2

-
+
2 X

E 2

---

*Respectively let us note **U0** and **U the** displacements on 0 and 0 given by [éq 2.1-3]. These the last correspond to the boundary conditions leading to the stress fields [éq 2.1-2]. With to start from these data, it is easy to build a field of displacement with a discontinuity on*

the edge. Indeed, knowing the normal constraint ***.n*** *on which one notes* ***F*** *(y), one obtains it*
0
0
jump of displacement (y) by reversing the exponential law of behavior of Barenblatt type:
CZM_EXP (see documentation on the elements with internal discontinuity and their behavior:
[R7.02.12]):

G ***F*** *y*
F *y*
C
( )
(y)
( )
= **-**

F *y*

C
() ln
C

for all y in [0, H]. Thus, the new displacement imposed on generating such a jump is equal
0
with ***U*** **-***. One thus built an analytical solution of the plane plate checking the equations*
0
of balance and compatibility with a discontinuity in 0 along which the jump of displacement
is not constant. Let us point out the boundary conditions of the problem:

U *=* ***U*** *(X, y) on 0*

éq
2.1-4
U *=* ***U0*** *(y)* **-** *(y) on 0*

2.2
Unicity of the solution

After having built an analytical solution it is important to make sure that the latter is single
to be able to compare it with the numerical solution. One shows, to see [bib2], that unicity is guaranteed

as soon as the following condition, on the geometry of the field like on the parameters material, is checked:
2 G
μ C
L <
.

éq 2.2-1
2
C
Dimensions of the plate and the parameters material previously given check this condition.

---

3 Modeling With

3.1 Characteristics of modeling

The idea is to carry out a digital simulation corresponding to the problem presented in the part the preceding one and to compare the results obtained. The elements with discontinuity allow to represent the crack along 0. The latter have as a modeling PLAN_ELDI and one behavior CZM_EXP. The other elements of the grid are elastic QUAD4 in modeling D_PLAN.

The values of the parameters of the function of Airy for the construction of the analytical solution are taken arbitrarily:

-1
-1
= 0 MPa.mm, = 1 4 MPa.mm, = 1 2 MPa and = 0 MPa

3.2 Characteristics of the grid

One carries out a grid of the plate structured in quadrangles with 20 meshs in the width and 50 in the height. One has the elements with discontinuity along the with dimensions 0 with the normal uur directed according to - X. This is carried out using key word CREA_FISS of CREA_MAILLAGE (see documentation [U4.23.02]).

3.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
CZM_EXP
AFFE_MODELE MODELING PLAN_ELDI
DEFI_MATERIAU RUPT_FRAG
SIGM_C

SAUT_C

CREA_MAILLAGE CREA_FISS

3.4
Sizes tested and results

Size tested	***Theory***	***Code_Aster***	***Difference (%)***
Variable threshold: VI1 On element MJ15	*4.9315E-01*	*4.9363194272125E-01*	*0.098*
Variable threshold: VI1 On element MJ45	*1.075*	*1.0757405707848*	*0.069*
Normal constraint: VI6 On element MJ30	*4.489E-01*	*4.4850081901631E-01*	*-0.089*

4
Summary of the results

These results enable us to conclude that the element with internal discontinuity leads to good *approximation of the analytical solution. Moreover, one study on the dependence with the grid was realized in [bib2]. It is noted that the error made on the jump of displacement decrease when one refines grid. That makes it possible to conclude that, in spite of a constant jump by element, this model allows to correctly reproduce a crack with a nonconstant jump by refining the grid.*

5 Bibliography

[1]
FUNG Y.C. : Foundation of Solid Mechanics, Prentice-Hall, (1979).
[2]
LAVERNE J.: Energy formulation of the rupture by models of cohesive forces: numerical considerations theoretical and establishments, Thesis of Doctorate of the University Paris November 13, 2004.
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HT-66/05/005/A

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Titrate:
SSNP131 - Identification of the energy criterion Gp in 2D

Date:
15/12/05
Author (S):
***Y. WADIER**, Key Mr. BONNAMY*
:
V6.03.131-A Page:
1/6

Organization (S): EDF-R & D /AMA, AUSY France

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.131

SSNP131 Identification of the energy criterion Gp in 2D

Summary

This test of nonlinear quasi-static mechanics makes it possible to present the calculation of the Gp parameter resulting from
the energy approach of the elastoplastic rupture and the identification of the values criticize

correspondent with
values of experimental tenacity given. He requires to represent the crack by a notch and to calculate elastic energy on the zone corresponding to the way of propagation of the notch.

Modeling is carried out with quadratic elements 2D, in plane deformation.

1 Problem of reference

1.1 Geometry

29mm

U

y imposed
has

.
H = 60mm

W=50mm
Center

Ux = 0
symmetry

L = 62.5mm

A geometry of test-tube CT25 is considered where the length of the ligament: = 27.5 mm have (a/W = 0.55). Test-tube CT25 is modelled in 2D plane deformations. For reason of symmetry, a half of this one is represented.

1.2
Material properties

Young modulus:
Temperature (°C)
E (Mpa)
23 220200
100 214100
150 206500
300 205000

Poisson's ratio: = 0.3

The traction diagram used is interpolated for the temperature of calculation starting from the values presented in the following table:

Material Dated: True Stress - True Strain
T = 23°C
T = 100°C
Strain
Stress [MPa]
Strain
Stress [MPa]
0,00000E+00 0,00000E+00 0,00000E+00
0,00000E+00
4,34654E-03 8,55922E+02 3,43968E-03
7,40663E+02
6,01497E-03 9,10460E+02 4,62837E-03

8,42149E+02
7,86211E-03 9,31797E+02 6,07988E-03
8,76312E+02
1,07579E-02 9,49055E+02 7,65463E-03
8,95206E+02
1,42214E-02 9,61578E+02 1,04175E-02
9,11072E+02
1,77918E-02 9,71929E+02 1,41780E-02
9,25022E+02
2,21851E-02 9,84491E+02 1,75432E-02
9,35214E+02
2,82764E-02 1,00147E+03 2,19425E-02
9,45695E+02
3,58111E-02 1,01932E+03 2,74167E-02
9,60732E+02
4,37307E-02 1,03519E+03 3,38670E-02
9,75804E+02
5,14523E-02 1,04865E+03 4,02058E-02
9,88245E+02
5,89828E-02 1,06076E+03 4,66164E-02
1,00014E+03
6,68527E-02 1,07021E+03 5,29036E-02
1,01000E+03
5,82359E-02
1,01757E+03

1.3
Boundary conditions and loadings

The loading is of displacement type imposed in a point located at the center of the pin which is modelled by four indeformable angular sectors. The temperature is imposed constant on the whole of the test-tube (T = 35°C). Half of the test-tube being modelled, a condition of symmetry is applied to the ligament located behind the notch.

2
Reference solution

2.1
Method of calculation used for the reference solution

The notch is made of a half-circle of ray R located in bottom of crack and of a fine zone representing the beginning of the ligament of the defect which will be represented by a zone of grid of the type
"chips". One determines at every moment the evolution of the quantity Gp (L
) defined by:

Gp (L
) = [
2 Welas (L
)]/L

where Welas (L
) is the elastic energy calculated on the formed zone of "chips" located behind
melts of notch and length L
. One must then calculate the maximum of this quantity compared to
L
, that one calls "Gp".

Gp =
{
Max Gp (L
)}
L

The moment criticizes where the propagation of the defect will start is then that where Gp reached the breaking value

"Gp crit".

2.2 References bibliographical

[1]
WADIER Y.
: «
Brief presentation of the energy approach of the rupture
elastoplastic applied to the rupture by cleavage", Note EDF R & D HT-64/03/001/A, January
2003.
[2]
WADIER Y., LORENTZ E.: "Breaking process in the presence of plasticity:
modeling of the crack by a notch". C.R.A.S.T. 332, IIb series, 2004.
[3]
LORENTZ E., WADIER Y.: "Energy approach of the elastoplastic rupture applied
with the modeling of the propagation of a notch". REEF, Flight 13, n°5-6-7, pp. 583-592,
2004.

---

3 Modeling With

3.1 Characteristics of modeling

The bottom of crack is modelled by a notch of ray 100 microns. A zone of 2 mm length is arranged behind this one in layers of 20 microns thickness elements (called also “chips”).

3.2 Characteristics of the grid

A number of nodes: 8260

A number of meshs and types: 1864 SORTED 6, 1420 QUAD 8

3.3 Functionalities tested

Orders

STAT_NON_LINE

CALC_THETA THETA_2D

CALC_G_THETA_T OPTION CALC_G

POST_ELEM ENER_ELAS

CREA_TABLE

4 Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
GP crit. probability rupture 5%	-	0.673449	-
GP crit. probability rupture 50%	-	0.800954	-
GP crit. probability rupture 95%	-	0.916242	-

4.2 Notice

The results observed to ensure itself of the not-regression of the code are the breaking values of energy parameter corresponding to the experimental probabilities of rupture to 5, 50 and 95% associated the values of following tenacities: Kj (5%) = 27,2 MPam; Kj (50%) = 34 MPam; Kj (95%) = 40 MPam

With these values correspond of the critical loadings identified by calculating the quantity G by
2
-
Théta method which is connected to tenacity via the formula of Irwin:
1
2

J =
K. Crowns
E
chosen for the Théta field are: [0.25 mm; 0.5 mm], [0.5 mm; 1.0 mm], [1.0 mm; 2.0 mm], [2.0 mm; 5.0 mm], [5.0 mm; 10.0 mm]. With these critical loadings the values correspond critical of the Gp parameter. One associates to them the breaking values of KGp deduced from Gp from
E
the formula of Irwin: K
=
Gp
Gp
.
2
1-

A law of probability of the type of the model of Beremin is employed to define graphs of probability according to Kj (see graphic below) it is written:

m
K
R
P (KGp)

Gp

= 1-

exp -

K

Gp

0

where m = 22.673, and K
0
Gp identified such as:

R
P (K
) 05
.
0
min =
Gp
,
R
P (KGpmoy) = 0.5,
R
P (K
) 95
.
0
max =
Gp
.

1
E 0,8
ur
Pt
U 0,6

é
R
ilit
B 0,4
R
oba 0,2
P
0
0
20
40
60
80
100
Kj (MPa.mm1/2)

Various results are posted in the file message:

· posting for each moment of the transient considered and each crown of the field theta well informed of the values G () and Kj deduced by the formula from Irwin.
· posting for each moment of the transient considered of the Gp parameter calculated in function distance to the bottom of notch.
· posting for each moment of the transient considered of noted the maximum Gp parameter and of the distance to the bottom of associated notch (L max).
· posting of the values of identifications for each tenacity and each field theta (urgent interpolated on the transient, critical Gp, KGp deduced by Irwin),
· posting for each moment of the transient given of the L max, Gp max, KGpmax (deduced by Irwin), Tfe (temperature in bottom of notch) and of the probability of rupture according to the evoked law previously.

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:
I. VAUTIER, L. LAMMERANT, H. DRION
Key:
V6.03.303-A Page:
1/12
Organization (S): EDF/IMA/MMN, SAMTECH SA
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.303

SSNP303 - Element in plane constraint and traction -
Perfect plasticity

Summary:

This test of quasi-static mechanics nonlinear 2D consists in charging three superimposed elements of plate
(type of element mecpqu4). The 4 nodes are common to the 3 elements. The elements have properties different (perfect plasticity) to obtain a suitable traction diagram. This test is drawn from the guide NAFEMS.
The goal is to compare the various methods of the Newton-Raphson type making it possible to solve the system
nonlinear equations (NEWTON: ("ELASTIC" MATRIX) and NEWTON: ("TANGENT" MATRIX) with REAC_INCR and REAC_ITER). The selected criterion of convergence corresponds to 0.01% of the residual force
(RESI_GLOB_RELA).
Modeling is carried out with plane elements of type MECPQU4.

Author (S)
:
I. VAUTIER, L. LAMMERANT, H. DRION

1
Problem of reference

1.1 Geometry
p/2
D
C
B
has
= B has = 1.0
With
B
p/2
1.2
Material properties
Material 1
Material 2
Material 3

E = 100000 MPa E = 60000 MPa
E = 40000 MPa
AND
= 0.25
= 0.25
= 0.25

y
y = 3 MPa
y = 6 MPa
y = 8 MPa
AND = 0.0
AND = 0.0
AND = 0.0

1.3
Boundary conditions and loadings
Not a:
ux =0.
uy= 0.
Not b:
uy =0.
Not D:
ux =0.
Loading by a P/2 force on the point B and C. the force P is increased in 6 stages in the manner

following:
Force P
3.00
6.00
9.00
12.95
15.00
16.93

2
Reference solution
2.1
Method of calculation used for the reference solution
The results considered as reference were obtained by the SAMCEF software by using 60 increments for each stage of loading. The characteristics of the various methods of resolution are the following ones:
With
Use of the elastic matrix.
B
Use of the tangent matrix; this one is revalued only with the first iteration of each increment (REAC_INCR = 1 and REAC_ITER = 0). It is about the method of Newton modified.
C
Use of the tangent matrix; this one is revalued with each iteration of each increment (REAC_INCR = 1 and REAC_ITER = 1). It is about the method of Newton traditional.
2.2
Results of reference
Results obtained with 60 increments for each stage of loading
Element 1

Element 2
Element 3
Force

xx
yy
xx
yy
xx
yy
3.00
1.500000D+00
6.938894D18
9.000000D01
1.040834D17
6.000000D01
6.938894D18
6.00
3.000000D+00
4.861944D13
1.800000D+00
2.081668D17
1.200000D+00
3.469447D18
9.00
3.147155D+00
3.199571D01
3.511707D+00
1.900098D01
2.341138D+00
1.279828D01
12.95
3.252919D+00
5.950074D01
5.814267D+00
3.523377D01
3.878832D+00
2.380030D01
15.00

3.213822D+00
4.873069D01
6.017834D+00
3.174572D02
5.768340D+00 5.231355D01
16.93
3.2092970D+00
4.753345D01
6.149462D+00
3.048490D01
7.571241D+00
7.863557D01

2.3
Uncertainty on the solution

Uncertainty lower than 1%.

2.4 References
bibliographical

[1]
Fundamental tests for two and three dimensional, small strain, elastoplastic finite element analysis, 1987, NAFEMS

3 Modeling With

3.1 Characteristics of modeling A

Use of elements QUAD4

N04
N03
N01
N02

Modeling in plane constraints: C_PLAN

The loading and the boundary conditions are modelled by:

· DDL_IMPO: (Node NO1 DX = 0, DY = 0)
(Node NO2 DY = 0)
(Node NO4 DX = 0)
· of the forces imposed on nodes NO2 and NO3.

3.2 Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 3 MECPQU4

3.3 Functionalities tested

Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
DEFORMATION

"SMALL"
[U4.32.01]
NEWTON
STAMP
"ELASTIC"
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

4
Results of modeling A
4.1 Values
tested

Identification	Moment	Reference	Aster	% difference
SIXX (mesh 1)	1	1,500000E+00	1,500000E+00	0
SIYY (mesh 1)	1	6,938894E18	1,291047E14	0
SIXX (mesh 2)	1	9,000000E01		

9,000000E01
0
SIYY (mesh 2)
1
1,040834E17
1,509903E14
0
SIXX (mesh 3)
1
6,000000E01
6,000000E01
0
SIYY (mesh 3)
1
6,938894E18
2,107830E14
0
SIXX (mesh 1)
2
3,000000E+00
3,000000E+00
0
SIYY (mesh 1)
2
4,861944E13
1,359551E13
0
SIXX (mesh 2)
2
1,800000E+00
1,800000E+00
0
SIYY (mesh 2)
2
2,081668E17
1,093097E13
0
SIXX (mesh 3)
2
1,200000E+00
1,200000E+00
0
SIYY (mesh 3)

2
3,469447E18
1,007126E13
0
SIXX (mesh 1)
3
3,147155E+00
3,145788E+00
-0,043
SIYY (mesh 1)
3
3,199571E01
3,167040E01
-1,017
SIXX (mesh 2)
3
3,511707E+00
3,512527E+00
0,023
SIYY (mesh 2)
3
1,900098E01
1,900224E01
0,007
SIXX (mesh 3)
3
2,341138E+00
2,341685E+00
0,023
SIYY (mesh 3)
3
1,279828E01
1,266816E01
-1,017
SIXX (mesh 1)
4
3,252919E+00
3,250728E+00
-0,067
SIYY (mesh 1)
4
5,950074E01
5,887464E01

-1,052
SIXX (mesh 2)
4
5,814267E+00
5,816159E+00
0,033
SIYY (mesh 2)
4
3,523377E01
3,521695E01
-0,048
SIXX (mesh 3)
4
3,878832E+00
3,882391E+00
0,092
SIYY (mesh 3)
4
2,380030E01
2,364650E01
-0,646
SIXX (mesh 1)
5
3,213822E+00
3,214367E+00
0,017
SIYY (mesh 1)
5
4,873069E01
4,887527E01
0,297
SIXX (mesh 2)
5
6,017834E+00
6,015985E+00
-0,031
SIYY (mesh 2)
5
3,174572E02
3,209818E02
1,11
SIXX (mesh 3)
5

5,768340E+00
5,769681E+00
0,023
SIYY (mesh 3)
5
5,231355E01
5,207413E01
-0,458
SIXX (mesh 1)
6
3,209297E+00
3,210194E+00
0,028
SIYY (mesh 1)
6
4,753345E01
4,777143E01
0,501
SIXX (mesh 2)
6
6,149462E+00
6,146791E+00
-0,043
SIYY (mesh 2)
6
3,048490E01
3,052330E01
0,126
SIXX (mesh 3)
6
7,571241E+00
7,572486E+00
0,016
SIYY (mesh 3)
6
7,863557E01
7,826545E01
-0,471

4.2 Remarks

To obtain a correct precision, it is necessary to force a significant number of increments for each stage of loading (60 increments).

The iteration count is equal to 411.

4.3 Parameters
of execution

Version: 3.09
Machine:
System:
Obstruction memory: 8
megawords
Time CPU To use:
507.8 seconds

---

5 Modeling
B

5.1

Characteristics of modeling B
Use of elements QUAD4
N04
N03
N01
N02
5.2
Characteristics of the grid
A number of nodes: 4
A number of meshs and types: 3 MECPQU4
Modeling in plane constraints: C_PLAN
The loading and the boundary conditions are modelled by:
· DDL_IMPO: (Node NO1 DX = 0, DY = 0)
(Node NO2 DY = 0)
(Node NO4 DX = 0)
· of the forces imposed on nodes NO2 and NO3.
5.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
DEFORMATION
"SMALL"
[U4.32.01]
NEWTON
STAMP
"TANGENT"
REAC_INCR
1
REAC_ITER
0

---

6 Results of modeling B

6.1 Values tested

Identification	Moment	Reference	Aster	% difference
SIXX (mesh 1)	1	1,500000E+00	1,500000E+00	0.000
SIYY (mesh 1)	1	6,938894E18	1,351398E14	0.000
SIXX (mesh 2)	1	9,000000E01	9,000000E01	0.000
SIYY (mesh 2)	1	1,040834E17	2,142673E14	0.000
SIXX (mesh 3)	1	6,000000E01	6,000000E01	

0.000
SIYY (mesh 3)
1
6,938894E18
2,924612E14
0.000
SIXX (mesh 1)
2
3,000000E+00
3,000000E+00
0.000
SIYY (mesh 1)
2
4,861944E13
9,617834E14
0.000
SIXX (mesh 2)
2
1,800000E+00
1,800000E+00
0.000
SIYY (mesh 2)
2
2,081668E17
8,301280E14
0.000
SIXX (mesh 3)
2
1,200000E+00
1,200000E+00
0.000
SIYY (mesh 3)
2
3,469447E18
9,360717E14
0.000
SIXX (mesh 1)
3
3,147155E+00
3,145788E+00
0.043
SIYY (mesh 1)
3

3,199571E01
3,167038E01
1.017
SIXX (mesh 2)
3
3,511707E+00
3,512527E+00
0.023
SIYY (mesh 2)
3
1,900098E01
1,900225E01
0.007
SIXX (mesh 3)
3
2,341138E+00
2,341685E+00
0.023
SIYY (mesh 3)
3
1,279828E01
1,266817E01
1.017
SIXX (mesh 1)
4
3,252919E+00
3,250686E+00
0.069
SIYY (mesh 1)
4
5,950074E01
5,886265E01
1.072
SIXX (mesh 2)
4
5,814267E+00
5,816233E+00
0.034
SIYY (mesh 2)
4
3,523377E01
3,520332E01
0.086

SIXX (mesh 3)
4
3,878832E+00
3,883081E+00
0.110
SIYY (mesh 3)
4
2,380030E01
2,365921E01
0.593
SIXX (mesh 1)
5
3,213822E+00
3,214343E+00
0.016
SIYY (mesh 1)
5
4,873069E01
4,886891E01
0.284
SIXX (mesh 2)
5
6,017834E+00
6,015971E+00
0.031
SIYY (mesh 2)
5
3,174572E02
3,207056E02
1.023
SIXX (mesh 3)
5
5,768340E+00
5,769686E+00
0.023
SIYY (mesh 3)
5
5,231355E01
5,207599E01
0.454
SIXX (mesh 1)
6
3,209297E+00

3,210140E+00
0.026
SIYY (mesh 1)
6
4,753345E01
4,775720E01
0.471
SIXX (mesh 2)
6
6,149462E+00
6,146788E+00
0.043
SIYY (mesh 2)
6
3,048490E01
3,052260E01
0.124
SIXX (mesh 3)
6
7,571241E+00
7,573072E+00
0.024
SIYY (mesh 3)
6
7,863557E01
7,827984E01
0.452

6.2 Remarks
Idem modeling A concerning the number of increments on the precision of the results.
The iteration count is equal to 361.
6.3 Parameters
of execution
Version: 3.09
Machine:
System:
Obstruction memory:
8 megawords
Time CPU To use:
504.9 seconds

---

7 Modeling
C
7.1
Characteristics of modeling C
Use of elements QUAD4
N04
N03
N01
N02
7.2
Characteristics of the grid
A number of nodes: 4
A number of meshs and types: 3 MECPQU4
Modeling in plane constraints: C_PLAN
The loading and the boundary conditions are modelled by:

· DDL_IMPO: (Node NO1 DX = 0, DY = 0)
(Node NO2 DY = 0)
(Node NO4 DX = 0)
· of the forces imposed on nodes NO2 and NO3.

7.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
ECRO_LINE
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
DEFORMATION
"SMALL"
[U4.32.01]
NEWTON
STAMP
"TANGENT"
REAC_INCR
1
REAC_ITER
1

8
Results of modeling C

8.1 Values tested

Identification	Moment	Reference	Aster	% difference
SIXX (mesh 1)	1	1,500000E+00	1,500000E+00	0
SIYY (mesh 1)	1	6,938894E18	1,351398E14	0
SIXX (mesh 2)	1	9,000000E01	9,000000E01	0
SIYY (mesh 2)	1	1,040834E17	2,142673E14	0
SIXX (mesh 3)	1	6,000000E01	6,000000E01	0
SIYY (mesh 3)	1	6,938894E18	2,924612E14	0
SIXX (mesh 1)	2	3,000000E+00	3,000000E+00	0
SIYY (mesh 1)				

2
4,861944E13
9,617834E14
0
SIXX (mesh 2)
2
1,800000E+00
1,800000E+00
0
SIYY (mesh 2)
2
2,081668E17
8,301280E14
0
SIXX (mesh 3)
2
1,200000E+00
1,200000E+00
0
SIYY (mesh 3)
2
3,469447E18
9,360717E14
0
SIXX (mesh 1)
3
3,147155E+00
3,145788E+00
-0,043
SIYY (mesh 1)
3
3,199571E01
3,167040E01
-1,017
SIXX (mesh 2)
3
3,511707E+00
3,512527E+00
0,023
SIYY (mesh 2)
3
1,900098E01
1,900224E01

0,007
SIXX (mesh 3)
3
2,341138E+00
2,341685E+00
0,023
SIYY (mesh 3)
3
1,279828E01
1,266816E01
-1,017
SIXX (mesh 1)
4
3,252919E+00
3,250686E+00
-0,069
SIYY (mesh 1)
4
5,950074E01
5,886268E01
-1,072
SIXX (mesh 2)
4
5,814267E+00
5,816233E+00
0,034
SIYY (mesh 2)
4
3,523377E01
3,520328E01
-0,087
SIXX (mesh 3)
4
3,878832E+00
3,883081E+00
0,11
SIYY (mesh 3)
4
2,380030E01
2,365919E01
-0,593
SIXX (mesh 1)
5

3,213822E+00
3,214343E+00
0,016
SIYY (mesh 1)
5
4,873069E01
4,886892E01
0,284
SIXX (mesh 2)
5
6,017834E+00
6,015971E+00
-0,031
SIYY (mesh 2)
5
3,174572E02
3,207066E02
1,024
SIXX (mesh 3)
5
5,768340E+00
5,769686E+00
0,023
SIYY (mesh 3)
5
5,231355E01
5,207598E01
-0,454
SIXX (mesh 1)
6
3,209297E+00
3,210140E+00
0,026
SIYY (mesh 1)
6
4,753345E01
4,775721E01
0,471
SIXX (mesh 2)
6
6,149462E+00
6,146788E+00
-0,043

SIYY (mesh 2)
6
3,048490E01
3,052262E01
0,124
SIXX (mesh 3)
6
7,571241E+00
7,573072E+00
0,024
SIYY (mesh 3)
6
7,863557E01
7,827982E01
-0,452

8.2 Remarks

Idem modeling A concerning the number of increments on the precision of the results.
The iteration count is equal to 360.

8.3 Parameters
of execution

Version: 3.09
Machine:
System:
Obstruction memory: 8
megawords
Time CPU To use:
471.2 seconds

9
Summary of the results

A significant number of increments is necessary to obtain a correct precision
: for
information, ten increments per stage of loading are not sufficient.
The following table recapitulates, for each modeling, the performances in iteration count and of time CPU.

Identification	Modeling A	Modeling B	Modeling C
Iteration count	411	361	360
Time CPU (seconds)	507.8	504.9	471.2

Organization (S): EDF/IMA/MMN, SAMTECH SA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.305

SSNP305 - Element of bar in compression - Appearance of a negative pivot

Summary:
This test of quasi-static mechanics linear 2D consists in charging an element of bar in compression. Of

one
side, the element is fixed according to the degrees of translation on a node. Other side, the element is fixed according to
the second degree of translation on a node in order to model the slip along a line. With some
moment the stiffness becomes negative (= negative slope). This test is drawn from guide NAFEMS (analytical solution).
The structure will be charged by using a piloting by displacement.
The plate is modelled by 12 plane elements (MECPQU4). The material has a linear behavior and one takes into account nonthe geometrical linearities. One uses the key word factor “COMP_ELAS” option “GREEN”.

---

1 Problem of reference

1.1 Geometry

1.2 Material properties

Isotropic elastic material
E = 200000 MPa
= 0.0

1.3 Boundary conditions and loadings

Not a:
ux =0.
uy= 0.
Not b:
ux =0.
Loading by a force P on the point B. the force will be increased by using a piloting by displacement of the point B.
L = 2500
L = 2500
To = 250

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical solution.

2.2
Results of reference

Vertical displacement = (*Q* -) *L*
1
Deformation "GREEN"

Q2
2

1 -

P = - *EAQ1*

3
2

(+) 2
2 1

2.3 References bibliographical

[1]
Benchmark tests for solution procedures for geometric non-linearity, NAFEMS, 1987

---

3 Modeling
With
3.1
Characteristics of modeling A

P
Ltot
N07
N06
E = 200000
E = 2nd 7

Modeling in plane constraints: C_PLAN
The loading and the boundary conditions are modelled by:
DDL_IMPO:
(NODE: N7 DX: 0.)
(NODE: N1 DX: 0.
DY: 0.)
In order to respect the best possible behavior of bar, one prolongs the length of the bar and one imposes on this surplus of matter a Young modulus of 2E7 MPa.
The other meshs are affected face value of 200000 MPa.

3.2
Characteristics of the grid

A number of nodes: 21
A number of meshs: 12 MECPQU4

3.3 Functionalities
tested

Orders
Keys
DEFI_MATERIAU
ELAS
[U4.23.01]
STAT_NON_LINE
COMP_ELAS
RELATION
`ELAS `
[U4.32.01]

DEFORMATION
`GREEN `
AFFE_CHAR_MECA_F
DDL_IMPO
[U4.25.01]
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

4
Results of modeling A
4.1 Values
tested

Identification	**Reference**	**Aster**	**% difference**
FY (N7) with DX = -250	1511441	1510290	0.076
FY (N7) with DX = -500	2545584	2543930	0.065
FY (N7) with DX = -750	3155464	3153710	0.055
FY (N7) with DX = -1050	3401961		

3400410
0.045
FY (N7) with DX = -1500
2969848
2968840
0.034
FY (N7) with DX = -2000
1697056
1696620
0.0256
FY (N7) with DX = -2500
0
1.E-5
0

4.2 Remarks

The application of the loading is carried out with 100 increments.

4.3 Parameters
of execution

Version: 3.09
Machine:
System:
Obstruction memory:
8 megawords
Time CPU To use:
170.29 seconds

5
Summary of the results

The results provided by Aster are in perfect agreement with the reference solution.
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HI-75/98/040 - Ind A

Author (S):
S. GRANET, *I. CORMEAU, E. LECLERE*

Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.311 document

SSNP311 - Biblio_131. Cracking in mode II of one elastoplastic test-tube

Summary:

This test results from the validation independent of version 3 in breaking process.

It is about a two-dimensional test in statics which aims at the validation of the calculation of G, and its not dependence with respect to the crown, in elastoplastic mode in an incremental calculation, on a geometry noncommonplace. The law of behavior used is an elastoplastic law of Von Mises with isotropic work hardening.

This case test includes/understands only one modeling 2D planes in which one studies the influence of a load incremental.

The results obtained with Code_Aster are compared with the calculations carried out using code ADINA.

---

1 Problem of reference

1.1 Geometry

The test-tube in the shape of twin wheel, represented in (A), is fixed at the system of loading (b) by six pins equivalent to articulations.

Dimensions of the parts are expressed in Misters.

Test-tube:

thickness B variable
6,36; 6,39; 6,44 mm
overall width
98 mm
outdistance between the axes of the pins
74 mm
width of the central part
6 mm
overall height
84 mm
outdistance between centers of the pins
31 mm
height in the center W
30 mm
length of the crack has
15, 18 or 21 mm
ligament B = W - has
15, 12 or 9 mm
bore of pins
8 mm

Carry-test-tube:

thickness 25
mm
external diameter
190 mm
outdistance between the center of the part and the 40,3 mm
centers of the circular cavities
ray of the cavities
20 mm
diameter of the 2 holes where the 10 mm are applied
loads

Titrate:

1.2 Properties of materials

Test-tube:

The material is elastoplastic, of Von Mises type, with isotropic work hardening, defined by a curve of uniaxial traction.

Young modulus: E = 74,2 GPa
Poisson's ratio: = 0,32

E tangent (uniaxial) (GPa)	*T (uniaxial) (MPa)*	*(%)*
72,74	*334,6*	*0,46*
50,69	*410,7*	*0,61*
15,00	*431,6*	*0,75*
4,75	*443,5*	*1,00*
1,82	*480,0*	*3,00*
0,80	*500,1*	*5,50*
0,0017	*505,2*	*300,0*

Carry-test-tube:

The material is elastic linear isotropic.

Young modulus: E = 206 GPa
Poisson's ratio: = 0,3

1.3 Boundary conditions and loading

The carry-test-tube has a fixed point UX = UY = 0 with the lower clamp hole and is subjected to one *vertical specific loading applied to the higher clamp hole UX = 0, FY = P variable.*

For a length of crack a/W = 0,5:

P varies:

0 NR with 11772 NR in 12 steps of 981 NR
11772 NR with 19620 NR in 16 steps of 490,5 NR
19620 NR with 23544 NR in 20 steps of 196,2 NR
23544 NR with 25114 NR in 16 steps of 98,1 NR

---

2 Reference solution

2.1 Method of calculation used for the reference solution

Calculation in finite elements with ADINA. Update of the matrix of tangent stiffness by the method BFGS (BROYDEN, FLETCHER, GOLDFARB and SHAMNO). Calculation of J per integral of Rice in
which the density of deformation energy is evaluated according to the theory of plasticity of Hencky (reversible elastic model nonlinear equivalent with the incremental theory of plasticity for one monotonous radial loading growing in the space of the principal constraints)

2.2 Results of reference

Response curve charges/displacement

P/1000
d/20

Response curve giving the P/1000 load according to d/20 displacement. Higher curve calculated in plane deformations, curves lower calculated in plane constraints. Curves in feature stopped are experimental results. Constraint of reference ref. = 334,6 MPa (first point on the traction diagram). Thickness of test-tube B = 6,36 or 6,39 Misters Longueur of crack a/W = 0,5.

Integral J according to the load

P/1000

*Standardized integral E*JII/(a*ref2) according to the P/1000 constraint, where ref. = 334,6 MPa, for a test-tube thickness B=6,44 mm*

One also has some tabulées values, for a length of crack a/W=0,5 and one calculation in plane deformations; the dispersion of JII is related to the choice of the contour of integration around melts of crack.

No the loading
P (KN)
*E*JII/(a*ref2)*
22

27,66
0,292 to 0,295
36
35,11
0,540 to 0,543
50
38,83
0,798 to 0,813
64
41,49
1,065 to 1,190

2.3
Uncertainty on the solution

The difference between experimental measurements and calculation does not exceed 7%, with regard to the curve of
answer charges/displacement.

The precision of the calculation of J is unknown; the error seems to grow with the level of load, like show the increasing dependence of J compared to the contour, which reaches a margin of variation of 12% with the step n° 64.

2.4 References
bibliographical

[1]
LESLIE BANKS-SILLS and DOV SHERMAN: Elasto-plastic analysis of has mode II fractures specimen. Int.J.Fracture, 46, 105-122, 1993.

3 Modeling With

3.1 Characteristics of modeling

3.1.1 Grid of the test-tube and the door test-tube

Grid of the test-tube and the door test-tube

Zoom on the bottom of crack

3.1.2 Definition of the rays of the crowns

We define the values of the higher and lower rays, to specify in the order CALC_THETA:

1st crown
2nd crown
3rd crown
4th crown
rinf (mm)
1
2
3
4
rsup (mm)
2
3
4
5

3.2
Characteristics of the grid

The grid consists of two objects:

· carries it test-tube consists of 718 nodes and 200 elements QUA8.
· the test-tube consists of 1741 nodes and 576 elements including 496 QUA8 and 80 TRI6.

3.3 Functionalities tested

Orders

AFFE_MODELE
MECHANICS
D_PLAN
ALL

AFFE_CHAR_MECA
FORCE_NODALE

STAT_NON_LINE

CALC_THETA
THETA_2D
MODULE_F0

CALC_G_THETA

CALC_G_THETA_T

Handbook deValidation
V6.03 booklet: Nonlinear statics of the plane systems
HT-66/02/001/A

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
Increment of load n° 22

G, crown n°1 (KN/mm)
6,7451
7,005
3,868
G, crown n°2 (KN/mm)

6,7451
6,99728
3,739
G, crown n°3 (KN/mm)
6,7451
6,9964
3,726
G, crown n°4 (KN/mm)
6,7451
6,998
3,75
Increment of load n°36

G, crown n°1 (KN/mm)
12,473
13,069
4,786
G, crown n°2 (KN/mm)
12,473
13,094
4,977
G, crown n°3 (KN/mm)
12,473
13,083
4,887
G, crown n°4 (KN/mm)
12,473
13,071
4,795
Increment of load n°50

G, crown n°1 (KN/mm)
18,433
19,49
5,744
G, crown n°2 (KN/mm)
18,433
19,573
6,184
G, crown n°3 (KN/mm)

18,433
19,577
6,204
G, crown n°4 (KN/mm)
18,433
19,574
6,194
Increment of load n°64

G, crown n°1 (KN/mm)
24,601
26,84
9,105
G, crown n°2 (KN/mm)
24,601 26,977
9,657
G, crown n°3 (KN/mm)
24,601
26,981
9,672
G, crown n°4 (KN/mm)
24,601
26,983
9,684

5
Summary of the results

The results concerning the rate of refund of energy give 1 maximum change of 9,7% by report/ratio with the reference solution on the last crown, for an announced precision of 12%. results are excellent taking into account the non-linear character of the test-tube.

S. GRANET, I. CORMEAU, B. KURTH

Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
V6.03.312 document

SSNP312 - DMT94.132 Fissures parallel with the interface
in a bimetallic test-tube CT

Summary:

This test results from the validation independent of version 3 in breaking process.

It is about a two-dimensional test in statics (plane deformations) which relates to the calculation of a parallel crack
with the interface between two materials, for a noncommonplace geometry in limited field.

The structure has an elastoplastic behavior of Von Mises with isotropic work hardening.

The objective of this case test is the study of the sensitivity of G to the choice of the crowns.

It includes/understands two plane modelings 2D in which one studies the influence of an incremental

displacement
imposed. The first modeling uses linear elements, the other of the quadratic elements.

1
Problem of reference

1.1 Geometry

All the dimensions are expressed in Misters the crack is to 0,2 mm of the interface, in the part higher of the test-tube.

1.2

Properties of materials

Material n° 1: austenitic steel

Elastoplastic of von Mises type to isotropic work hardening
Young modulus E1 = 2.105 MPa, Poisson's ratio 1 = 0,3
Yield stress y1 = 310 MPa
Uniaxial traction diagram:

(MPa)
0 310 600 700
(%)
0 0,155 40 100

Material n° 2: ferritic steel

Elastoplastic of von Mises type to isotropic work hardening
Young modulus E2 = 2.105 MPa, Poisson's ratio 2 = 0,3
Yield stress y2 = 442 MPa

(MPa)
0 442 600 650
(%)
0 0,221 40 100

Material n° 3: quasi indeformable pins

Isotropic linear rubber band
Young modulus E3 = 6 1010 MPa, Poisson's ratio 3 = 0,3

1.3
Boundary conditions and loading

Being given the dissymmetry of materials, the totality of the test-tube is modelled.

Blockings:

UX = UY = 0
at the point B (center of the lower pin)
UX = 0
at point A (center of the higher pin)

Loading by imposed displacement:

0 UY 1 mm at point A, by equal increments of 0,02 mm

The loading is thus monotonous growing.

2
Reference solution

2.1
Method of calculation used for the reference solution

Calculation by finite elements with CASTEM2000 and the method theta.

2.2
Results of reference

Response curve force-displacement to point A

Vertical displacement of the two lips of the crack

Rate of refund of energy G according to displacement in A

Semi-empirical formula of ASTM [bib2]

*JASTM = (2 + 0,522*b0/w) *A/b0 where b0 = W - a0 is the initial length of the ligament and where A is the surface*
under the curve load-displacement at point A, i.e. the work of the load applied.

2.3
Uncertainty on the solution

The maximum change between results CASTEM2000 and the formula of ASTM is approximately 9% for
first crown (nearest to the crack) and the maximum loading. This variation decreases when
one takes crowns further away from the bottom of crack.

2.4 References
bibliographical

[1]
X.Z. SUO and J. BROCHARD: Elastoplastic calculation of a bimetallic test-tube CT with
a crack close to the interface. Report ECA DMT/94-132
[2]
American Society for Testing and Materials. Annual Book Standard of ASTM, flight 3.01,

Section 3, Metals Test Methods and Analytical Procedures, E813 article, page 711, 1990.

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3 Modeling
With

3.1
Characteristics of modeling

The totality of the test-tube is with a grid in quadrangular with 4 nodes or triangular elements to 3 nodes.

It comprises 799 nodes, 624 quadrangles, 185 triangles and 261 segments.

3.2
Characteristics of the grid

Very small elements (0,02 mm) with the point of the crack.
The first crown is located in only one material, the 4 other crowns cross the interface
between two materials.

Y
X

Lip of the crack
Interface between
2 materials
Melts of
fissure

3.3 Functionalities tested

Calculation of the rate of refund of energy G by the method THETA for various crowns.

Orders

STAT_NON_LINE
COMP_INCR
VMIS_ISOT_TRAC

NEWTON
TANGENT

DEFI_FOND_FISS
MELTS
GROUP_NO

NORMAL

CALC_THETA
THETA_2D
GROUP_NO

CALC_G_THETA_T
COMP_ELAS
ELAS_VMIS_TRAC

4
Results of modeling A

The rate of refund of energy G is calculated by the method THETA for the 5 following crowns:

· Couronne 0: Rinf = 0,02 mm Rsup = 0,18 mm

· Couronne 1: Rinf = 0,2 mm Rsup = 1 mm

· Couronne 2: Rinf = 1 mm Rsup = 2 mm

· Couronne 3: Rinf = 2 mm Rsup = 3 mm

· Couronne 4: Rinf = 3 mm Rsup = 5 mm

4.1 Values
tested

Identification Reference
***Aster** %*
difference
J ASTM
G (N/mm) Crown n°0 UY=0,2 mm
5,82
5,76
-1,02
G (N/mm) Crown n°0 UY=0,4 mm
22,60
21,97
-2,80
G (N/mm) Crown n°0 UY=0,6 mm
47,24
48,32
2,291
G (N/mm) Crown n°0 UY=0,8 mm
74,70
79,03
5,786
G (N/mm) Crown n°0 UY=1,0 mm
103,74
111,3
7,305

G (N/mm) Crown n°1 UY=0,2 mm
5,82
6,10
4,82

G (N/mm) Crown n°1 UY=0,4 mm
22,60
22,79
0,84
G (N/mm) Crown n°1 UY=0,6 mm
47,24
46,51
-1,54
G (N/mm) Crown n°1 UY=0,8 mm
74,70
72,88
-2,44
G (N/mm) Crown n°1 UY=1,0 mm
103,74
100,4
-3,202

G (N/mm) Crown n°2 UY=0,2 mm
5,82
6,07
4,28
G (N/mm) Crown n°2 UY=0,4 mm
22,60
23,43
3,69
G (N/mm) Crown n°2 UY=0,6 mm
47,24
47,97
1,54
G (N/mm) Crown n°2 UY=0,8 mm
74,70
74,95
0,32
G (N/mm) Crown n°2 UY=1,0 mm
103,74
103,44
-0,28
Handbook deValidation
V6.03 booklet: Nonlinear statics of the plane systems
HT-66/02/001/A

Identification
Reference
Aster
% difference
J ASTM
G (N/mm) Crown n°3 UY=0,2 mm
5,82
6,08
4,39
G (N/mm) Crown n°3 UY=0,4 mm
22,60
23,46
3,82
G (N/mm) Crown n°3 UY=0,6 mm
47,24
48,37
2,40
G (N/mm) Crown n°3 UY=0,8 mm
74,70
75,56
1,14
G (N/mm) Crown n°3 UY=1,0 mm
103,74
104,35
0,59

G (N/mm) Crown n°4 UY=0,2 mm
5,82
6,09
4,52

G (N/mm) Crown n°4 UY=0,4 mm
22,60
23,42
3,63
G (N/mm) Crown n°4 UY=0,6 mm
47,24
48,43
2,53
G (N/mm) Crown n°4 UY=0,8 mm
74,70
75,69
1,32
G (N/mm) Crown n°4 UY=1,0 mm
103,74
104,53
0,77

Stability of G to the choice of the crowns

Identification
Crown 2
Crown 3
Crown 4
% maximum variation.
G (N/mm) UY=0,2 mm
6,07
6,08
6,08
0,16
G (N/mm) UY=0,4 mm
23,43
23,46
23,42
0,17
G (N/mm) UY=0,6 mm
47,97
48,37
48,43
0,85
G (N/mm) UY=0,8 mm
74,95
75,56
75,69

0,53
G (N/mm) UY=1,0 mm
103,44
104,35
104,53
0,60

4.2 Remarks

The calculation of reference (Castem 2000) and Aster calculation use the same grid strictly.

The absolute value of the variation on the calculation of G for crowns 0 and 1 grows according to displacement to reach a value from approximately 5%.

For the other crowns, the variation decreases to reach a quasi null value.

Stability on crowns 2, 3 and 4 is very good, the difference between crowns is always lower than *1%.*

---

5 Modeling
B

5.1
Characteristics of modeling

The totality of the test-tube is with a grid in quadrangular with 8 nodes or triangular elements to 6 nodes.

It comprises 2416 nodes, 625 quadrangles, 185 triangles and 264 segments.

5.2
Characteristics of the grid

5.3 Functionalities
tested

Calculation of the rate of refund of energy G by the method THETA for various crowns.

Orders

STAT_NON_LINE
COMP_INCR
VMIS_ISOT_TRAC

NEWTON
TANGENT

DEFI_FOND_FISS
MELTS
GROUP_NO

NORMAL

CALC_THETA
THETA_2D
GROUP_NO

CALC_G_THETA_T
COMP_ELAS
ELAS_VMIS_TRAC

6
Results of modeling B

The rate of refund of energy G is calculated by the method THETA for the 5 following crowns:

· *Couronne 0: Rinf = 0,02 mm Rsup = 0,18 mm*

· *Couronne 1: Rinf = 0,2 mm Rsup = 1 mm*

· *Couronne 2: Rinf = 1 mm Rsup = 2 mm*

· *Couronne 3: Rinf = 2 mm Rsup = 3 mm*

· *Couronne 4: Rinf = 3 mm Rsup = 5 mm*

6.1 Values tested

Identification
Reference
Aster
% difference
J ASTM
G (N/mm) Crown n°0 UY=0,2 mm
5,82
6,0
3,18
G (N/mm) Crown n°0 UY=0,4 mm
22,60
21,63
-4,29
G (N/mm) Crown n°0 UY=0,6 mm
47,24
46,14
-2,32
G (N/mm) Crown n°0 UY=0,8 mm
74,70
73,06
-2,20
G (N/mm) Crown n°0 UY=1,0 mm
103,74
100,85
-2,782

G (N/mm) Crown n°1 UY=0,2 mm
5,82
5,33
-8,43
G (N/mm) Crown n°1 UY=0,4 mm
22,60
20,41
-9,71
G (N/mm) Crown n°1 UY=0,6 mm
47,24

43,22
-8,52
G (N/mm) Crown n°1 UY=0,8 mm
74,70
68,13
-8,80
G (N/mm) Crown n°1 UY=1,0 mm
103,74
93,94
-7,34

G (N/mm) Crown n°2 UY=0,2 mm
5,82
5,39
-7,35
G (N/mm) Crown n°2 UY=0,4 mm
22,60
21,18
-6,29
G (N/mm) Crown n°2 UY=0,6 mm
47,24
44,18
-6,48
G (N/mm) Crown n°2 UY=0,8 mm
74,70
68,64
-8,11
G (N/mm) Crown n°2 UY=1,0 mm
103,74
93,90
-9,48

Identification
Reference
Aster
% difference
J ASTM
G (N/mm) Crown n°3 UY=0,2 mm
5,82
5,27
-9,51
G (N/mm) Crown n°3 UY=0,4 mm
22,60
20,31
-10,11
G (N/mm) Crown n°3 UY=0,6 mm
47,24
42,81
-9,37
G (N/mm) Crown n°3 UY=0,8 mm
74,70
67,19
-10,06
G (N/mm) Crown n°3 UY=1,0 mm
103,74
92,35
-10,98

G (N/mm) Crown n°4 UY=0,2 mm
5,82
5,36
-7,96
G (N/mm) Crown n°4 UY=0,4 mm
22,60
20,82
-7,88
G (N/mm) Crown n°4 UY=0,6 mm
47,24

43,95
-6,97
G (N/mm) Crown n°4 UY=0,8 mm
74,70
68,53
-8,27
G (N/mm) Crown n°4 UY=1,0 mm
103,74
93,84
-9,54

Stability of G to the choice of the crowns

Identification
Crown 2
Crown 3
Crown 4
% maximum variation.
G (N/mm) UY=0,2 mm
5,39
5,27
5,36
2,27
G (N/mm) UY=0,4 mm
21,17
20,31
20,82
4,23
G (N/mm) UY=0,6 mm
44,18
42,81
43,95
3,20
G (N/mm) UY=0,8 mm
68,64
67,19
68,53
2,30
G (N/mm) UY=1,0 mm
93,90
92,34
93,84
1,86

6.2 Remarks

The value of G of the Aster model is logically lower than that of the reference.

The variation is approximately 10% for crowns 1 2 3 and 4. For crown 0, the average deviation is

approximately 3%.

7
Summary of the results

It should initially be announced that the reference solution is not an exact solution and that it does not apply, in general, in the case of the Bi-materials. Moreover it is based on one calculation of the linear elements. It is however exploitable for this study because the crack is not located at the interface of two materials.

Modeling A (degree 1) gives results in conformity with those of the reference.

Modeling B (degree 2) revealed a variation from approximately 8% on the value of G.

One can notice that the crowns far away from the crack provide more precise results and more stable than those close to the bottom of crack. The low-size crowns give results worse than those whose rays are important. Consequently, it seems judicious to use large-sized crowns for a modeling 2D.

Version
6.0

Titrate:
SSNP501 - Crushing of a polyurethane ring between 2 plates
Date:
14/10/02
Author (S):
NR. TARDIEU, B. GREENHOUSE
Key:
V6.03.501-A Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.501

SSNP501 - Crushing of a ring in polyurethane between two indeformable plates without friction

Summary:

The test consists in simulating crushing in plane constraints of an elastic circular polyurethane ring

by two indeformable symmetrical plates. The objective is to test the functionalities related to the contact. This test
comprise a sticking together on a zone of contact important length with the presence of large elastic strain.
A symmetrical imposed displacement is applied to the two plates; the resulting force as well as the pressure
of contact for various points in contact are compared with the results obtained in the article of reference.

In three modelings suggested, the ring is modelled with meshs QUAD4 in plane constraints:

· ***modeling A****, a contact node-meshs (CONTACT)* **without friction** *treated with the method of active constraints was defined between the plate and the ring,*
· ***modeling B****, a contact node-meshs (CONTACT)* **without friction** *treated with the method Lagrangian was defined between the plate and the ring,*
· ***modeling C****, a contact node-meshs (CONTACT* **without friction** *treated with the method continue was defined between the plate and the ring.*

1 Problem of reference

1.1 Geometry

ray external of the ring
6,35 cm
interior ray of the ring
4,15 cm
imposed displacement
4,45 cm

1.2 Properties of material

Ring: polyurethane, elastic law of behavior.

Young modulus:
E= 407 N/cm ²
Poisson's ratio:
= 0,48
Coefficient of friction:
μ = 0

1.3 Boundary conditions and loadings

The constraints are plane.

An incremental displacement imposed from 0 to 4,45 cm is applied to the nodes of the plates indeformable.

Notice on the units:

Dimensions and displacements are in centimetres thus, to remain homogeneous, them pressures must have entered in N/cm ².

1.4 Conditions initial

None.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The solution results from a computer code and an experimental test.

For the reference solution valid for a modeling of the whole plate, it is necessary to divide normal resultant by two to obtain a reference valid for a half-plate.

2.2
Results of reference

The normal force of reaction is as follows:

Imposed displacement (cm)
Force reaction (NR)
1,1125 8,0083
2,2250 16,0166
3,3375 24,0250
4,4500 32,0333

The normal pressure of contact is bench-mark datum. But, the grids used are different.
This pressure will be used to define tests of not-regression.

2.3
Uncertainties on the solution

These results are relatively approximate bus directly raised on the curve paper.

2.4 References
bibliographical

[1]
A.F. SALEEB, K. CHEN, and T.Y.P. CHANG: "Year effective two dimensional frictional contact model for arbitrary curved geometry " - Int. J. Num. Meth. Eng. 37 (1994) p. 1297-1321.

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3 Modeling
With

3.1
Characteristics of modeling

A modeling testing the functionalities of contact node-meshs (CONTACT) without friction treaty with the method of the active constraints was implemented. Taking into account the symmetry of problem, it includes/understands a quarter of the ring as well as the grid of an indeformable plate.

Boundary condition:
Conditions of symmetry: the nodes of group LAB located in the X=0 plan are blocked according to direction X (DX= 0),
the nodes of group LCD located in the Y=0 plan are blocked according to direction Y (DY= 0),
all the nodes of the group of mesh "Plate" are blocked according to direction X (DX= 0)
To avoid the rigid movements of body, nodes A and P1 have same vertical displacement.

Loadings:
Imposed displacement following Y on all the nodes of the plate: DY varies from 0 to 2,225 cm.
(the value of 4,45 cm is the vertical bringing together of the two symmetrical plates).

Note:

The grid was carried out in cm.

3.2
Characteristics of the grid

The ring and the plate are with a grid in elements QUAD4, and it plate is rigidified because all these nodes
have the same imposed displacement.

A number of nodes: 290
A number of meshs and type: 241 QUAD4 and 96 SEG2

3.3 Functionalities
tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING: "C_PLAN"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
METHOD: "FORCED"

DDL_IMPO
STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"

DEFORMATION: "GREEN"

4
Results of modeling A

4.1 Values tested

Identification	*Displacements*	*Reference*	*Aster*	*% difference*
force reaction (NR)	*1,1125 cm*	*-8,01*	*-8,56*	*6,94*
force reaction (NR)	*2,2250 cm*	*-16,02*	*-16,21*	*1,23*
force reaction (NR)	*3,3375 cm*	*-24,02*	*-23,56*	*-1,92*
force reaction (NR)	*4,4500 cm*	*-32,03*	*-31,68*	*-1,09*

4.2 Remarks

We illustrated the deformation of the ring to the step of time corresponding to a displacement of 4,45 cm:

---

5 Modeling
B

5.1
Characteristics of modeling

A modeling testing the functionalities of contact node-meshs (CONTACT) without friction treaty with the Lagrangian method was implemented. Taking into account the symmetry of the problem,
it includes/understands a quarter of the ring as well as the grid of an indeformable plate.

Boundary condition:
Conditions of symmetry: the nodes of group LAB located in the X=0 plan are blocked according to direction X (DX= 0),
the nodes of group LCD located in the Y=0 plan are blocked according to
direction Y (DY= 0),
all the nodes of the group of mesh "Plate" are blocked according to
direction X (DX= 0)

To avoid the rigid movements of body, nodes A and P1 have same vertical displacement.

Loadings:
Imposed displacement following Y on all the nodes of the plate: DY varies from 0 to 2,225 cm.
(the value of 4,45 cm is the vertical bringing together of the two symmetrical plates).

Note:

The grid was carried out in cm.

5.2
Characteristics of the grid

The grid is in any point identical to the grid used for modeling A.

5.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING: "C_PLAN"

MODI_MAILLAGE

ORIE_PEAU_2D

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
DDL_IMPO

CONTACT
METHOD: “LAGRANGIAN”

STAT_NON_LINE
COMP_ELAS
RELATION: “ELAS”

DEFORMATION: “GREEN”

6
Results of modeling B

6.1 Values
tested

Identification Moments
Reference Aster
% difference
force reaction (NR)
Dépl. 1,1125 cm
-8,01
-8,56
6,94
force reaction (NR)
Dépl. 2,2250 cm
-16,02
-16,21
1,23
force reaction (NR)
Dépl. 3,3375 cm
-24,02
-23,56
-1,92
force reaction (NR)
Dépl. 4,4500 cm

-32,03
-31,68
-1,09

6.2 Remarks

The results are almost identical to those of modeling A.
Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
HT-66/02/001/A

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7 Modeling
C

7.1
Characteristics of modeling

A modeling testing the functionalities of contact node-meshs (CONTACT) without friction treaty with the method of the active constraints was implemented. Taking into account the symmetry of problem, it includes/understands a quarter of the ring as well as the grid of an indeformable plate.

Boundary condition:
Conditions of symmetry: the nodes of group LAB located in the X=0 plan are blocked according to direction X (DX= 0),
the nodes of group LCD located in the Y=0 plan are blocked according to direction Y (DY= 0),
all the nodes of the group of mesh "Plate" are blocked according to direction X (DX= 0)

To avoid the rigid movements of body, nodes A and P1 have same vertical displacement.

Loadings:
Imposed displacement following Y on all the nodes of the plate: DY varies from 0 to 2,225 cm.
(The value of 4,45 cm is the vertical bringing together of the two symmetrical plates).

Note:

The grid was carried out in cm.

7.2
Characteristics of the grid

The grid results from the file "ssnp501b.mail" in which the meshs of ends A and D were withdrawn from the group of mesh LESC.

Note:

The method continues does not accept the modifications of the grid what implies this strategy.

7.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING: "C_PLAN"

DEFI_GROUP
CREA_GROUP_NO
UNION

DEFI_MATERIAU
ELAS

CONTACT
METHOD: "CONTINUES"

AFFE_CHAR_MECA
DDL_IMPO

STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"

DEFORMATION: "GREEN"

SOLVEUR
METHOD: "LDLT"

RENUM=' SANS'

8
Results of modeling C

8.1 Values
tested

Identification Moments Reference Aster
% difference
force reaction (NR)
Dépl. 1,1125 cm
-8,01
-8,56
6,94
force reaction (NR)

Dépl. 2,2250 cm
-16,02
-16,21
1,23
force reaction (NR)
Dépl. 3,3375 cm
-24,02
-23,56
-1,92
force reaction (NR)
Dépl. 4,4500 cm
-32,03
-31,68
-1,09

8.2 Remarks

The results are very close with those to modelings A and B.

9
Summary of the results

Whatever the type of modeling of the zone of contact, the results obtained are satisfactory.
The variations observed on the force of reaction are weak. But the values of reference are very approximate because they are extracted from a curve paper.

The grid of the code computer taken in reference and that used by Aster are different. Moreover, it is not
not explained in the reference how is extracted the normal pressure from contact. Thus, it does not have
summer carried out of tests of reference on this pressure. However tests of not-regression are carried out on the contact pressure (SIYY to the node in contact). Pace of this pressure and the zone of contact are identical between the two computer codes.

Titrate:
SSNP502 - Crushing of a polyurethane ring between 2 plates Dates
:

01/09/05
Author (S):
S. LAMARCHE, Mr. TORKHANI, NR. TARDIEU
Key:
V6.03.502-B Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.03 booklet: Nonlinear statics of the plane systems
Document: V6.03.502

SSNP502 - Crushing of a ring in polyurethane between two indeformable plates with friction

Summary:

The test consists in simulating crushing in plane constraints of an elastic circular polyurethane ring by two indeformable symmetrical plates. The objective is to test the functionalities related to the contact. This test

comprise a sticking together on a zone of contact important length with the presence of large elastic strain.
A symmetrical imposed displacement is applied to the two plates; the resulting force as well as the pressure
of contact for various points in contact are compared with the results obtained in the article of reference.

In three modelings suggested, the ring is modelled with meshs QUAD4 in plane constraints:

- *modeling A, a contact node-meshs (CONTACT) with friction treated with the method Lagrangian was defined between the plate and the ring,*
- *modeling B, a contact node-meshs (CONTACT) with friction treated with the method of penalization was defined between the plate and the ring,*
- *modeling C, a contact node-meshs (CONTACT) with friction treated with the method continue was defined between the plate and the ring.*

1
Problem of reference

1.1 Geometry

ray external of the ring
6,35 cm
interior ray of the ring
4,15 cm
imposed displacement
4,45 cm

1.2
Properties of material

Ring: polyurethane, elastic law of behavior.

Young modulus:
E= 407 N/cm ²
Poisson's ratio:
= 0,48
Coefficient of friction:
µ = 0,4

1.3
Boundary conditions and loadings

The constraints are plane.

An incremental displacement imposed from 0 to 4,45 cm is applied to the nodes of the plates indeformable.

Notice on the units:

Dimensions and displacements are in centimetres thus, to remain homogeneous, them pressures must have entered in N/cm ².

*1.4 Conditions
initial*

None.

2 Reference solution

2.1 Method of calculation used for the reference solution

The solution results from a computer code and an experimental test.

For the reference solution valid for a modeling of the whole plate, it is necessary to divide normal resultant by two to obtain a reference valid for a half-plate.

2.2
Results of reference

The normal force of reaction is as follows:

Imposed displacement (cm)
Force reaction (NR)
1,1125 8,0083
2,2250 16,0166
3,3375 24,0250
4,4500 32,0333

The normal pressure of contact is bench-mark datum. But, the grids used are different.
This pressure will be used to define tests of not-regression.

2.3
Uncertainties on the solution

These results are relatively approximate bus directly raised on the curve paper.

2.4 References
bibliographical

[1]
A.F. SALEEB, K. CHEN, and T.Y.P. CHANG: "Year effective two dimensional frictional contact model for arbitrary curved geometry " - Int. J. Num. Meth. Eng. 37 (1994) p. 1297-1321.

---

3 Modeling
With

3.1
Characteristics of modeling

A modeling testing the functionalities of contact node (CONTACT) with friction treated with the Lagrangian method was implemented. Taking into account the symmetry of the problem, it a quarter of the ring as well as the grid of an indeformable plate includes/understands.

Boundary condition:
Conditions of symmetry: the nodes of group LAB located in the X=0 plan are blocked according to direction X (DX= 0),

the nodes of group LCD located in the Y=0 plan are blocked according to direction Y (DY= 0),

all the nodes of the group of mesh "Plate" are blocked according to direction X (DX= 0)
To avoid the rigid movements of body, nodes A and P1 have even vertical displacement.

Loadings:
Imposed displacement following Y on all the nodes of the plate: DY varies from 0 to 2,225 cm.
(the value of 4,45 cm is the vertical bringing together of the two symmetrical plates.)

Note:

The grid was carried out in cm.

3.2
Characteristics of the grid

A number of nodes: 291
A number of meshs and type: 241 QUAD4 and 51 SEG2

3.3 Functionalities tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "C_PLAN"

MODI_MAILLAGE ORIE_PEAU_2D

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = "LAGRANGIAN"

FRICTION = "COULOMB"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

DEFORMATION = ' GREEN'

4

Results of modeling A

4.1 Values
tested

Identification Displacements
Reference Aster
% difference
force reaction (NR)
1,1125 cm
-8,01
-8,66
8,13
force reaction (NR)
2,2250 cm
-16,02
-16,46
2,77
force reaction (NR)
3,3375 cm
-24,02
-23,98
-0,18
force reaction (NR)
4,4500 cm
-32,03
-31,32
0,88

4.2 Remarks

One can visualize the influence of friction by looking at the shear stress to the nodes in contact. It is necessary to make the difference between SIXY with friction and SIXY without friction to eliminate them problems of averages on the nodes of the edge.

---

5 Modeling B

5.1 Characteristics of modeling

A modeling testing the functionalities of contact node-meshs (CONTACT) with friction treaty with the method of penalization was implemented. Taking into account the symmetry of the problem, it includes/understands a quarter of the ring as well as the grid of an indeformable plate.

Boundary condition:
Conditions of symmetry: the nodes of group LAB located in the X=0 plan are blocked according to direction X (DX= 0),
the nodes of group LCD located in the Y=0 plan are blocked according to direction Y (DY= 0),
all the nodes of the group of mesh "Plate" are blocked according to direction X (DX= 0)
To avoid the rigid movements of body, nodes A and P1 have even vertical displacement.

Loadings:
Imposed displacement following Y on all the nodes of the plate: DY varies from 0 to 2,225 cm.
(the value of 4,45 cm is the vertical bringing together of the two symmetrical plates.)

Note:

The grid was carried out in cm.

5.2
Characteristics of the grid

The grid is in any point identical to the grid used for modeling A.

5.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "C_PLAN"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA DDL_IMPO

CONTACT
METHOD = "PENALIZATION"
FRICTION = "COULOMB"
E_T = "1.E+06"
STAT_NON_LINE COMP_ELAS

RELATION = “ELAS”

DEFORMATION = ' GREEN'

6 Results of modeling B

6.1 Values tested

Identification	Displacements	Reference	Aster	% difference
force reaction (NR)	1,1125 cm	-8,01	-8,66	8,13
force reaction (NR)	2,2250 cm	-16,02	-16,46	2,77
force reaction (NR)	3,3375 cm	-24,02	-23,98	-0,18
force reaction (NR)	4,4500 cm	-32,03	-31,32	0,88

6.2 Notice

The results are very close to those of modeling A.

---

7 Modeling C

7.1 Characteristics of modeling

A modeling testing the functionalities of contact node-meshs (CONTACT) with friction treated with the method continues was implemented. Taking into account the symmetry of the problem, it a quarter of the ring as well as the grid of an indeformable plate includes/understands.

Boundary condition:
Conditions of symmetry: the nodes of group LAB located in the X=0 plan are blocked according to direction X (DX= 0),
the nodes of group LCD located in the Y=0 plan are blocked according to direction Y (DY= 0),
all the nodes of the group of mesh "Plate" are blocked according to direction X (DX= 0)
To avoid the rigid movements of body, nodes A and P1 have same vertical displacement.

Loadings:
Imposed displacement following Y on all the nodes of the plate: DY varies from 0 to 2,225 cm.
(the value of 4,45 cm is the bringing together vertical of the two symmetrical plates).

Note:

The grid was carried out in cm.

7.2
Characteristics of the grid

The grid results from the file "ssnp501b.mail" in which the meshs of ends A and D were withdrawn from the group of mesh LESC.

Note:

The method continues does not accept the modifications of the grid what implies this strategy.

7.3 Functionalities
tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING = "C_PLAN"

DEFI_GROUP CREA_GROUP_NO UNION

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = "CONTINUES"

AFFE_CHAR_MECA CONTACT
SEUIL_INIT = 0.1

AFFE_CHAR_MECA DDL_IMPO

STAT_NON_LINE COMP_ELAS
RELATION = "ELAS"

DEFORMATION = ' GREEN'
SOLVEUR
METHOD = "LDLT"
RENUM = "WITHOUT"

8
Results of modeling C

8.1 Values
tested

Identification Displacements
Reference Aster
% difference
force reaction (NR)
1,1125 cm
-8,01
-8,66
8,13
force reaction (NR)
2,2250 cm
-16,02
-16,46
2,77
force reaction (NR)
3,3375 cm

-24,02
-23,98
-0,18
force reaction (NR)
4,4500 cm
-32,03
-32,31
0,88

8.2 Notice

The results are very close to those to modelings A and B.

9
Summary of the results

Whatever the type of modeling of the zone of contact, the results obtained are satisfactory.
The variations observed on the force of reaction are weak. But the values of reference are very approximate because they are extracted from a curve paper.

The grid of the code computer taken in reference and that used by Aster are different. Moreover, it is not
not explained in the reference how is extracted the normal pressure from contact. Thus, it does not have
summer carried out of tests of reference on this pressure. However tests of not-regression are

carried out on the contact pressure (SIYY to the node in contact). Pace of this pressure and the zone of contact are identical between the two computer codes.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.101
SSNV101 - Tensile test shearing
with the model of Chaboche
Summary:
Problem of quasi static evolution nonlinear of mechanics of the structures.
Analyze response of an element of volume to a loading of traction-shearing which imposes a state of uniform stress-strain.
There are 2 modelings: one in 3D and one in plane constraints.
This test validates the numerical integration of the elastoplastic model of behavior to 2 variables kinematics
of Chaboche.

Code_Aster ®
Version
4.0
Titrate:
SSNV101 Test of traction-shearing with the model of Chaboche
Date:
01/12/98
Author (S):
P. SCHOENBERGER
Key:
V6.04.101-B Page:
2/8

1 Problem of reference

1.1 Geometry

Y, Dy
Face YZ: (1, 3, 5, 7)
1
2

Face XZ: (3, 4, 7, 8)

Face 1YZ: (2, 4, 6, 8)
5
6

Face 1XZ: (1, 2, 5, 6)
O
FAC
E 1XZ

O
O
shearing
Face 1Y Z

3
4
X, dx
O pressure
Face YZ

T () function effort
O
7
8
Z, dz
1.2
Material properties
isotropic elasticity
E = 145.200. MPa
= 0.3
Chaboche plasticity
Ro = 87. MPa
A1 = 187.
IH = 151. MPa
A2 = 29.
B = 2.3
C1 = 341.
K = 0.43
C2 = 17.184.
W = 6.09
1.3
Boundary conditions and loadings
N04
dx = Dy = 0.
Face YZ:
FX = FY = F (T)
N08
dx = Dy = dz = 0.
Face XZ:
FX = F (T)
N02, N06
dx = 0.
Face 1YZ:
FY = F (T)
Face 1XZ:
FX = F (T)
F (Newton)
100.
T (second)
1.
1.4 Conditions
initial
Null constraints and deformations with T = 0.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

In the particular case of traction imposed shearing,

0

0
O
O 0
X
y
I
I
(

T) = (*T*)

=

-
=
0
I =
O
0

0, *X*
y
X
I
I
I/2
0
and

1 2
T
, ,

0
0

0

0
0
- *X*/2

0 0
I

T
(*X I* constraint of kinematic work hardening)
one can write the model of Chaboche in the form of a system of 7 differential equations
y = (, *X*, *X*, *y*, *y*, *p*
1
2
1
2
)
ordinary in
.

F
(*y*, *T*) *y* = *G* (*y*, *T*)

-
O =
3
p O - (*x1* + *x2*)
R (*p*)
E

2

-
O = 3 *p*

(*O* - (*y1*+ *y2*) *R* (*p*)
2µ
2

2

O

ix = *ic*
I
With (*p*) -

I
X p I
,

1 2
3

E -

=

2

O

I
y
= *C*
I
I
With (*p*)
-

- *iy*
p I =,
1 2
3

2µ

3

3

0
=

(*X* +
1
x2)
O
(1x *x2*)
O -

2

-
+

2

R
+

(3 - + - + -
O
(*there y*
y
y
O

1
2) (
(1 2) *p R* (*p*) *p*

with, with T = 0:

=
2 +
2
3
because threshold F =
O
O
R
O
O
(
)

0

=
O
O O/*E*

=
O
O O/2µ
x1 = 2 = 1 = 2 =
=
O
X O
y O
y O
Po
0
and one imposes (*T*) = + *T*
O
.
This system is solved numerically by a "Backward difference formulated" using the library scientist NAG on CRAY.

2.2
Results of reference

With the imposed loading, there is *O* = 0.435
One compares with Aster the values, *X*, *X*, *y*, *y*, *p*
1
2
1
2
who must be identical in all them
nodes at the moment T = 1.435 dryness.

2.3
Uncertainty on the solution

Uncertainty of NAG: the resolution is carried out with 218 increments of calculated times automatically.

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D:

y
F (Newton)
35.875
F
1
2
25
F
F
T (second)
1 1.435
F
2F
X
F
2F
7
8
F
Z

3.2
Characteristics of the grid

1 HEXA8.

3.3 Functionalities
tested

Order
Key word factor
Simple key word

Argument
Keys
DEFI_MATERIAU
CHABOCHE_FO
[U4.23.01]
STAT_NON_LINE
COMP_INCR
RELATION
“CHABOCHE”
[U4.32.01]
NEWTON
STAMP
“TANGENT”
CONVERGENCE
TYPE_MATR_COMP
“TANG_VIT”
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/98/040 - Ind A

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
in all nodes with T = 1.435

0.0970

0.0971
0.05

0.1454
0.1455
0.07
X
51.0960
51.0847
0.01
1
X
7.9546
7.9574
0.02
2
y
76.6450
76.627
0.01
1
y
11.9320
11.9359
0.01
2
p
0.1922
0.1923
0.04

143.5000
143.4998
0.0001
11

4.2 Parameters of execution

Version: 4.01.09
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
21 seconds

---

5 Modeling
B
5.1
Characteristics of modeling
Modeling in plane constraints

y
F
F
F (Newton)
35.875
4
3
25
F
2F
T (second)
2F
6
5
1 1.435
2F
1
2
X
3F
F

5.2

Characteristics of the grid
2 meshs QUAD4.
5.3 Functionalities
tested
Order
Key word factor
Simple key word
Argument
Keys
DEFI_MATERIAU
CHABOCHE
[U4.23.01]
STAT_NON_LINE
COMP_INCR
RELATION
“CHABOCHE”
[U4.32.01]
NEWTON
STAMP
“TANGENT”
CONVERGENCE
TYPE_MATR_COMP
“TANG_VIT”

6
Results of modeling B
6.1 Values
tested

Identification
Reference
Aster
% difference

0.0970
0.0971
0.05

0.1454
0.1455
0.05
X
51.0960
51.1011
0.01
1
X
7.9546
7.9599
0.07
2
y
76.6450
76.6150
0.04
1
y
11.9320
11.9345
0.02
2
p
0.1922
0.1923
0.05

143.5000
143.6072
0.07
11

6.2 Remarks

The values of shearings are multiplied by
2 in the posting of the results of the variables

interns.

6.3 Parameters of execution

Version: 4.00.12
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
25 seconds

7

Summary of the results

Good precision at the time of the comparison of the results, in spite of the number of very different increments
for NAG (218) and Aster (12).

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.102
SSNV102 - Tensile test shearing
with the model of S. TAHERI

Summary:
The problem is quasi-static nonlinear in mechanics of the structures.
One analyzes the response of an element of volume to a loading in traction-shearing, carried out in such way
that that imposes a uniform state of stress-strain in the element.
There are 2 modelings: one in voluminal 3D and another in plane constraints 2D.
One validates by this test the numerical integration of the elastoplastic model of behavior of Said Taheri.

---

1 Problem of reference

1.1 Geometry

y
Face YZ: (1, 3, 5, 7)
1
2

Face XZ: (3, 4, 7, 8)

Face 1YZ: (2, 4, 6, 8)
5

6

Face 1XZ: (1, 2, 5, 6)
(*T*) *O*
Face 1

X Z
3
4
(*T*) imposed shearing
(

T)
O
O
Face 1

Y Z
X
(*T*) imposed pressure
O
Face YZ
(*T*)
function of effort
7
8
Z
1.2
Material properties
isotropic elasticity
E = 200.000 MPa
= 0,3
plasticity Said Taheri
Cinf = 0.065 MPa
C1 = -0.012 Mpa
S = 450
B = 30
m = 0.1
has = 312
= 0.3
Ro = 72
1.3
Boundary conditions and loadings
N04

dx = Dy = 0
Face YZ:
FX = FY = - F (T)
N08
dx = Dy = dz = 0
Face XZ:
FX = - F (T)
N02, N06
dx = 0
Face 1YZ:
FY = F (T)
Face 1XZ:
FX = F (T)
F (NR)
88.
T (S)
0.
1.

1.4 Conditions
initial

Null constraints and deformations with T = 0.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

One numerically integrates the following system between T = 0 and T = 1.
(Nonlinear ordinary Differential connection of 6 equations to 6 unknown factors solved using

library NAG by a “Backward difference method”)

-

p = *O*
-
éq 2.1 1

E

-

p = *O*

2µ
-
éq 2.1 2

F
p -
p = 0
-
éq 2.1 3

F
p -
p

= 0
-
éq 2.1 4
3 *F*
F
F
F

-
-
Kx
Cs
2

Ky
Cs
HR
D has
Z
2
2 (
+
)- (+
)
(
)
-
-

N
F
4
N
F
3 *F*
N
F
N

(

p - *p*)

+ (*p* - *p*)

2
JR
3
p 2 (*Qx*

C p)

(*Qy*

C p)

+
+
+
+
+
p

F
F
= -

-

2
-
O
O

éq 2.1 5

C
3
3

1+

JR +
C
2

2

(*S*
N
N

N
N
- +
-

p
p
p)
C
p
(*S p p p*)
U
p
p
2

(-2)
4

N
F
N
F
- *HR* + *has D Z*

(- + -
p
p)
(*p p*)
KX
3
+

CS 3

N
F
+ 3
C

(*S* - + (
N
F
-

0
-
p
p
p)
p
p
p)
2C *S*
p
éq 2.1 6
U
2
2

=
with
and

p
U
= *b1*-

S

X = *C* (*S*
N
-
p
p
p)

C - *C*

v
=
N

C
Y
= *C*

(*S* -
p
p
p)

1 - *D*
1/2

-

9 2
2
up W =
D = 1 - *me*

D
U

=
X + 3 *Y*

4

-

C = *C* - *C E up*

1

R

=

(*Da Z* +r) 0
LP
K = *v U*
Q = *v*

1/2
S

2
4
2
Z =

(*N*
N
-
+ -
p
p)
(*p p*)

LP

3

H = *W U*
J = *W*

S
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/96/044 - Ind A

with the initial conditions:

R
( )
( )
0
0
=
/

(2
1 2
O + 3 2
O)

( )
0
= ( )
0
O
88
. 88. 0

E

from where (*T* =)

1
=

88.
0
0
O

( )
0
= ( )
0

2µ
0
0
0

(
p)
0
= ( )
0
N
p
= *p* = 0

R ()
0
= (1-)
m ro = (*O*)

p

2.2
Results of reference

Values of,
p
p
p and *p* with the nodes with T = 1 S.

2.3
Uncertainty on the solution

Uncertainty of library NAG.

2.4 References

bibliographical

[1]
User's manual library NAG on CRAY.
[2]
S. ANDRIEUX - P. SCHOENBERGER - S. TAHERI: With three dimensional cyclic constitutive law for metals with has semi-discrete memory variable - HI-71/8147 (1992)
[3]
P. GEYER - J.M. PROIX - P. SCHOENBERGER - S. TAHERI: Modeling of the phenomena of progressive deformation - Collection of the notes intern DER 93NB00153

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---

3 Modeling

With
3.1
Characteristics of modeling
Modeling 3D:
Cubic elementary with a grid using a hexahedron with 8 nodes.
F
y
22 NR
F
1
2
F
T
F
1s
5
F
6
2F
3
has
X
4
F
2F
7
8
F
Z
3.2
Characteristics of the grid
1 mesh HEXA8, width side has = 1.
3.3 Functionalities
tested
Order
Key word factor
Simple key word
Argument
Keys
DEFI_MATERIAU
TAHERI
[U4.23.01]
STAT_NON_LINE

COMP_INCR
RELATION
“TAHERI_FO”
[U4.32.01]
NEWTON
STAMP
“TANGENT”
CONVERGENCE
TYPE_MATR_COMP
“TANG_VIT”

---

4 Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
in all nodes			
	0.01721	0.01722	0.02
	0.02573	0.02574	0.01

0.01678
0.01677
0.04
p

0.02515
0.02516
0.04
p
p
0.03356
0.03354
0.06

176.00000
175.99999
0.0001
p

4.2 Remarks

The limitation with 10 of the maximum number of local iterations is very sufficient for a method of NEWTON exact in this case.

The reduction in the tolerance on total convergence in displacement does not bring profit significant in precision.

The number of increments of load (8) led to a satisfactory precision of the result.

4.3 Parameters of execution

Version: 03.02.11
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
18 seconds

---

5 Modeling

B

5.1 Characteristics of modeling

Modeling in plane constraints 2D

y
F
N04
N03
F
F (T)
44 NR
X
2F
N01
N02
F
T
1 S

5.2 Characteristics of the grid

Square quadrangle with 4 nodes in plane constraints with:

· width = 1,
· thickness = 1.

5.3 Functionalities tested

Order	**Key word factor**	**Simple key word**	**Argument**	**Keys**
DEFI_MATERIAU	TAHERI			[U4.23.01]
STAT_NON_LINE	COMP_INCR	RELATION	"TAHERI"	[U4.32.01]

NEWTON
STAMP
“TANGENT”
CONVERGENCE
TYPE_MATR_COMP
“TANG_VIT”

---

6 Results of modeling B

6.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
in all nodes			
	0.01721	0.017224	0.08
	0.02573	0.025727	0.008
	0.01678	0.016784	0.02

p

0.02515
0.025156
0.02
p
p
0.03356
0.03354
0.06

176.
175.9998
0.0001
p

6.2 Parameters of execution

Version: 03.02.11
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
16 seconds

---

7 Summary of the results

Good precision at the time of the comparison with NAG in spite of some difficulties of convergence with this mathematical library.

Code_Aster ®
Version
5.0

Titrate:
SSNV103 - Tensile test shearing models of Rousselier
Date:
03/10/02
Author (S):
R. *Key* ***MASSON***
:
V6.04.103-C Page:
1/8

Organization (S): EDF/MMC

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.103

SSNV103 - Tensile test shearing
model of Rousselier

Summary:

It is about a nonlinear quasi-static problem in mechanics of the structures.

One analyzes the response of an element of volume to a loading in traction-shearing, carried out of such
way that that imposes a uniform state of stress-strain.

The case test includes/understands 1 modeling: in 3D.

It validates the numerical integration of the elastoplastic model of behavior with damage of
G. Rousselier.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-26/02/009/A

1
Problem of reference

1.1 Geometry

y
Face YZ: (1, 3, 5, 7)
1
2

Face XZ: (3, 4, 7, 8)

Face 1YZ: (2, 4, 6, 8)
5
6

Face 1XZ: (1, 2, 5, 6)
O
Face 1

X Z
3
4

O imposed shearing
O
Face 1

Y Z
X
imposed pressure
O
Face YZ
(T) function of effort
7

8
O
Z

1.2
Material properties

isotropic elasticity:
E = 206.400.MPa
= 0.3

plasticity:
D = 2.

(coefficients of the model of F = 5.104
Rousselier)
O
1 = 490.MPa

The rational traction diagram entered point by point with:

R (p) =r + R
R E
-
I
(O I) LP
with
p: cumulated plastic deformation
and
laughed = 1500 MPa
ro = 520.MPa
B = 2.4

1.3
Boundary conditions and loadings

N04
dx = Dy = 0
Face YZ:
FX = FY = F (T)
N08
dx = Dy = dz = 0

Face XZ:
FX = F (T)
N02, N06
dx = 0
Face 1YZ:
FY = F (T)

Face 1XZ:
FX = F (T)

F (Newton)
409.68
409.707
T (second)
1.

1.4 Conditions
initial

Null constraints and deformations with T = 0.

2
Reference solution

2.1
Method of calculation used for the reference solution

The model 3D of speed is written:

& - & E - &e = 0
(linear tensor isotropic elasticity)

&

- &p D exp H =

0
1

F

& - &e - &p
=

0

&f

= 0

0
O
O

what, in the case of a loading of imposed traction-shearing (T) = (T) O
0

0

0 0

0
conduit to integrate a system of 6 ordinary differential equations in y = (, p
E
E
) of
the form (
With y, T) y& = G (y, T).

& + 2 F E E & - E
O
O
E
&e = 0

& + 2 F E 2µ &
O
O
E - 2 µ &
E = 0

&
O
-
&p - &e

= 0
eq O

3
&
O
-
&p - &e
0

2

=
eq O

(S)

&

- &p D exp
H

= 0

1

1
2

O
R
&
O

+ D F E exp
H
O
O

+ 3 &

-
p&
eq O
3

1

eq O
p

H

+
H

+

-
-
&
eq O
O
F E
D 1 O
F E exp
1 O
F E 1
=

0

1

1

with with T = 0:

F = 0, ()
0
= 1 , ( )
0
= 0

from where:

( )
( )
0
0
- R (0
O
eq O
) + D F exp
= 0
1 O

31

who is solved by a method of NEWTON for ()
0 :

( )
1
0
=
( )
0 O = E ()
0

E

( )
1
0
=
( )
0 O = E ()
0
2µ

p ()

0
=
0

2.2
Results of reference

One imposes (T) = ()
0 + T with O = O = 150.MPa.

One obtains ()
0 = 1.73138 and ()
1 = 2.73138.

The system (S) is then solved numerically by a "Backward difference formulated" using scientific library NAG on CRAY. Result of reference = (,) to the nodes with T = 1.

2.3
Uncertainty on the solution

Uncertainty related to library NAG.

2.4 References

bibliographical

[1]
User's manual library NAG on CRAY.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-26/02/009/A

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D: *1 cubic HEXA8*

y
F
F
1
102.426 NR
2
F
F
5
F
6
T
1 S

2F
3
X
4
F
2F
7
8
F
Z

3.2 Functionalities tested

Order
Key word factor
Simple key word
Argument

DEFI_MATERIAU
ROUSSELIER_FO

STAT_NON_LINE
COMP_INCR
RELATION
"ROUSSELIER"

NEWTON
STAMP
"TANGENT"

CONVERGENCE
TYPE_MATR_COMP
"TANG_VIT"

4
Results of modeling A

4.1 Values
tested

Identification Reference
***Aster** %*
difference
in all the nodes

0.07830 0.07838 0.111

0.11700 0.11706 0.05
p
0.15260 0.15264 0.024

409.7070 409.7076 1.51 10-4
11

4.2 Remarks

One could expect a better correlation, but it should be stressed that library NAG uses the function R (p) in algebraic form, whereas Code_Aster uses it in the form of a curve data point by point.

Moreover, it seems that the integration of the rate of the function threshold poses problems with NAG, whatever that is to say precision required in addition (the value of the threshold F being appreciably different from 0 in end

of integration). However, one can note the constancy of this correlation throughout integration
(T [
0]
1
,) .

5
Summary of the results

The values of Code_Aster are in concord with the values of reference.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.104
SSNV104 - Contact of two phères
Summary:
Calculation consists in crushing two quarters of spheres one on the other to test the algorithm of unilateral contact in statics. The solution is compared with the analytical result of Hertz. This functionality returns within the framework mechanics of the structures having a nonlinear behavior.
Three axisymmetric modelings suggested differ by the type of finite elements used (modeling AXIS, meshs TRIA3, QUAD4 and QUAD8).

---

1 ***Problem of reference***

1.1 Geometry

Two half-spheres: axisymmetric model
With
B
Z2
Z1
I
G
H
ray R = 50 mm
G'

y
C
D
X
Taking into account the differences in grid, positions of the nodes H and I, indicated here in manner approximate, are different in 3 modelings (one will note nodes ha, IA, HB, IB, HC, IC).

1.2
Material properties

E = 20.000. MPa
= 0.3

1.3
Boundary conditions and loadings

DX blocked on the axis AC
DY imposed 2 mm for the nodes of AB
+2 mm for the CD nodes

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical method for calculation of yy in G (and G'): it is the solution of a problem of Hertz

- E 1
2h

=

yy
1-2 R

where H is imposed crushing (H = 2 - (- 2) = 4 mm).

2.2
Results of reference
yy at the point G (analytical solution).
Displacements in three points of the edge (of which G).
xx, yy and zz in a mesh being pressed on AG.
2.3 Reference
bibliographical

[1]
G. DUMONT
: "Method of the active constraints applied to the unilateral contact"
Note HI-75/93/016.

---

3 Modeling
With
3.1
Characteristics of modeling
3.2
Characteristics of the grid
Nodes: 110 nodes.
Meshs: 170 TRIA3 and 53 SEG2.
3.3 Functionalities
tested
AFFE_CHAR_MECA
LIAISON_UNIL_NO
STAT_NON_LINE

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
Tolerance
yy mesh M1 node N110 (G)
2798.3
2636.5
5.8%
7%
yy mesh M8 node N110 (G)
2798.3
2976.7
6.4%
7%
DX node N110 (G)
0.
1.14 1017
1017 (ABS)
1013
DY node N110 (G)
0.
2.63 104
1014 (ABS)
1013
DX node N100 (ha)
1.23616 101

DY node N100 (ha)
1.43310 101
DX node N92 (IA)
1.76462 101
DY node N92 (IA)
6.94980 101

4.2 Remarks

The node G belongs to 2 meshs (M1 and M8): one can make the average of both yy corresponding to compare with the theoretical value, from where an error of 0.3%.

4.3 Parameters of execution

Version: 3.02.24
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
5 seconds

---

5 Modeling B

5.1 Characteristics of modeling

5.2 Characteristics of the grid

Nodes: 410.
Meshs: 30 TRIA3, 324 QUAD4, 93 SEG2.

5.3 Functionalities tested

AFFE_CHAR_MECA
LIAISON_UNIL_NO
STAT_NON_LINE

---

6 Results of modeling B

6.1 Values
tested
Identification
Reference
Aster
% difference
Tolerance
yy mesh M31 node N291 (G)
2798.3
-2477.
11.5%
12%
DX node N291 (G)
0
2. 1017
1017 (ABS)
1013
DY node N291 (G)
0
5.8. 1017
1017 (ABS)
1013
DX node N287 (HB)
1.22920 101
DY node N287 (HB)
1.62911 101
DX node N285 (IB)
1.89036 101
DY node N285 (IB)
6.29666 101

6.2 Parameters
of execution

Version: 3.02.24
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
6 seconds

7 Modeling
C

7.1
Characteristics of modeling

7.2
Characteristics of the grid

Nodes: 660.
Meshs: 176 QUAD8 and 80 SEG3.

7.3 Functionalities
tested

Orders
Keys
AFFE_CHAR_MECA
LIAISON_UNIL_NO
[U4.25.01]
STAT_NON_LINE
[U4.32.01]

8

Results of modeling C

8.1 Values

tested

Identification

Reference

Aster

% difference

Tolerance

yy mesh M1 node N660 (G)

2 798.3

2419.8

13.5%

14%

DX node N660 (G)

0

3.4 1017

1017 (ABS)

1013

DY node N660 (G)

0

3.4 1014

1014 (ABS)

1013

DX node N644 (HC)

1.10481 101

DY node N644 (HC)

1.11082 101

DX node N606 (IC)

2.10057 101

DY node N606 (IC)

7.37809 101

8.2 Parameters

of execution

Version: 3.02.24

Machine: CRAY C90

Obstruction memory:

8 MW

Time CPU To use:

6 seconds

---

9 Summary of the results

The comparison of each of 3 modelings to the analytical reference (limited to the point G) is satisfactory for modeling A, less for modelings B and C.

The comparison of 3 modelings between them shows that:

· the deformations are superposable,

· the stress fields have marked enough local differences, in particular in zones Z1 and Z2. The phase of independent validation should make it possible to include/understand why.

In the command files, one ensures oneself of the not-degradation of the results by testing them displacements in two nodes of the edge, H and I. These nodes occupying of the positions slightly different according to modelings', one should not seek to compare the values of the cases A, B, C.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
Document: V6.04.112

SSNV112 - Hollow roll into incompressible (great deformations)

Summary:

This test makes it possible to validate the quasi-incompressible elements in great deformations, in statics for one three-dimensional, axisymmetric or two-dimensional problem (plane deformations). A cylinder is considered hollow subjected to an internal radial displacement. The material has a Poisson's ratio equal to 0.4999 and one use the quasi-incompressible elements (modeling INCO) with the deformations of SIMO_MIEHE.
Four modelings are carried out for this problem. Modelings A and B make it possible to test quasi-incompressible modeling 3D (3D_INCO), on the one hand with HEXA20 (A) and on the other hand with TETRA10 (B). Modelings C and D are studies 2D being based on mixed grids QUAD8 and TRIA6. Modeling C is the study in plane deformations (D_PLAN_INCO), modeling D is a study axisymmetric (AXIS_INCO).

This test is similar to the test SSLV130, which tests the quasi-incompressible elements under the assumption of small deformations.
The numerical results are satisfactory for all modelings.

---

1 Problem of reference

1.1 Geometry

y
R
E
F

C
45°
D
P
Ur
With
B
Z
X
Internal ray

= 0.1 m has
External ray
B = 0.2 m

Co-ordinates of the points:

WITH B
E
F
C
D
*X 0.1.0.2.0.1*cos (45) 0.2*cos (45) 0.1*cos (22.5) 0.2*cos (22.5)*
y
*0 0.0.1*sin (45)*
*0.1*sin (45)*
*0.1*sin (22.5) 0.1*sin (22.5)*
Z
0 0
0
0
0
0

1.2
Properties of material

E = 2.105 MPa
= 0.4999

1.3
Boundary conditions and loadings

Radial displacement U
5 m
0
10
.
6
-
=
(expansion)

2
Reference solution

2.1
Method of calculation

For the studied problem, displacement U is radial and thus of the form
U =
0]

0,

[U,

.
One deduces the general form from it from the tensor of the deformations in great deformations:

2

1
(+ u')
0
0

B =
T
FF =
U
0
1
(+)2 0

R

0
0
1

as well as the form of the tensor of the constraints, which is written simply if one takes into account does it
that J = det F = 1 for an incompressible problem:
D
= - pId + μ B, is:

2
2
1
U 2 1

= - p +
rr
μ 1 (+ u') - 1 (+) -
3
3

R
3

1
2
2
U 2 1

= - p +

μ- 1 (+ u') + 1 (+) -
3
3

R
3

1
2
1
U 2 2
= - p + μ - 1
(+ u') - 1
(+) +
zz
3
3

R
3

=
=
= 0
R
rz
Z

The writing of the equilibrium equations leads to the checking of only one equation:
-
'+ rr
= 0
rr

R
who allows to determine the pressure p knowing the field of radial displacement U:

U 2

1
4
2
U
u'
U (1+ u') 2
(+)
R

p'= μ 1 (+ u' U
) ' -
'
1+
-
+
-

3
3

2

R
R
R
R
R

2.2
Particularization of the solution
1+ u'
0
0

U

The condition of incompressibility is written det F = 1 with F = 0
1+

0. Displacement U

R

0
0
1
thus check the following differential equation:
ru'+u + u' U = 0

éq 2.2-1
The imposed loading is as follows U = U 0 in R = A.

The solution in displacement is thus:

U = - R + 2
R + U (U + 2a)
R

0
0

U = U = 0

Z

The tensor of the deformations thus has as an expression:

2
R
B =
rr

2
R + U (U + 2a)
0
0

2

R + U (U + 2a)
B
=
0
0

2
R

B = 1
zz

B
= B
= B = 0
R
Z
Z

And the constraints are worth:

2
2

2
R
1 R + U (U +

2a)

= - p +
0
0
1
rr
μ
-
-

3 2
R + U (U + 2a) 3
2
R
3

0
0

2
2

1
R
2 R + U (U + 2a)
0
0
1

= - p +

μ-

+
-

3 2
R + U (U + 2a)
3
2
R
3

0
0

2
2

1
R
1 R + U (U + 2a)
0
0
2
= - p +
zz
μ-
-
+

3 2
R + U (U + 2a) 3
2
R
3

0
0

=
= = 0

R
Z
Z

with p obtained by integration of [éq 2.2-1] which is worth:

U U
(
+ 2a

)
2
(
+ 2)
p = μ 0
0
-
0
0
-
() + 1
(
+ 2) + 2
0
0
+

6r

2
(U U has
3U U
(
+ 2a) + R 2
0
0
) Log R Log [U U has R] C
2

where C is a constant

One obtains finally the following numerical values:

in R = 0.1
U = 6. 10 5
-
in R = 0.2
= 3.00067 10 5
-
R
ur
= 59
- .9955
= 0.
rr
rr

= 99.9566

= 40.006

= 19.9326
= 20.
zz
zz

The passage in the Cartesian system is done using the following relations:

= cos2 +
2
xx
rr
sin - 2 sin cos
R

= sin2 +
2
yy
rr
cos + 2 sin cos
R

= sin cos -
2
2
xy
rr
sin cos - 2
R (cos - sin)

2.3 Sizes and results of reference

One compares with the values of reference:

- *displacements (U, v) at points A and F,*
- *the constraints (xx, yy, zz, xy) at points A and F,*
- *constraints of Von Mises and Tresca as well as the eigenvalues of the tensor of constraints at point A.*

3 Modeling With

3.1 Characteristics of modeling

Grid with incompressible elements 3D of type HEXA20 only

y
B
Face blocked in dx
F
With
Normally blocked face
E
Face with imposed pressure
Face with imposed radial displacement
45°
X

Along axis Z:

- *total thickness E = 0.01*
- *2 layers of elements*

Limiting conditions:

DDL_IMPO =
GROUP_NO = ' FACSUP' DZ =
0.

GROUP_NO = ' FACINF' DZ =
0.

faces AEFD (z=0 and Z = 0.01)

GROUP_NO = ' FACEAB' DX =
0.

face AB
FACE_IMPO = GROUP_MA = ' FACEEF'
DNOR =
0.

face EF
GROUP_MA = ' FACEAE' DNOR =
-6.10-5
face AE

3.2
Characteristics of the grid

A number of nodes: 1501 nodes
A number of meshs: 240 HEXA20
Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HT-66/03/008/A

Code_Aster ®
Version

3.3 Functionalities tested

Orders

AFFE_MODELE MODELING “3D_INCO”
GROUP_MA
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA DDL_IMPO
GROUP_NO
FACE_IMPO
GROUP_MA

PRES_REP
GROUP_MA

STAT_NON_LINE COMP_INCR
RELATION ELAS
DEFORMATION SIMO_MIEHE
NEWTON
REAC_ITER
1

3.4 Sizes tested and results

Displacements and the constraints are evaluated at points A and F. the components of the field EQUI_NOEU_SIGM are tested at point A only.

Identification Reference
Aster
% difference
With
U 0. 6.6703
10-21 -

v
6. 10-5
6.0046 10-5 -0.077

xx
99.9566 99.3400
-0.617

yy
-59.9955 -60.9543

1.598

zz
19.9326 19.2770
-3.289

xy
0. -1.1617
-
VMIS 138.5226 138.6161
0.067
TRESCA 159.9521 160.0601
0.068
PRIN_1 -59.9955 -60.8372
1.403
PRIN_2 19.9326 19.2770
-3.289
PRIN_3 99.9566 99.2229
-0.734
VMIS_SG
138.5226 1.8.6161 -0.067

Identification Reference

Aster
% difference
F
U
-2.1218 10-5 -2.1219
10-5
0.007

v
+2.1218 10-5 2.1219
10-5
0.007

xx
20.003 20.029
0.129

yy
20.003 19.980
-0.115

zz
20.003 20.001
-0.011

xy
20.003 20.026
0.111

3.5 Remarks

One obtains very good results since for all the examined sizes, the difference between solution obtained with the code and the analytical solution is lower than 0.1% for displacements and lower than 1.6% for the constraints.

---

4 Modeling B

4.1 Characteristics of modeling

Grid with incompressible elements 3D of type TETRA10 only

F
Normally blocked face
y
D
E
C

45°
With
B
X
Face with imposed pressure
Face blocked out of Dy
Face with radial displacement imposed Face blocked out of Dy

AB is on axis OX (contrary to modeling A).
The grid was obtained with GMSH for a density of 0,01.

Limiting conditions:

DDL_IMPO =
GROUP_NO = ' FACSUP' DZ =
0.

GROUP_NO
= ' FACINF'
DZ
=

0.

faces AEFD (z=0 and Z = 0.01)
GROUP_NO
= ' FACEAB'

DY
=

0.

face AB
FACE_IMPO = GROUP_MA = ' FACEEF' DNOR =
0.

face EF

= GROUP_MA = ' FACEAE' DNOR =
-6.10-5
face AE

4.2
Characteristics of the grid

A number of nodes: 2064
A number of meshs: 1121 TETRA10
Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HT-66/03/008/A

Code_Aster ®
Version
7.2

4.3 Functionalities tested

Orders

AFFE_MODELE MODELING "3D_INCO"
GROUP_MA
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

FACE_IMPO
GROUP_MA

STAT_NON_LINE COMP_INCR
RELATION
ELAS
DEFORMATION
SIMO_MIEHE
NEWTON
REAC_ITER
1

4.4 Sizes tested and results

One notes the results obtained for the points A and F.

Identification Reference
Aster
% difference
With
U
6. 10-5 6.009
10-5 0.158

v
0. 2.65
10-23
-

xx
-59.9955 -60.90
1.512

yy
99.9566
98.63
-1.323

zz
19.9326
19.39
-2.707

xy
0. -2.765
-
VMIS 138.5226

TRESCA 159.9521

PRIN_1 -59.9955

PRIN_2 19.9326

PRIN_3 99.9566

VMIS_SG

138.5226

Identification Reference
Aster
% difference
F
U
2.1218 10-5 2.1198
10-5
-0.096

v
2.1218 10-5 2.1198
10-5
-0.096

xx
20.003
19.94
-0.302

yy
20.003 19.90
-0.496

zz
20.003 20.025
0.110

xy
-20.003 -19.90
-0.535

4.5 Remarks

The results obtained are completely correct since the constraints are obtained with one precision lower than 3% even 0.5% at the point F. the variation is a little more important here than for HEXA20, but can be explained by the fact why the loading is imposed here in manner a little less specify since displacement U at point A, is defined only with one accuracy of 0.158% against 0.077% (evening factor 2, that one finds on the constraints).
Handbook of Validation

---

5 Modeling C

5.1 Characteristics of modeling

Grid with incompressible elements 2D of type QUAD8 and TRIA6

y
B
Face blocked in dx
F
With
Normally blocked face
E
Face with imposed pressure
Face with imposed radial displacement
45°
X

Limiting conditions:

DDL_IMPO =

GROUP_NO = ' GRNM11'
DX =
0.

side AB
FACE_IMPO = GROUP_MA = ' GRMA12'
DNOR =
0.
dimensioned
EF
=
GROUP_MA = ' GRMA13'
DNOR =
-6. 10-5
face AE

Name of the nodes:

With = N2, B = N361, C = N121, D = N584, E = N155, F = N503

5.2
Characteristics of the grid

A number of nodes: 591
A number of meshs: 200 TRIA6, 50 QUAD8.

5.3 Functionalities
tested

Orders

AFFE_MODELE MODELING
“D_PLAN_INCO”
GROUP_MA
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA DDL_IMPO
GROUP_NO
FACE_IMPO
GROUP_MA

STAT_NON_LINE COMP_INCR
RELATION ELAS

DEFORMATION
SIMO_MIEHE
NEWTON
REAC_ITER
1

5.4
Sizes tested and results

One notes the result obtained for the points A and F.

Identification Reference
Aster
% difference
With
U 0. -5.93
10-21
-

v

6. 10-5
6.0046 10-5
0.077

xx
99.9566 99.7104 -0.246

yy
-59.9955 -61.0467 1.752

zz
19.9326 19.5237 -2.052

xy
0. 1.9020
-
VMIS 138.5226 19.1945 0.485
TRESCA 159.9521 160.7273
0.485
PRIN_1 -59.9955 -61.0318
1.727
PRIN_2 19.9326 19.5237 -2.052
PRIN_3 99.9566 99.6955 -0.261
VMIS_SG
138.5226 139.1945
0.485

Identification Reference
Aster
% difference
F
U
-2.1218 10-5 -2.1212
10-5
-0.029

v
+2.1218 10-5 2.1212
10-5
-0.029

xx
20.003 20.0456 0.213

yy
20.003 19.9883 -0.073

zz
20.003 20.0048 0.009

xy
20.003 20.0252 0.111

5.5 Remarks

As for modeling 3D, the results obtained are completely satisfactory.
Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HT-66/03/008/A

---

6 Modeling
D

6.1
Characteristics of modeling

Incompressible elements axi (TRIA6 + QUAD8)

Center cylinder
Node blocked out of Dy
y

E
F
0.01m
C
D
With
B
X
Face with imposed pressure
Face with imposed displacement

Limiting conditions:

DDL_IMPO =
GROUP_NO = ' FACSUP'
DY =
0.

y=0.1
GROUP_NO
= ' FACINF'

DY =
0.

y=0
FACE_IMPO = GROUP_MA = ' FACEAE'
DX = 6. 10-5
face AE

6.2
Characteristics of the grid

A number of nodes: 175.
A number of meshs and types: 20 QUAD8, 40 TRIA6.

6.3 Functionalities
tested

Orders

AFFE_MODELE MODELING
"AXIS_INCO"
GROUP_MA
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

FACE_IMPO
GROUP_MA

STAT_NON_LINE COMP_INCR
RELATION
ELAS
NEWTON
REAC_ITER
1

DEFORMATION
SIMO_MIEHE

13/14

6.4
Sizes tested and results

One notes the results obtained for A and F.

Identification Reference
Aster
% difference
With
U
6. 10-5
6.0000 10-5 0.00

v 0. 5.71 1021
-

xx
-59.9955 -59.8619
-0.223

yy
19.9326 19.9708
0.192

zz
99.9566 99.9171
-0.039

xy
0. -3.03
10-7
-
VMIS 138.5226 138.3727
-0.108
TRESCA 159.9521 159.7790
-0.108
PRIN_1 -59.9955 -59.8619
-0.223
PRIN_2 19.9326 19.9708
0.192
PRIN_3 99.9566 99.9171
-0.0039

VMIS_SG
138.5226 138.3727
-0.108

Identification Reference
Aster
% difference
F
U
3.0007 10-5 3.0011
10-5
0.038

v
0. 4.90
10-22
-

xx
0. 2.59
10-2
-

yy
20. 19.9975 -0.013

zz
40.006 39.9965
-0.024

xy
0. -4.87
10-3
-

6.5 Remarks

The precision obtained is very good since all the constraints are obtained with a precision lower than 0.5%.

Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HT-66/03/008/A

7
Summary of the results

With a Poisson's ratio very close to 0.5, one finds the results of the solution analytical incompressible in great deformations, with a completely correct precision.

Organization (S): EDF/MTI/MMN, EDF/UTO/SIS, SAMTECH

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.115 document

SSNV115 - Iron corrugated in behavior
nonlinear

Summary:

This problem validates the elastoplastic law of behavior with criterion of Von Misès with linear work hardening
isotropic for modelings of plates [R3.07.03] and voluminal hulls [R3.07.04] where effects of membrane and of inflection are also important.

The geometry of the model respects 3 constraints:

- ***the thickness is low to respect the assumption of the thin hulls,***
- ***the problem must be in plane deformation according to OZ,***
- ***the curve according to OY is selected so that the "inflection" and the "membrane" are both significant.***

There is no analytical solution. Modeling A (2D D_PLAN) is used as reference. The test does not have
physical significance and the values of displacements obtained are very important compared to

dimensions of the initial structure. This test is thus rather a test of not-regression and comparison inter-modelings.

The results (in displacement) differ from 2 to 3% between modelings plates and the reference 2D. This variation
is reduced to 0.5% between modelings voluminal hulls and the reference 2D.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/01/010/A

1
Problem of reference

1.1 Geometry

y
B
D
With
C
X
X
01
Z
y seen of "crosses"

R
R
H
With
C
X
X
R
R

0

Characteristics of the hull:

.
thickness H = 0.05 mm,
.
radius of curvature R = 1 mm,
.
L= width AB = CD = 0.1 mm,
.
position of the first center of curve: 0 = (0, - R) and OA = R = 01
. ,
.
*the angle is selected so that the surface **upper** of the hull than item X is with*
(y = 0), i.e. aligned with A and C,

1 H
cos = 1 - 4 R

H
.
position of the second center of curve: 0 2 cos, -
and 0
1
R
R
, X
R

.
2
=

1.2
Material properties

E = 2.000 MPa
= 0.3
One uses an elastoplastic law of behavior with criterion of Von Misès with work hardening
isotropic linear: y = 100 MPa AND: 200 MPa.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/01/010/A

1.3
Boundary conditions and loadings

.
on AB: embedding: DX = DY = DZ = DRX = DRY = DRZ = 0,
.
on all the hull: deformation planes according to OZ => DZ = DRX = DRY = 0,
.
on CD: linear effort (by unit of length OZ) according to OX given by: fx = 50 N/mm It is equivalent with a pressure of pX = fx /h = 100 MPa being exerted on the side CD,
.
the loading is applied gradually to the structure. The way of loading is cut out in 10 equal increments.

fx 5.
0.
1. T

2
Reference solution

2.1
Method of calculation used for the reference solution

Modeling A (2D D_PLAN) is used as reference for modelings of hull.

2.2
Results of reference

Displacements according to OX and OY of item X in Misters.

2.3
Uncertainty on the solution

The experiment shows that if one doubles the number of elements in the two directions, the result varies of less than 2%.

The selected criteria of convergence must also make it possible to reach the precision estimated for this calculation 2D: (2 or 3%).

3 Bibliography

[1]
F. VOLDOIRE, C. SEVIN: Axisymmetric thermoelastic hulls and 1D. Documentation of Reference of Code_Aster [R3.07.02].
[2]
P. MASSIN: Elements of plate DKT, DST, DKQ, DSQ and Q4. Documentation of Reference of Code_Aster [R3.07.03].
[3]
P. MASSIN, A. LAULUSA: Elements of three-dimensional hull. Documentation of Reference of Code_Aster [R3.07.04].

4/14

4 Modeling
With

4.1
Characteristics of modeling

Discretization: 20 X 4 elements QUAD8 with modeling D_PLAN.

Boundary conditions:

y
H
bout1
0
bout2
X
0 :
DX = DY = 0.
bout1: DX = 0.

Name of the nodes: not X = group_no X = N148

Loading: linear force (by unit of length OZ) FX distributed on the group_ma bout2
FX = 5. /h = 100. This loading is equivalent to a pressure of 100 MPa.

4.2
Characteristics of the grid

A number of nodes:
289
A number of meshs and type:
80 QUAD8

4.3 Functionalities
tested

Orders

STAT_NON_LINE COMP_INCR RELATION
“VMIS_ISOT_LINE”

5
Results of modeling A

5.1 Values
tested

With the sequence number 10

Identification
Aster (mm)
DX (X) with T = 1.
0.02743
DY (X) with T = 1.
-0.2804

5.2 Parameters
of execution

Version:
5.02.22

Machine:
Origin 2000
System:
UNICOS 8
Obstruction memory:
100 Mo
Time CPU To use:
12.5 seconds

---

6 Modeling B

6.1 Characteristics of modeling

B
X
Fx
D
With
C
Fx
Z

One seeks a movement independent of Z; only one "line" of triangular elements is thus enough.

Cutting: 20 quadrangles => 40 triangles DKT. Modeling DKT.

The thickness of the elements is divided into 17 layers for nonlinear calculation [R3.07.03]. Each layer comprises 3 points of integration in higher skin of layer, in the middle of each layer and in lower skin of layer. The model here studied thus includes/understands 15 points of integration in the thickness of the plate.

Boundary conditions:

AB (GROUP_NO: bout1): DX = DY = DZ = DRX = DRY = DRZ = 0

ALL: "YES": DZ = DRX = DRY = 0

Loading: nodal forces out of C and D FX = p Lh/2 = 0.25 NR.
X

6.2
Characteristics of the grid

A number of nodes:
42
A number of meshs and type:
40 TRIA3

6.3 Functionalities
tested

Orders

AFFE_MODELE

MODELING
DKT
AFFE_CARA_ELEM HULL
THICK
STAT_NON_LINE COMP_INCR RELATION
"VMIS_ISOT_LINE"
"COQUE_NCOU"

6/14

7
Results of modeling B

7.1 Values tested

With the sequence number 10 = 1 is T.

Identification Reference Aster (mm)
% difference
DX (X)
0.02743 0.02681 -2.275
DY (X)
-0.2804 -0.2886
2.937
FX (A)
-0.25 -0.249 -0.054

Note:

If one further increases the number of layers for integration in the thickness, the relative error on DX (X) passes in lower part of 2%. For 19 layers one finds an error of 1.29% thus. That on DY (X) remains unchanged.

7.2 Parameters of execution

Version:
5.02.22

Machine:
Origin 2000
System:
UNICOS 8
Obstruction memory:
100 Mo
Time CPU To use:
13.7 seconds

---

8 Modeling C

8.1 Characteristics of modeling

Z
B
X
Fx
D
With
C
Fx
Z

One seeks a movement independent of Z; only one "line" of quadrangular elements is enough thus.

Cutting: 40 quadrangles DKQ. Modeling DKT.

The thickness of the elements is divided into 7 layers for nonlinear calculation [R3.07.03], in order to *to have a very high degree of accuracy on the state of stresses in the thickness of the plate. Each layer comprise 3 points of integration in higher skin of layer, in the middle of each layer and in skin lower of layer. The model studied here thus includes/understands 15 points of integration in the thickness of the plate.*

Boundary conditions:

AB (GROUP_NO: bout1): DX = DY = DZ = DRX = DRY = DRZ = 0

ALL: "YES": DZ = DRX = DRY = 0

Loading: nodal forces out of C and D FX = p Lh/2 = 0.25 NR.
X

8.2
Characteristics of the grid

A number of nodes:
82
A number of meshs and type:
40 QUA4

8.3 Functionalities
tested

Orders

AFFE_MODELE

MODELING
DKT
AFFE_CARA_ELEM HULL
THICK
STAT_NON_LINE COMP_INCR RELATION
"VMIS_ISOT_LINE"
"COQUE_NCOU"
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures

9
Results of modeling C

9.1 Values tested

With the sequence number 10 is, T = 1.

Identification	*Reference*	*Aster (mm)*	*% difference*
DX (X)	*0.02743*	*0.0270*	*-1.44*
DY (X)	*-0.2804*	*-0.288*	*2.966*
FX (A)	*-0.25*	*-0.25*	*0*

Note:

If one further increases the number of layers for integration in the thickness the relative error on DX (X) passes in lower part of 1%. That on DY (X) remains unchanged.

9.2 Parameters of execution

Version: 5.02.20

Machine:
Origin 2000
System:
UNICOS 8.0
Obstruction memory:
100 Mo
Time CPU To use:
15.9 seconds

---

10 Modeling D

10.1 Characteristics of modeling

Z
B
X

D
With
E
C
Z

One seeks a movement independent of Z; only one "line" of quadrangular elements is enough thus.

Cutting: 8 quadrangles MEC3QU9H. Modeling COQUE_3D.

The thickness of the elements is divided into 3 layers for nonlinear calculation [R3.07.04]. Each layer comprises 3 points of integration in higher skin of layer, in the middle of each layer and in lower skin of layer. The model here studied thus includes/understands 7 points of integration in the thickness of the plate.

Boundary conditions:

AB (GROUP_NO: AB): DX = DY = DZ = DRX = DRY = DRZ = 0

ALL: "YES": DZ = DRX = DRY = 0

Loading: two types of loading are applied:
•
nodal forces out of C and D and E (node medium on the side CD) FX (C) = FX (D) =pxLh/6 =0.08333N.

FX (E) =2pxLh/3=0.33N.
•
force distributed on the side CD FX = 5N/mm.

10.2 Characteristics of the grid

A number of nodes:
43 external + 8 interns
A number of meshs and types:
8 QUA9 + 1 SEG3

10.3 Functionalities
tested

Orders

AFFE_MODELE

MODELING
COQUE_3D
AFFE_CARA_ELEM HULL
THICK

A_CIS
AFFE_CHAR_MECA
FORCE_NODALE

FORCE_ARETE
STAT_NON_LINE COMP_INCR RELATION
"VMIS_ISOT_LINE"
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/01/010/A

---

11 Results of modeling D

11.1 Values tested

With the sequence number 10 = 1 is T. The results are identical with FORCE_NODALE or

FORCE_ARETE.

Identification Reference Aster (mm)
% difference
DX (X)
0.02743 0.02762
0.701
DY (X)
-0.2804 -0.2807
0.091

11.2 Parameters
of execution

Version:
5.02.20

Machine:
Origin 2000
System:
UNICOS 8.0
Obstruction memory:
100 Mo
Time CPU To use:
45.7 seconds

11/14

12 Modeling

E

12.1 Characteristics of modeling

Z
B
X
D
With
X E
xC
Z

One seeks a movement independent of Z; only one "line" of quadrangular elements is enough thus.

Cutting: 12 triangles MEC3TR7H. Modeling COQUE_3D.

The thickness of the elements is divided into 3 layers for nonlinear calculation [R3.07.04]. Each layer comprises 3 points of integration in higher skin of layer, in the middle of each layer and in lower skin of layer. The model here studied thus includes/understands 7 points of integration in the thickness of the plate.

Boundary conditions:

AB (GROUP_NO: AB): DX = DY = DZ = DRX = DRY = DRZ = 0

ALL: "YES": DZ = DRX = DRY = 0

Loading: two types of loading are applied:

•
nodal forces out of C and D and E (node medium on the side CD) FX (C) = FX (D) =pxLh/6 =0.08333N.

FX (E) =2pxLh/3=0.33N.

•

force distributed on the side CD FX = 5N/mm.

12.2 Characteristics of the grid

A number of nodes:
75 external + 24 interns
A number of meshs and types:
24 TRIA7 + 1 SEG3

12.3 Functionalities
tested

Orders

AFFE_MODELE

MODELING
COQUE_3D
AFFE_CARA_ELEM HULL
THICK

A_CIS
AFFE_CHAR_MECA
FORCE_NODALE

FORCE_ARETE
STAT_NON_LINE COMP_INCR
RELATION
“VMIS_ISOT_LINE”
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/01/010/A

---

13 Results of modeling E

13.1 Values tested

With the sequence number 10 = 1 is T. The results are identical with FORCE_NODALE or FORCE_ARETE.

Identification	Reference	Aster (mm)	% difference
DX (X)	0.02743	0.0275	0.244
DY (X)	-0.2804	-0.2820	0.556

13.2 Parameters of execution

Version:
5.02.20

Machine:
Origin 2000

---

14 Modeling F

14.1 Characteristics of modeling

y
0
X
C
Fx
Z

Cutting: 20 segments => 20 segments SEG3. Modeling COQUE_D_PLAN.

The thickness of the elements is divided into 7 layers for nonlinear calculation [R3.07.02]. Each layer comprises 3 points of integration in higher skin of layer, in the middle of each layer and in lower skin of layer. The model here studied thus includes/understands 15 points of integration in the thickness of the plate.

Boundary conditions:

(NODE: 0): DX = DY = DZ = DRX = DRY = DRZ = 0

Loading:
· nodal force out of C: FX (C) = p H = 5N/mm.
X

14.2 Characteristics of the grid

A number of nodes:
41
A number of meshs and type:
20 SEG3

14.3 Functionalities
tested

Orders

AFFE_MODELE

MODELING
COQUE_D_PLAN
AFFE_CARA_ELEM HULL
THICK

A_CIS
AFFE_CHAR_MECA
FORCE_NODALE

STAT_NON_LINE COMP_INCR
RELATION
"VMIS_ISOT_LINE"
NEWTON
STAMP
"ELASTIC"

---

15 Results of modeling F

15.1 Values tested

With the sequence number 10 = 1 is T. Values given by using as tangent matrix that calculated numerically are:

Identification	Reference	Aster (mm)	% difference
DX (X)	0.02743	0.02753	0.381
DY (X)	-0.2804	-0.2848	1.556

With the sequence number 10 = 1 is T. Values given by using as tangent matrix the matrix rubber band are:

Identification Reference Aster (mm)
% difference
DX (X)
0.02743 0.02753
0.383
DY (X)
-0.2804 -0.2848
1.558

Note:

To put 3 layers for integration in the thickness leads to an error of 2.4% on the estimate DX (X).

15.2 Parameters of execution

Version:
5.02.20

Machine:
Origin 2000
System:
UNICOS 8.0
Obstruction memory: 100 Mo
Time CPU To use: 72.5 seconds

16 Summary of the results

One notices the good adequacy of the reference solution Aster 2D deformation planes with *results obtained by modelings in voluminal hulls. The variation on displacements at the point of maximum arrow on the initial geometry is indeed lower than 1%. The variation with modeling in linear hull is of about a 1.5% on the estimate of the maximum arrow of sheet. This variation becomes more important for modelings in elements of plates which do not take into account curve of corrugated sheet. The relative error on the estimate of the maximum arrow does not seem to want to go down in lower part from 3%, and this same by increasing the number of layers for to improve integration of plasticity in the thickness of the element. It is noticed for this reason that one increase in the number of layers in the thickness makes it possible to improve the estimate of displacement*
DX at the point where the arrow is maximum without to improve the estimate of the latter, and it,

for the whole of the studied models. The difference in quality of results between the various models undoubtedly comes from the taking into account of the curve of corrugated sheet.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.118 document
SSNV118 - Tensile test shearing
with the viscoplastic model of Chaboche

Summary:
Nonlinear quasi static problem of mechanics of the structures in transient.
Analyze response of an element of volume to a loading of traction-shearing which imposes a state of uniform stress-strain.
On an identical problem, one carries out two modelings to test the taking into account of the parameters constant or depend on the temperature and integration with a tangent or elastic matrix.
This test validates the numerical integration of the model of behavior elastoviscoplastic of fascinating Chaboche
in account the phenomenon of memorizing of work hardening.

---

1 ***Problem of reference***

1.1 Geometry

Z, dz
D
5
8
7
Face YZ: (1, 4, 5, 8)
6
Face XZ: (1, 2, 5, 6)

D
D
Face 1YZ: (2, 3, 6, 7)
Face 1XZ: (4, 3, 8, 7)
D

D

1
4
y, Dy
D: imposed pressure
: imposed shearing
D
3
2
X, dx

1.2 ***Material properties***

Isotropic elasticity E = 145.000 MPa = 0.3
Model viscoplasticity VISCOCHAB
K
35 MPa
B

12
ETA
0.04
C2
65000 MPa
A_K
1.
M_R
2
C1
1950 MPa
M_2
4
A_R
0.65
G_R
2107
M_1
4
D2
0.552 101
K_0
70 MPa S1/N
DRIVEN
19
D1
0.397 103
G_X2
1. 1012
MPam1 S1
NR
24
Q_M
460
G_X1
2. 1013
G2_0
1300 MPa
MPam1 S1
ALP
0 MPa
Q_0
40 MPa

G1_0
50 MPa
A_I
0.5
QR_0
200 MPa
1.3
Boundary conditions and loadings
N6
dx = Dy = dz = 0
Face XZ: FX = D/4
N7
dx = Dy = 0
Face YZ: FY = D/4, FX = D/4
N2, N3
Dy = 0
Face 1XZ: FX = D/4
Face 1YZ: FY = D/4, FZ = D/4
1.4 Conditions
initial
Null constraints and deformations with T = 0.
D
P
0
D
D (T) and D (T) linear, the point P being reached into 10 S with D (10) = 150 MPa and D (10) = 60 MPa

---

2
Reference solution
2.1
Method of calculation used for the reference solution

One uses to establish the reference solution the software SIDOLO which allows simulation and identification of laws of behavior.

The equations of the model are written by the user in FORTRAN in the form of a system of equations first order differentials, solved by a method of Runge Kutta of order 4 with adaptive step.

2.2
Results of reference

xx, xy, xx, xy, X1xx, X 2xx, p, R, Q, xx at the moment P (T = 10 S) or X1et X 2 are the variables of kinematic work hardening, p cumulated plastic deformation, R (p, Q) the variable of work hardening isotropic and the internal variable allowing the taking into account of the memory of work hardening.

2.3
Uncertainty on the solution

Uncertainty of SIDOLO.

2.4 References
bibliographical

[1]
SIDOLO, version 2.3, Note of use, École Nationale Supérieure of the Mines of Paris,
Center Materials, September 1995.

---

3 Modeling
With
3.1
Characteristics of modeling

Modeling 3D

Z

5
8
7
6
1
4
y
3
2
X

3.2
Characteristics of the grid

1 HEXA8

3.3 Functionalities
tested

Order
Key word factor
Simple key word
Argument
Keys
DEFI_MATERIAU
VISCOCHAB
[U4.23.01]
STAT_NON_LINE
COMP_INCR
RELATION
“VISCOCHAB”
[U4.32.01]
NEWTON
STAMP
“TANGENT”
NEWTON
ITER_LINE_MAXI
5
CONVERGENCE
ITER_INTE_PAS
10

---

4 Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
xx	150	149.991	0.006
xy	60	59.949	0.009
xx	1.49455 E2	1.50735 E2	0.856
xy	0.888452 E2	0.896134 E2	0.865
X xx 1	12.4955	12.4880	0.060
X 2xx	30.0352	30.0546	0.065

p
1.69335 E2
1.70435 E2
0.709
R
8.36836
8.43440
0.789
Q
6.76633 E4
6.81646 E4
0.741

1.33485 E2
1.34492 E2
0.754
xx

4.2 Remarks

One uses only 11 increments of time in Aster, but the step of time is redécoupé by 10 for the local integration of the equations of the model.
SIDOLO uses several hundreds of step of times, calculated automatically.

4.3 Parameters of execution

Version: 3.06
Machine: CRAY C90
System:
UNICOS
Obstruction memory:
8 MW
Time CPU To use:
68.8 seconds
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/96/044 - Ind A

Code_Aster **®**
Version
3
Titrate:
SSNV118 Test tensile cisailement - Chaboche viscoplastic
Date:
21/07/99
Author (S):

5 Modeling
B
5.1
Characteristics of modeling

Modeling 3D

Z
5
8
7
6
1
4
y
3
2
X

5.2
Characteristics of the grid

1 HEXA8

5.3 Functionalities
tested

Order
Key word factor
Simple key word
Argument
Keys
DEFI_MATERIAU
VISCOCHAB_FO
[U4.23.01]
STAT_NON_LINE
COMP_INCR
RELATION
“VISCOCHAB_FO”
[U4.32.01]
NEWTON
STAMP
“ELASTIC”
NEWTON
ITER_LINE_MAXI

5
CONVERGENCE
ITER_INTE_PAS
15

6
Results of modeling B

6.1 Values tested

Identification	***Reference***	***Aster***	***% difference***
xx	*150*	*149.899*	*0.067*
xy	*60*	*59.969*	*0.052*
xx	*1.49455 E2*	*1.50922 E2*	*0.982*
xy	*0.888452 E2*	*0.897261 E2*	

0.991
X xx
1
12.4955
12.4831
0.100
X 2xx
30.0352
30.0459
0.035
p
1.69335 E2
1.69886 E2
0.385
R
8.36836
8.40477
0.435
Q
6.76633 E4
6.79380 E4
0.406

1.33485 E2
1.34060 E2
0.431
xx

6.2 Remarks

The precision of the results is of the same order as for modeling A with a tangent matrix rubber band and a smaller recutting of the step of time for the local integration of the equations of model.

6.3 Parameters of execution

Version: 3.06
Machine: CRAY C90
System:
UNICOS
Obstruction memory:
8 MW
Time CPU To use:
94.5 seconds

HI-75/96/044 - Ind A

7 Summary of the results

The equations of the model being strongly nonlinear, it is necessary to use increments of small times to obtain a precise solution.

On this test presenting a geometry and boundary conditions simple, the recutting of the step of time at the local level makes it possible to improve the precision of the results without increasing the time too much of calculation.

Author (S):
E. LORENTZ

Organization (S): EDF/IMA/MMN

Handbook of Validation

V6.04 booklet: Nonlinear statics of the voluminal structures

V6.04.121 document

SSNV121 - Rotation and traction hyper-rubber band of a bar

Summary:

This test of quasi-static mechanics consists in making turn of 90° a parallelepipedic bar, with
to subject to an important traction for finally letting it return in a discharged state. One validates thus kinematics of the great deformations hyper-rubber bands (order STAT_NON_LINE [U4.32.01], key word
COMP_ELAS), and thus in particular great rotations, for a relation of elastic behavior linear.
The bar is modelled by a voluminal element (HEXA8, modeling A) or plan (QUAD4, assumption plane deformations, modeling B).
The results obtained by Code_Aster do not differ from the theoretical solution.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/96/044 - Ind A

---

1 **Problem of reference**

1.1 Geometry

y
1.000 (mm)
1
2
3
4
X
1.000 (mm)

1.2 **Material properties**

Behavior hyper-rubber band of Coming St - Kirchhoff:
E
E
E = 200.000.MPa
S
= (

tr
+
1+)(1-
2)
(E) 1
E
1 +
= 0 3
.
1.3
Boundary conditions and loadings
The loading is applied in two times: first of all, an overall rotation of the structure, followed by a traction in the new configuration:
Overall rotation (0 < T < 1 S)
Traction (1 S < T < 2 S)
T
2 '
4 '
1
2
2 '
4 '
3
4
1 '
1 '
3

2
Reference solution
2.1
Method of calculation used for the reference solution

It is about a plane problem. One can seek the solution in the form of a rigid rotation and one lengthening of a factor in direction *Y*.

- *X* - *Y*

U (*X*, *Y*, *Z*) =
(1+) *X* - *Y*

0

The gradient of the transformation and the deformation of Green-Lagrange are then:

0
-1

0
E 0

0

(+ 2)
F
=
1 +
0
0 **E**

= 0 0
0
with *E* =
2

0
0

1

0 0 0
The relation of behavior leads then to a tensor of Lagrangian constraints diagonal:

(1) *E*
S

=
xx

(1+) (1 - 2) *E*

E
S
= *S*
=
yy
zz

(1+) (1 - 2) *E*
The boundary condition of the equilibrium equation then enables us to determine the value of lengthening:
(1-)
+1 +
= (
2
FS)
= (1+)
E
(
)(
)
T
S
(
=
1 +)(1- 2)
T
yx
xx
2

The constraint of Cauchy is given by:

S yy
1

xx
=
zz
=
=
F S F *T*

1+
Det **F**

yy
= (1+)

S xx
Lastly, the force exerted on the faces:
· [2,4]: *F*
=
=
y
yy
[
S 2,4]
yy So [2,4]
· [4,3]: *F*
=
= 1+
X
xx
[
S 4,] 3
xx (
) *So* [4,] 3
· [1,2,3,4]: *F*
=
= 1+
Z
zz

[
S 1,2,3,4]
zz (
) *So* [1,2,3,4]
where *S* [
O]
initial surfaces of the faces represent.

2.2 Results of reference

One adopts like results of reference displacements, the constraint of Cauchy and the force exerted on the faces [2,4] and [4,3].

At time T = 2 S:

One seeks *T* such as lengthening
= 01.
==> *T* = 31 096.154 MPa.
The constraint of Cauchy is then:

=
=
xx
zz
11 013.986 MPa

=
yy

31 096.154 MPa
The exerted forces are:
F
= 12.115.385
.
×
X
So [4,] *NR*
3
F
= 31 096.154 ×
y
So [2,4] *NR*
F
= 12 115.385 ×
Z
So [, 12, 34] *NR*
At time T = 3 S:
The bar returned in its initial state:
= 0

= 0
F =

0

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
Eric LORENTZ “a nonlinear relation of behavior hyperelastic” Notes intern
EDF/DER HI-74/95/011/0

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/96/044 - Ind A

Code_Aster ®
Version
3
Titrate:
SSNV121 Rotation and traction hyper-rubber band of a bar
Date:

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3 Modeling
With

3.1
Characteristics of modeling

Voluminal modeling:
1 mesh HEXA 8
1 mesh QUAD4
Z
5
6
y
7
8
1
2
1.000 (mm)
3
4
X

Boundary conditions:

R T
( )
(3,7): DX = 0

DY = 0
1
(1,5): DX = - 1.000 R (T)
DY = - 1.000 R (T)
(2,6): DX = - 2.000 R (T)
(4,8): DX = - 1.000 R (T)
0
1
2
3
T
Loading: Traction on the face [2,4,8,6]
net [2,4,8,6] (QUAD4): FY = 31 096.154 F (T) MPa
F T
( )
1
0
1
2
3
T
3.2
Characteristics of the grid
A number of nodes: 8
A number of meshs: 2
1 HEXA8
1 QUAD4
3.3 Functionalities
tested
STAT_NON_LINE
COMP_ELAS
DEFORMATION: “GREEN”
CALC_NO
OPTION: “FORC_NODA”
GEOMETRY: “DEFORMED”
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/96/044 - Ind A

---

4 Results of modeling A

4.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
T = 2 Displacement DX (NO2)	100	100	0
T = 2 Displacement DY (NO4)	1100	1100	0
T = 2 Constraints SIGXX (PG1)	11013.986	11013.986	0
T = 2 Constraints SIGYY (PG1)	31096.154	31096.154	0
T = 2 Constraints SIGZZ (PG1)	11013.986	11013.986	0
T = 2 Constraints SIGXY (PG1)	0	109	

/
T = 2 Constraints SIGXZ (PG1)
0
1010
/
T = 2 Constraints SIGYZ (PG1)
0
1010
/
T = 3 Displacement DX10 (NO2)
0
1011
/
T = 3 Displacement DY (NO4)
0
1012
/
T = 3 Constraints SIGXX (PG1)
0
109
/
T = 3 Constraints SIGYY (PG1)
0
1010
/
T = 3 Constraints SIGZZ (PG1)
0
109
/
T = 3 Constraints SIGXY (PG1)
0
1011
/
T = 3 Constraints SIGXZ (PG1)
0
1010
/
T = 3 Constraints SIGYZ (PG1)
0
1011
/
T = 2 nodal Force DX (NO8)
3.0289 109

3.0288 109
-0.002%
T = 2 nodal Force DY (NO8)
7.774 109
7.774 109
0
T = 2 nodal Force DZ (NO8)
3.0289 109
3.0288 109
-0.002%

4.2 Remarks

Calculation of the nodal force:

The force applied *F* to a face described by a linear mesh is distributed by:

1/4
1/4
F
= 1
node
F

4
1/4
1/4

4.3 Parameters
of execution

Version: 3.03.30
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
62.3 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling 2D plane deformations

y
1
2
3
4
X

Boundary conditions:

R T
( )
3 :
DX = 0

DY = 0
1
1 :
DX = - 1.000 R (T)
DY = - 1.000 R (T)
2 :
DX = - 2.000 R (T)
4 :
DX = - 1.000 R (T)
0
1
2
3
T

Loading:

Traction on the face [2,4]
net [2,4]: FY = 31 096.154 F (T) MPa
F T
( )
1
0
1

2
3
T

5.2
Characteristics of the grid

A number of nodes: 4
A number of meshs: 2
1 QUAD4
1 SEG2

5.3 Functionalities
tested

STAT_NON_LINE
COMP_ELAS
DEFORMATION: "GREEN"
CALC_NO
OPTION: "FORC_NODA"
GEOMETRY: "DEFORMED"

6
Results of modeling B

6.1 Values
tested

Identification
Reference
Aster
% difference
T = 2 Displacement DX (NO2)
100

100
0
T = 2 Displacement DY (NO4)
1100
1100
0
T = 2 Constraints SIGXX (PG1)
11013.986
11013.986
0
T = 2 Constraints SIGYY (PG1)
31096.154
31096.154
0
T = 2 Constraints SIGZZ (PG1)
11013.986
11013.986
0
T = 2 Constraints SIGXY (PG1)
0
10-10
/
T = 3 Displacement DX (NO2)
0
1012
/
T = 3 Displacement DY (NO4)
0
1012
/
T = 3 Constraints SIGXX (PG1)
0
1010
/
T = 3 Constraints SIGYY (PG1)
0
1010
/
T = 3 Constraints SIGZZ (PG1)
0
1010
/
T = 3 Constraints SIGXY (PG1)

0
1010
/
T = 2 nodal Force DX (NO4)
6.0577 106
6.0577 106
0
T = 2 nodal Force DY (NO4)
15.5481 106
15.5481 106
0

6.2 Remarks

Calculation of the nodal force:

The force applied *F* to a face described by a linear mesh is distributed by:

1/2
1/2
F
= 1
node
F

2

6.3 Parameters
of execution

Version: NEW 3.03.30
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
48.3 seconds

---

7 Summary of the results

It appears at the end of this test that the numerical solution coincides remarkably with the solution analytical. It will be noticed however that the strong not linearity due to great rotations requires a relatively fine discretization in time, without being penalizing on the precision since, contrary to an incremental law of behavior, the errors do not cumulate a step of time on the other.

Organization (S): EDF/IMA/MNN

Handbook of Validation

V6.04 booklet: Nonlinear statics of the voluminal structures

V6.04.122 document

SSNV122 - Rotation and following traction hyper-rubber band of a bar

Summary:

This test of quasi-static mechanics consists in making turn of 90° a parallelepipedic bar and to

to subject to an important traction by means of following forces. One validates the kinematics of large thus
deformations hyper-rubber bands (order STAT_NON_LINE [U4.32.01], key word COMP_ELAS), and thus in
private individual great rotations, for a relation of elastic behavior linear, as well as the catch in
count following forces (order STAT_NON_LINE [U4.32.01] key word TYPE_CHARGE: "SUIV").
The bar is modelled by a voluminal element (HEXA8, modeling A).
The results obtained by Code_Aster do not differ from the theoretical solution.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/96/044 - Ind A

Code_Aster ®
Version
3
Titrate:
SSNV122 Rotation and following traction hyper-rubber band of a bar
Date:
23/07/99
Author (S):
E. LORENTZ
Key:
V6.04.122-A Page:
2/8

1
Problem of reference

1.1 Geometry

y
1.000 (mm)
1
2
3
4
X
1.000 (mm)

1.2
Material properties

Behavior hyper-rubber band of COMING SAINT - KIRCHHOFF:
E
E
E = 200.000. MPa
S
= (

tr
+
1+)(1-
2)
(E) 1
E
1 +
= 0 3
.
1.3
Boundary conditions and loadings

The loading is applied in two times: first of all, an overall rotation of the structure, followed by a traction exerted by following forces.

Overall rotation (0 < T < 1 S)
Traction (1 S < T < 2 S)
T = p *NR*
NR: normal
external with
face [2, 4].
2 '
4 '
1
2
2 '
4 '
3
4
1 '
1 '
3

2
Reference solution
2.1
Method of calculation used for the reference solution

It is about a plane problem. One can seek the solution in the form of a rigid rotation followed of one dilation of a factor *has* in a direction and *B* in the other:

X
- *Y*
B (- *Y*)
- *X* - *bY*
rotation

traction

Y
X
X has
that is to say *U* = *AX*
- *Y*

Z
Z
Z
0

The gradient of the transformation and the deformation of Green-Lagrange are then:

2
0
- *B*

0
E

0

has -
0
1

X

ex =
F
=
has
0
0 **E**

= 0 *ey*
0
2
where
2
B - 1

0 0

1

0
0

0
E y =
2
The relation of behavior leads to a tensor of Lagrangian constraints diagonal (with
and µ coefficients of Lamé):
S
= + 2µ
+
xx
(
) *E*
E

X
y
E
= 1+ 1 - 2
S
= *E*
+ + 2µ
yy
X
(
)
(
)(
)
E y
where
E
µ = (21+)
S
= *E*
+ *E*
zz
X
y
One deduces the tensor from it from the constraints of Cauchy, him so diagonal:

B
has
=
=
= 1
X
S y
y
S X
Z
Sz
has
B
B has
Finally the boundary conditions are written:
= 0 (edge libr)
E

= -
X

(traction)
y
p
One can moreover calculate the efforts exerted on the faces:
[1, 3]
F = - *B S*
y
y
O [1, 3]
[3, 4]
F = 0
X
[
- *ab S*
on the lower side of the face
Z

O 1, 2, 3,4
1, 2, 3, 4]
[
]
F =
Z
Z ab So

[1, 2, 3,4] on the higher side of the face
where *So* [] represent initial surfaces of the faces.

2.2
Results of reference

One adopts like results of reference displacements, the deformations of Grenn-Lagrange, them constraints of Cauchy and forces exerted on the faces [1, 3], [3, 4] and [1, 2, 3, 4] in end of loading (T = 2 S).

One seeks *p* such as dilation *has* = 1,1

==> *p* = 26610.3 MPa.

Dilation *B* and displacements are then:

B = 0.9539 *E* = 0.105 *E* = -
X
y
0.045

The constraints of Cauchy vallent:

= 0
= 26610.3 MPa
=
X
y
Z 6597.6 MPa

Lastly, the exerted forces are:

F
=
X
0
F
= -
y
25384 *So* [1,] *NR*
3
F
= -
9
Z
6.9228 10
NR
(lower side)

2.3
Uncertainty on the solution

Analytical solution.

2.4 References

bibliographical
[1]
Eric LORENTZ "a nonlinear relation of behavior hyperelastic" Notes intern
EDF/DER HI-74/95/011/0

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3 Modeling
With

3.1
Characteristics of modeling

Voluminal modeling:
1 mesh HEXA 8

1 mesh QUAD4
Z
5
6
y
7
8
1
2
1.000 (mm)
3
4
X
· rigid phase of rotation 0 T1 S
[3,7] *DX* = 0
DY = 0
DZ = 0
[
T

T
1,5] *DX* = 1000
-
sin
DY
1000 1 cos
DZ
0

2
= -
-

2
=
[2,6]
DZ = 0
[4,8]
DZ = 0
· phase of traction: 1s T 2s
-
boundary conditions (TYPE_CHARGE: “DIDI”)
[3,7] *DX* = 0 *DY* = 0 *DZ* = 0

[1,5]
DY = 0 *DZ* = 0
[2,6]
DZ = 0
[4,8]
DZ = 0
-
loading: pressure (negative) on the face [2, 4, 8, 6]
(PRES_REP): net [2, 4, 8, 6] (QUAD4): CLOSE = 26610.3 (T1).

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs: 2
1 HEXA8
1 QUAD4

3.3 Functionalities
tested

Order
Keys

STAT_NON_LINE
COMP_ELAS
DEFORMATION: "GREEN"
[U4.32.01]
EXCIT
TYPE_CHARGE: "DIDI"
EXCIT
TYPE_CHARGE: "SUIV"
CALC_NO
OPTION: "FORC_NODA"
GEOMETRY: "DEFORMED"
[U4.61.03]
CALC_ELEM
OPTION: "EPSG_ELNO_DEPL"
[U4.61.02]

Date:
23/07/99
Author (S):
E. LORENTZ
Key:
V6.04.122-A Page:
7/8

4 Results of modeling A

4.1 Values tested

The values are tested at the end of the loading (T = 2s)

Identification	**Reference**	**Aster**	**% difference**
Displacement DX (NO2)	1953.94	1953.92	0
Displacement DY (NO2)	100.	100.	0
Constraints SIXX (PG1)	0	8. 1010	
Constraints SIYY (PG1)	26610.3	26610.3	0
Constraints SIZZ (PG1)	6597.6	6597.6	0
Constraints SIXY (PG1)	0	1026	
Constraints SIXZ (PG1)	0	1011	
Constraints SIYZ (PG1)	0		

1010
Deformation EPXX (PG1)
0.105
0.105
0
Deformation EPYY (PG1)
0.045
0.045
0
Deformation EPZZ (PG1)
0
1016
Deformation EPXY (PG1)
0
1014
Deformation EPXZ (PG1)
0
1014
Deformation EPYZ (PG1)
0
1016
Nodal reaction DX (NO3)
0
103
Nodal reaction DY (NO3)
6.3462 109
6.3461 109
0.001
Nodal reaction DZ (NO3)
1.7307 109
1.7307 109
0.004

4.2 Remarks

Calculation of the nodal force:

The force applied *F* to a face described by a linear mesh is distributed by:

1/4
1/4
F
= 1
node
F

4

1/4
1/4
4.3 Parameters
of execution
Version: 3.05.32
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
33.59 seconds

---

5 Summary of the results

It appears at the end of this test that the numerical solution coincides remarkably with the solution analytical. It will be noticed however that the strong not linearity due to great rotations requires a relatively fine discretization in time, without being penalizing on the precision since, contrary to an incremental relation of behavior, the errors do not cumulate a step time on the other.

24/08/99
Author (S):
B. QUINNEZ, L. VIVAN
Key:
V6.04.123-A Page:
1/6
Organization (S): EDF/IMA/MMN, CISI

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.123

SSNV123 - Solid mass resting on a mattress
rubber band

Summary

This test makes it possible to validate modeling “APPUI_REP” [U4.22.04] for elements of faces of elements
three-dimensional. It corresponds to a static analysis of a cube subjected to its own weight, and which rests on
an elastic mattress.

1
Problem of reference

1.1 Geometry

case 1
case 2
y
Z
H
D
C
G
F
E
H
G
C
C
B
D
With
B
With
has
B
X
X
E
F
Z
= 1. m has
B = 1.5 m

C = 0.5 m

1.2

Material properties

E = 2.1 1011 Pa

= 0.3

= 7800 kg/m3

E_N = 7.107 N/m3

1.3

Boundary conditions and loadings

· Chargement: actual weight following Z

Following displacements X and Y blocked with zero.

· Chargement: actual weight following Y

Following displacements X and Z blocked with zero.

1.4 Conditions

initial

Without object.

2

Reference solution

2.1

Method of calculation used for the reference solution

Each node of the solid mass must undergo a displacement equal to:

a.

B.

C. *G*

C G

case 1:

D =

=
1
a.
B E
E
F
F
B.C.G has.
B G
case 2:
D =
=
2
C E has
E
F
F

2.2
Results of reference

case 1: displacement following Z
case 2: displacement following y

2.3
Uncertainty on the solution

Analytical solution.

---

3 Modeling
With
3.1

Characteristics of modeling
y
case 1
Z
case 2
With
B
E
D
y
With
X
F
Z
C
B
X
Modeling APPUI_REP: 1 QUAD8
Modeling APPUI_REP: 2 TRIA6
Boundary conditions:
Boundary conditions:
for all the nodes DX = DY = 0.
for all the nodes DX = DZ = 0.

3.2
Characteristics of the grid

A number of nodes: 22
A number of meshs and types: 2 PENTA15

3.3 Functionalities
tested

Orders
Keys
DEFI_GROUP
CREA_GROUP_NO
GROUP_MA
[U4.12.03]
CREA_MAILLAGE
CREA_GROUP_MA
GROUP_MA
[U4.12.06]
DEFI_MATERIAU
APPUI_ELAS
[U4.23.01]
AFFE_MODELE

MODELING: APPUI_REP
[U4.22.01]
CALC_MATR_ELEM
RIGI_MECA
[U4.41.01]
Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HI-75/98/040 - Ind A

4
Results of modeling A
4.1 Values
tested
Case 1
Identification
Reference
Aster
% difference
WITH DZ
-5.46557E-04
-5.46485E-04
-0.013
B DZ
-5.46557E-04
-5.46455E-04
-0.019
C DZ
-5.46557E-04
-5.46455E-04
-0.019
D DZ

-5.46557E-04
-5.46485E-04
-0.013
E DZ
-5.46557E-04
-5.46615E-04
0.011
F DZ
-5.46557E-04
-5.46645E-04
0.016
G DZ
-5.46557E-04
-5.46645E-04
0.016
H DZ
-5.46557E-04
-5.46615E-04
0.011
Case 2
Identification
Reference
Aster
% difference
WITH DY
-1.63967E-03
-1.63951E-03
-0.010
B DY
-1.63967E-03
-1.63966E-03
-0.001
C DY
-1.63967E-03
-1.63966E-03
-0.001
D DY
-1.63967E-03
-1.63951E-03
-0.010
E DY
-1.63967E-03
-1.64014E-03

0.029
F DY
-1.63967E-03
-1.64019E-03
0.032
G DY
-1.63967E-03
-1.64019E-03
0.032
H DY
-1.63967E-03
-1.64014E-03
0.029

4.2 Parameters of execution

Version: 3.06.04
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
5 seconds

5
Summary of the results

The results obtained agree well with the results of reference.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.124

SSNV124 - Analyze regularized limit.
Law of Norton-Hoff

Summary

This test makes it possible to validate the operators used analyzes regularized limit of it. One calculates the load limits by
a kinematic approach regularized by the method of Norton-Hoff-Friaâ.
One considers a rectangular plate (modeling A) or a cube (modeling B) or a cylinder
axisymmetric (modeling C). The constitutive material checks the criterion of von Mises and the structure is subjected
with loadings on the edges. Calculation makes it possible to obtain the limiting load in the direction of the loading.
The structure is modelled by incompressible elements and the loading is standardized.
The resolution by the regularized method of Norton-Hoff-Friaâ is carried out in order
STAT_NON_LINE
[U4.32.01]. A postprocessing in order POST_ELEM [U4.61.04] makes it possible to obtain the value of a terminal
higher of the limiting load, .ainsi qu' an estimate.
The reference solution is analytical and the results are in perfect agreement with the values of reference.

1 Problem of reference

1.1 Geometry

Z
H
G
y
With
D
B
1
With
E
F
1
3
X
y
B
D
1
C
C
has
B
X
2D_PLAN and AXIS
3D

1.2 Material properties

Young modulus: *E* = 200.000 *MPa*.
Poisson's ratio: = 0.5
Elastic limit: =
y
10 *MPa*.
Coefficient of the law of Norton-Hoff: *N* = 5

1.3
Boundary conditions and loadings

Conditions limit in 2D:
· on AB: DX = 0.
· on BC: DY = 0.
Conditions limit in 3D:
· EFGH (FACEXINF): DX = 0.
· ADEH (FACEYINF): DY = 0.
· DCFE (FACEZINF): DZ = 0.
Conditions limit in AXIS:
· on BC and AD: DY = 0.
The loading parameterized by is:
· in 2D:
FY = 1. on AD
· in 3D:
FX = 0.2 on ABCD (FXSUP)
FY = 0.8 on BCFG (FYSUP)
· in AXIS:
FX = 1. on AB.

2
Reference solution

2.1
Method of calculation used for the reference solution

One considers a rectangular plate (modeling A) or a cube (modeling B) or a cylinder axisymmetric (modeling C). The constitutive material checks the criterion of von Mises, with for threshold *Y*.

The structure is subjected to pressures on the edges horizontal - *F* and vertical - (1 -) *F* with

0.5 (= 1.en 2D, = 0.8 in 3D). In plane 2D, one considers two ways of making: on the one hand in amplifying the two pressures together, in addition while amplifying that horizontal pressure, and in leaving the constant vertical. Into axisymmetric, the solid is subjected to the internal pressure only - *F*. One obtains the exact limiting load and that by the method of regularization [R7.07.01] in this direction of loading, for the criterion of von Mises, with threshold *Y*.

Modeling
case

sup
estimated
power
lim

lim
lim
L0 (**U**)
With
plane 2D
2

2

0
y
N
=
y
2
y
.
.
lim
3
.
2 - 1
F
3 2 - .
1
F
3 2a - 1
F
1 + *N*

Abis
plane 2D
2 3

nothing
-
y
1 -
y
-
1
+

2 3
1
F
+
F
.0 F
3
0
F

3
0
F

B
3D
1

0
=
y
1
y
1
y
N
0 8
,

=
lim
.
.
.
.

3 2 -
3 + 1 *F*
3 2
- 3 +1 *F*
3 2
- 3 +
F
+
1
1 *N*
C
2D AXIS

2

0
=
y
B
2 3
y
B
2 3
B
N
1
= 2 3
y
lim
.
.ln
.
.ln
.
.ln
.

3
F
has
3
F
has
3
F
1 + *N has*
2.2
Results of reference
Modeling
case

sup
estimated
lim

power *L0* (**U**)
lim
lim
With
plane 2D
11.547
11.547
9.6225
0
Abis
plane 2D
14.6837
14.6837
nothing
0.25
B
3D
13.867
13.867
11.556
0
C
2D AXIS
12.685
12.685

8.5545
0

2.3 References
bibliographical

[1]
VOLDOIRE F., SCREWS E.: Calculation of load limits by the method of Norton-Hoff-Friaâ.
[R7.07.01]

---

3 Modeling
With

3.1
Characteristics of modeling

One considers a rectangular plate modelled by element QUAD8 of an incompressible type: miplqu8. The two cases are studied: the first with the two amplified loads, the second with amplified horizontal pressure and the constant vertical.

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 mesh of the incompressible type QUAD8.

3.3 Functionalities
tested

Orders
Key word factor
Single-ended spanner word
Argument
Keys
DEFI_MATERIAU
NORTON-HOFF

NR
[U4.23.01]
SY
AFFE_CHAR_MECA
LIAISON_CHAMNO
CHAM_NO
[U4.25.01]
NUME_LAGR
“AFTER”
STAT_NON_LINE
COMP_INCR
RELATION
“NORTON_HOFF”
[U4.32.01]
SOLVEUR
METHOD
“LDLT”
AFFE_CHAR_MECA
LIAISON_CHAMNO
CHAM_NO
[U4.25.01]
POST_ELEM
CHAR_LIMITE
ALL
“YES”
[U4.61.04]
TEST_TABLE
COUNT
“CHAR_LIMI_SUP”
[U4.72.01]
“CHAR_LIMI_ESTIM”
“PUIS_PERMANENTE”

4 Results of modeling A

4.1 Values tested

Identification
Case
Reference
Aster
% difference
Tolerance

Charge higher limit

With
11.547
11.547
0.0
0.1%
Abis
14.6837
14.6837
0.0
0.1%
Charge estimated limit
With
9.6225
9.6225
0.0
0.1%
Abis
nothing
nothing
Permanent power
With
0
0
0.0
0.1%
Abis
0.25
0.25
0.0
0.1%

4.2 Parameters of execution

Version: 4.03
Machine: CRAY C98
System: 9.0
UNICOS
Obstruction memory:
8 megawords
Time CPU To use:
8.7 seconds

5 Modeling B

5.1 Characteristics of modeling

One considers a cube modelled by element HEXA20 of an incompressible type: minc_hexa20.

5.2 Characteristics of the grid

A number of nodes: 20.
A number of meshs and types: 1 mesh of the incompressible type HEXA20.

5.3 Functionalities tested

Orders
Key word factor
Single-ended spanner word
Argument
Keys
DEFI_MATERIAU
NORTON-HOFF
NR
[U4.23.01]
SY
AFFE_CHAR_MECA
LIAISON_CHAMNO
CHAM_NO
[U4.25.01]
NUME_LAGR
“AFTER”
STAT_NON_LINE
COMP_INCR
RELATION
“NORTON_HOFF”

[U4.32.01]
SOLVEUR
METHOD
"LDLT"
AFFE_CHAR_MECA
LIAISON_CHAMNO
CHAM_NO
[U4.25.01]
POST_ELEM
CHAR_LIMITE
ALL
"YES"
[U4.61.04]
TEST_TABLE
COUNT
"CHAR_LIMI_SUP"
[U4.72.01]
"CHAR_LIMI_ESTIM"
"PUIS_PERMANENTE"

6 Results of modeling B

6.1 Values tested

Identification	Reference	Aster	% difference	Tolerance
Charge higher limit	13.867505	13.867505	0.0	0.1%
Charge estimated limit	11.556	11.556	0.0	0.1%

6.2 Parameters of execution

Version: 4.03
Machine: CRAY C98
System: 9.0

UNICOS
Obstruction memory:
8 megawords
Time CPU To use:
5.3 seconds
Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HI-75/98/040 - Ind A

---

7 Modeling C

7.1 Characteristics of modeling

One considers a cylinder modelled by axisymmetric elements QUAD8 of the incompressible type: miaxqu8, according to a regulated grid.

7.2 Characteristics of the grid

A number of nodes: 96
A number of meshs and types: 25 meshs of the incompressible type QUAD8.

7.3 Functionalities tested

Orders
Key word factor
Single-ended spanner word
Argument
Keys
DEFI_MATERIAU
NORTON-HOFF
NR
[U4.23.01]
SY
AFFE_CHAR_MECA
LIAISON_CHAMNO
CHAM_NO
[U4.25.01]
NUME_LAGR
“AFTER”
STAT_NON_LINE
COMP_INCR
RELATION

"NORTON_HOFF"
[U4.32.01]
SOLVEUR
METHOD
"LDLT"
AFFE_CHAR_MECA
LIAISON_CHAMNO
CHAM_NO
[U4.25.01]
POST_ELEM
CHAR_LIMITE
ALL
"YES"
[U4.61.04]
TEST_TABLE
COUNT
"CHAR_LIMI_SUP"
[U4.72.01]
"CHAR_LIMI_ESTIM"
"PUIS_PERMANENTE"

8 Results of modeling C

8.1 Values tested

Identification	Reference	Aster	% difference	Tolerance
Charge higher limit	12.685	12.6866	0.0	0.1%
Charge estimated limit	8.5545	8.72227	1.96	2.0%

8.2 Parameters of execution

Version: 4.03
Machine: CRAY C98

System: 9.0
UNICOS
Obstruction memory:
8 megawords
Time CPU To use:
4.3 seconds

9
Summary of the results

The numerical results are in perfect agreement with the values of reference. In the case axisymmetric, the light differences are explained by the fact why displacement is into 1/*R* in analytical solution, which is not included/understood in the base of the selected finite elements.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.125 document

SSNV125 - Tensile test shearing with polycrystalline model CFC

Summary:

Analyze response of an element of volume to a loading of traction-shearing which imposes a state of uniform stress-strain.

One carries out two modelings to test the taking into account of the parameters constant or dependent on temperature and integration with the elastic matrix (only available for explicit integration used).

This test validates the numerical integration of the model of polycrystalline behavior elastoviscoplastic for cubic structural materials to centered faces.

1

Problem of reference

1.1 Geometry

Z, dz
D
6
7
D
8
5
Face YZ: (3, 1, 7, 6)
Face XY: (4, 2, 1, 3)
Face 1YZ: (4, 2, 5, 8)
D
Face 1XY: (8, 5, 7, 6)
D

3
1

y, Dy
D: imposed pressure
D: imposed shearing
D
4
2
X, dx

1.2
Material properties

Isotropic elasticity E = 192.500 MPa = 0.3
Model viscoplasticity POLY_CFC (units: MPa, S)

DL
149.67
DA
0.0268
NR
7.77
K
13.31 MPa.s1/N

TAU_0
86.5 MPa
Q1
7.29 MPa
B1
5.67
HL
2.43
Q2
16.25 MPa B2
20.04
C1
4000 MPa
D1
42.69
C2
73.26

1.3
Boundary conditions and loadings

N3
dx = Dy = dz = 0
Face YZ: FZ = D/4
N4
Dy = dz = 0
Face XY: FY = D/4
N1, N2
dz = 0
Face 1YZ: FZ = D/4

Face 1XY: FY = D/4, FZ = D

1.4 Conditions
initial

Null constraints and deformations with T = 0.

D
P
0
D

Linear way of loading: D (T) and D (T), the point P being reached in 10 seconds with D (10) = 200 MPa and D (10) = 100 MPa

---

2 Reference solution

2.1 Method of calculation used for the reference solution

One uses to establish the reference solution the software SiDoLo [1] which allows simulation and identification of relations of behavior.

The equations of the model are written by the user in FORTRAN in the form of a system of equations first order differentials, solved by a method of Runge Kutta of order 2 with adaptive step.

2.2 Results of reference

zz, yz, zz, yz at the moments (T = 10 S); yz and zz at the moments (T = 6 S, 8 S and 9,2 S).

2.3
Uncertainty on the solution

Uncertainty of SiDoLo [bib1].

2.4 References
bibliographical

[1]
SiDoLo, version 2.3, Note of use, École Nationale Supérieure of the Mines of Paris,
Center Materials, September 1995.

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D

Z
7
5
8

6
3
1
y
4
2
X

3.2
Characteristics of the grid

1 HEXA8 (8 points of Gauss)

3.3 Functionalities tested

Order Mot-clé
factor
Key word Key Argument
simple
DEFI_MATERIAU POLY_CFC

[U4.23.01]
STAT_NON_LINE COMP_INCR RELATION
"POLY_CFC"
[U4.32.01]
NEWTON
STAMP
"ELASTIC"
CONVERGENCE
RESO_INTE
"RUNGE_KUTTA_2"
CONVERGENCE
RESI_GLOB_RELA
10-4
CONVERGENCE
RESI_INTE_RELA
10-3

Handbook of Validation

4
Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
zz (10s)	200	199,986	-0,007%
yz (10s)	100	99,988	-0,012%
zz (6s)	6.233769 E4	6,233769 E4	-0,000%
yz (6s)	4,051949 E4	4,051951 E4	-0,000%
zz (8s)			

9,222209 E4
9,205512 E4
-0,191%
yz (8s)

6,224790 E4
6,186647 E4
-0,613%
zz (9,2s)

1,402150 E3
1,387270 E3
-1,061%
yz (9,2s)

1,000010 E3
9,695271 E4
-3,048%
zz (10s)

1,841500 E3
1,845873 E3
0,238%
yz (10s)
1,347820 E3
1,326605 E3
-1,574%

4.2 Remarks

The moment 6s corresponds to a loading where there was not plasticization yet.

One uses 11 increments of time in Aster, and the step of time is redécoupé in manner adaptive on the level of the local integration of the equations of the model (explicit cf Integration [R5.03.14]).

SiDoLo uses several hundreds of step of times, calculated automatically.

4.3 Parameters

of execution

Version: 4.00.09

Machine: CRAY C90

System:
UNICOS 8.0
Obstruction memory:
8 MW
Time CPU To use:
179 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling 3D

Z
5
8

7
6
1
4
y
2
3
X

5.2
Characteristics of the grid

1 HEXA8 (8 points of Gauss)

5.3 Functionalities
tested

Order Mot-clé
factor
Key word
Key argument
simple
DEFI_MATERIAU POLY_CFC_FO

[U4.23.01]
STAT_NON_LINE COMP_INCR
RELATION
"POLY_CFC_FO"
[U4.32.01]
NEWTON
STAMP
"ELASTIC"
CONVERGENCE
RESO_INTE
"RUNGE_KUTTA_2"
CONVERGENCE
RESI_GLOB_RELA
10-3
CONVERGENCE
RESI_INTE_RELA
10-3

---

6 Results of modeling B

6.1 Values tested

Identification	Reference	Aster	% difference
zz (10s)	200	199,850	-0,075%
yz (10s)	100	99,872	-0,127%
zz (6s)	6.233769 E4	6,233769 E4	-0,000%
yz (6s)	4,051949 E4	4,051951 E4	-0,000%
zz (8s)			

9,222209 E4
9,197502 E4
-0,278%
yz (8s)

6,224790 E4
6,179939 E4
-0,721%
zz (9,2s)

1,402150 E3
1,384319 E3
-1,272%
yz (9,2s)

1,000010 E3
9,671650 E4
-3,284%
zz (10s)

1,841500 E3
1,840552 E3
-0,051%
yz (10s)
1,347820 E3
1,322064 E3
-1,911%

6.2 Remarks

Modeling B uses the key word factor POLY_CFC_FO with a constant evolution of parameters.

The criterion of total convergence (RESI_GLOB_RELA) is higher of a factor 10 compared to modeling A (saving of time of calculation but loss of a factor approximately 10 on the results of constraint); it is noted that the answers in deformation remain of an order of magnitude close to those modeling A. Moreover, with an accuracy of 102 on balance one has an error of 6% on deformation yz.

6.3 Parameters
of execution

Version: 4.00.09

Machine: CRAY C90

System:
UNICOS 8.0
Obstruction memory:
8 MW
Time CPU To use:
105 seconds

7
Summary of the results

The matrix of tangent behavior is the elastic matrix for the explicit resolution used, it is necessary to consider increments of small times to have convergence, even if method of integration comprises an adaptive step division of local time.

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HI-75/01/010/A

Code_Aster ®
Version
8.3

Titrate:
SSNV127 - Roll in a boring with contact and friction
Date:
04/05/06
Author (S):
Mr. KHAM, S. LAMARCHE, P. MASSIN, Key Mr. TORKHANI: V6.04.127-C Page:
1/18

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.127

SSNV127 - Roll in a boring with contact
and friction

Summary:

This problem corresponds to a quasi-static analysis of a problem of mechanics with contact and friction.
A cylinder is compressed in a cylindrical boring of slightly higher diameter by a force concentrated applied to its axis.

This test, named "problem of Klang", is rather largely used in the literature to validate modelings of contact with friction and was in particular used by P. Alart and A. Curnier [bib1] to validate their finite elements of contact and friction.

Five modelings 2D are proposed (A, B, C and D with linear elements and E with elements quadratic):
Modeling A tests the "LAGRANGIAN" algorithm of the method with master-slave pairing.
Modeling B tests the "LAGRANGIAN" algorithm of the method with nodal pairing.
Modeling C tests the algorithm of the method "PENALIZATION" with master-slave pairing, penalization relates only to friction.
Modeling D tests the algorithm of the method "PENALIZATION" with master-slave pairing, penalization relates to the contact and friction.
Modeling E tests the "LAGRANGIAN" algorithm of the method with master-slave pairing.
Modelings F and H test the algorithm of the "CONTINUOUS" method with quadratic elements (SEG3) and linear (SEG2) of contact, respectively.

The results are compared with an analytical solution given by Klang [bib2].
Instead of reproducing this relatively complicated analytical solution we will use the values of pressures obtained from this one [bib1].
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HT-62/06/005/A

---

1 ***Problem of reference***

1.1 Geometry

Plane constraints

y
Q

X
= contact angle
= angle for the slip

Ray of the cylinder: R = 5.999 cm.

Ray of boring: R = 6. cm.

Position of the points of reference on the surface of contact: a point all three degrees of angle with to leave bottom, until 60°.

1.2 ***Material properties***

Roll and boring:

Young modulus:
E = 2.1 1011 N/m2

Poisson's ratio:
= 0.3

Coefficient of friction:
μ = 0.4

1.3
Boundary conditions and loadings

The solid mass containing boring is supposed infinite being, its displacements will be blocked (according to X and y)
on a concentric circle with boring.

The cylinder is subjected to a force distributed Q according to thickness (Z) being worth: Q = 1875 103 N/m.
This force is applied in an increment.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is analytical [bib2].

2.2

Results of reference

Prediction on the zone of contact: 60 degrees.
Prediction on the beginning of the zone of slip: 26,2 degrees.

Efforts of pressure on the points of the surface of contact:

Identification

Reference
SIXX for an angle of 0°
1.7813E+07
SIXX 3°
1.7813E+07
SIXX 6°
1.7750E+07
SIXX 9°
1.7688E+07
SIXX 12°
1.7594E+07
SIXX 15°
1.7470E+07
SIXX 18°
1.7312E+07
SIXX 21°
1.7125E+07
SIXX 24°
1.6906E+07
SIXX 27°
1.6656E+07
SIXX 30°
1.6343E+07
SIXX 33°
1.5937E+07
SIXX 36°
1.5406E+07
SIXX 39°
1.4781E+07
SIXX 42°
1.4031E+07
SIXX 45°
1.3094E+07
SIXX 48°
1.1169E+07

SIXX 51°
1.0593E+07

2.3 References bibliographical

[1]
P. Alart, A. Curnier "A mixed formulation for frictional contact problems" Methods Computer in Applied Mechanics and Engineering (1991) p. 353-375
[2]
Mr. Klang "One interior contact under friction between cylindrical elastic bodies in contact" Thesis, Linköping University, Linköping, 1979.

---

3 Modeling With

3.1 Characteristics of modeling

The symmetry of the problem makes it possible to model of it only half (X 0).

60 finite elements SEG2 are laid out regularly on the initial surface of contact (3 degrees of angle for each one).

The cylinder and circular volume surrounding boring are with a grid with elements QUA4 and TRIA3.

bd4
CONTACT
METHOD = “LAGRANGIAN”
bd3
COULOMB = 0.4

APPARIEMENT=' MAIT_ESCL'
ad2
Master: bcc1
Slave: bcc2
Q/2
NO2 X
ad1
bcc2
cc3
bcc1
ad3
cc4
ad4

Boundary condition:

.
on the GROUP_MA
CC4:
DX = 0, DY = 0.
.
on the GROUP_MA
AD1, AD2, AD3, AD4, BD3, and BD4:
DX = 0.

Loadings:

The symmetry of the problem compared to the plan X = 0 makes it possible to model the force concentrated by one
nodal force Fy = 937.5 103 NR, equivalent to Q/2 for a cylinder length unit, applied to
group nodes O2, center of the cylinder.
This force is applied into 1 increment.

3.2
Characteristics of the grid

A number of nodes:

1281
A number of meshs and types:
128 SEG2
156 TRIA3
1108 QUAD4

3.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "C_PLAN"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = "LAGRANGIAN"

FRICTION = "COULOMB"
COULOMB = 0.4
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

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4 Results of modeling A

4.1 Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification	Reference	Aster	% difference
SIXX for an angle of 0°	1.7813E+07	1.79080E+07	0.534
SIXX 3°	1.7813E+07	1.88485E+07	5.814
SIXX 6°	1.7750E+07	1.89858E+07	6.962
SIXX 9°	1.7688E+07	1.88134E+07	6.363
SIXX 12°	1.7594E+07	1.85821E+07	5.616
SIXX 15°	1.7470E+07	1.83315E+07	4.931
SIXX 18°	1.7312E+07	1.78831E+07	3.299

SIXX 21°
1.7125E+07
1.74723E+07
2.028
SIXX 24°
1.6906E+07
1.67279E+07
-1.053
SIXX 27°
1.6656E+07
1.60957E+07
-3.364
SIXX 30°
1.6343E+07
1.56801E+07
-4.056
SIXX 33°
1.5937E+07
1.57565E+07
-1.132
SIXX 36°
1.5406E+07
1.55705E+07
1.068
SIXX 39°
1.4781E+07
1.51262E+07
2.336
SIXX 42°
1.4031E+07
1.43093E+07
1.984
SIXX 45°
1.3094E+07
1.33902E+07
2.262
SIXX 48°
1.1169E+07
1.24478E+07
11.450
SIXX 51°
1.0593E+07
1.11500E+07

5.259

---

5 Modeling
B

5.1
Characteristics of modeling

This modeling is identical to modeling A (and in particular grid). Only differs
method of pairing which here is “NODAL”.

bd4
CONTACT
METHOD = “LAGRANGIAN”
bd3
COULOMB = 0.4

APPARIEMENT=' NODAL'
ad2

Q/2
NO2 X
ad1
bcc2
cc3
bcc1

ad3
cc4
ad4

5.2 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = “C_PLAN”

AFFE_CHAR_MECA
CONTACT
PAIRING = “NODAL”

METHOD = “LAGRANGIAN”
FRICTION = “COULOMB”
COULOMB = 0.4
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

6
Results of modeling B

6.1
Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification	Reference	Aster	% difference
SIXX for an angle of 0°	1.7813E+07	1.86019E+07	4.429
SIXX 3°	1.7813E+07	1.93157E+07	8.436
SIXX 6°	1.7750E+07	1.93512E+07	9.021
SIXX 9°	1.7688E+07	1.91026E+07	7.998
SIXX 12°	1.7594E+07	1.88145E+07	6.937
SIXX 15°	1.7470E+07	1.85112E+07	5.960
SIXX 18°	1.7312E+07	1.80078E+07	4.019
SIXX 21°	1.7125E+07	1.75572E+07	2.524

SIXX 24°
1.6906E+07
1.67641E+07
-0.839
SIXX 27°
1.6656E+07
1.63429E+07
-1.879
SIXX 30°
1.6343E+07
1.63762E+07
0.203
SIXX 33°
1.5937E+07
1.63898E+07
2.842
SIXX 36°
1.5406E+07
1.59991E+07
3.850
SIXX 39°
1.4781E+07
1.53865E+07
4.097
SIXX 42°
1.4031E+07
1.44452E+07
2.952
SIXX 45°
1.3094E+07
1.34146E+07
2.449
SIXX 48°
1.1169E+07
1.23898E+07
10.931
SIXX 51°
1.0593E+07
1.08630E+07
2.549

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7 Modeling
C

7.1
Characteristics of modeling

This modeling is identical to modeling A (and in particular grid). Only differs
method of resolution which is here "PENALIZATION" with penalization only on friction.

bd4
CONTACT
METHOD = `PENALIZATION
bd3
COULOMB = 0.4

APPARIEMENT=' MAIT_ESCL'
ad2
Master: bcc1
Slave: bcc2
Q/2
NO2 X
ad1
bcc2
cc3
bcc1
ad3
cc4
ad4

7.2 Functionalities tested

Orders Key word factor Key word

AFFE_MODELE
AFFE
MODELING = “C_PLAN”

AFFE_CHAR_MECA
CONTACT
METHOD = “LAGRANGIAN”

FRICTION = “COULOMB”
COULOMB = 0.4
E_T =6.E9
COEF_MATR_FROT =0.3
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

---

8 Results of modeling C

8.1
Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification Reference
Aster %
difference
SIXX for an angle of 0°
1.7813E+07
1.86714E+07
4.819
SIXX 3°
1.7813E+07
1.97269E+07
10.745
SIXX 6°
1.7750E+07
1.99928E+07
12.636
SIXX 9°
1.7688E+07
1.98849E+07
12.421
SIXX 12°
1.7594E+07
1.97193E+07
12.080
SIXX 15°
1.7470E+07
1.95408E+07
11.854
SIXX 18°
1.7312E+07
1.91611E+07
10.681
SIXX 21°
1.7125E+07
1.88051E+07
9.811
SIXX 24°
1.6906E+07

1.82459E+07
7.926
SIXX 27°
1.6656E+07
1.78217E+07
6.999
SIXX 30°
1.6343E+07
1.71305E+07
4.819
SIXX 33°
1.5937E+07
1.64093E+07
2.964
SIXX 36°
1.5406E+07
1.55834E+07
1.152
SIXX 39°
1.4781E+07
1.46776E+07
-0.699
SIXX 42°
1.4031E+07
1.36676E+07
-2.589
SIXX 45°
1.3094E+07
1.27603E+07
-2.548
SIXX 48°
1.1169E+07
1.24156E+07
11.161
SIXX 51°
1.0593E+07
1.08692E+07
2.608

9 Modeling D

9.1 Characteristics of modeling

This modeling is identical to modeling A (and in particular grid). Only differs method of resolution which is here "PENALIZATION" with penalization on the contact and friction.

bd4
CONTACT
METHOD = `PENALIZATION
bd3
COULOMB = 0.4

APPARIEMENT=' MAIT_ESCL'
ad2
Master: bcc1
Slave: bcc2
Q/2
NO2 X
ad1
bcc2
cc3
bcc1
ad3
cc4
ad4

9.2 Functionalities

tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = “C_PLAN”

AFFE_CHAR_MECA
CONTACT
METHOD = “LAGRANGIAN”

FRICTION = “COULOMB”
COULOMB = 0.4
E_N =1.E18
E_T =6.E9
COEF_MATR_FROT =0.3
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

---

10 Results of modeling D

10.1 Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification Reference
Aster %
difference
SIXX for an angle of 0°
1.7813E+07
1.867141E+07
4.819
SIXX 3°
1.7813E+07
1.972695E+07
10.745
SIXX 6°
1.7750E+07
1.999288E+07
12.636
SIXX 9°
1.7688E+07
1.988495E+07
12.421
SIXX 12°
1.7594E+07
1.971935E+07
12.080
SIXX 15°
1.7470E+07
1.954087E+07
11.854
SIXX 18°
1.7312E+07
1.916115E+07
10.681
SIXX 21°
1.7125E+07
1.880513E+07
9.811
SIXX 24°
1.6906E+07
1.824592E+07
7.926
SIXX 27°

1.6656E+07
1.782171E+07
6.999
SIXX 30°
1.6343E+07
1.713057E+07
4.819
SIXX 33°
1.5937E+07
1.640937E+07
2.964
SIXX 36°
1.5406E+07
1.558344E+07
1.152
SIXX 39°
1.4781E+07
1.467761E+07
-0.699
SIXX 42°
1.4031E+07
1.366763E+07
-2.590
SIXX 45°
1.3094E+07
1.276022E+07
-2.549
SIXX 48°
1.1169E+07
1.241550E+07
11.160
SIXX 51°
1.0593E+07
1.086923E+07
2.608

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11 Modeling E

11.1 Characteristics of modeling

The symmetry of the problem makes it possible to model of it only half (X 0).

30 finite elements SEG3 are laid out regularly on surface of contact. Because of curve of these elements, one uses the method of projection "QUADRATIC".

The cylinder and circular volume surrounding boring are with a grid with elements QUA8 and TRIA6.

bd4
CONTACT
METHOD = "LAGRANGIAN"
bd3
COULOMB = 0.4

APPARIEMENT=' MAIT_ESCL'
ad2
Master: bcc1
Slave: bcc2
Q/2
NO2 X
ad1
bcc2
cc3
bcc1
ad3
cc4

ad4

Boundary condition:

.

on the GROUP_MA
CC4:
DX = 0, DY = 0.
.
on the GROUP_MA
AD1, AD2, AD3, AD4, BD3, and BD4:
DX = 0.

Loadings:

The symmetry of the problem compared to the plan X = 0 makes it possible to model the force concentrated by one
nodal force Fy = 937.5 103 NR, equivalent to Q/2 for a cylinder length unit, applied to
group nodes O2, center of the cylinder.
This force is applied into 1 increment.

11.2 Characteristics of the grid

A number of nodes:
1603
A number of meshs and types:
88 SEG3
58 TRIA6
456 QUAD8

11.3 Functionalities tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "C_PLAN"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = "LAGRANGIAN"

FRICTION = "COULOMB"
COULOMB = 0.4
PROJECTION =QUADRATIQUE
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

12 Results of modeling E

12.1 Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification Reference
Aster %
difference
SIXX for an angle of 0°
1.7813E+07
1.87916E+07
5.494
SIXX 3°

1.7813E+07
1.87072E+07
5.020
SIXX 6°
1.7750E+07
1.85202E+07
4.340
SIXX 9°
1.7688E+07
1.83433E+07
3.705
SIXX 12°
1.7594E+07
1.81013E+07
2.884
SIXX 15°
1.7470E+07
1.77266E+07
1.469
SIXX 18°
1.7312E+07
1.74321E+07
0.694
SIXX 21°
1.7125E+07
1.68102E+07
-1.838
SIXX 24°
1.6906E+07
1.64256E+07
-2.841
SIXX 27°
1.6656E+07
1.62913E+07
-2.189
SIXX 30°
1.6343E+07
1.57932E+07
-3.364
SIXX 33°
1.5937E+07
1.55232E+07
-2.596

SIXX 36°
1.5406E+07
1.48572E+07
-3.562
SIXX 39°
1.4781E+07
1.41428E+07
-4.317
SIXX 42°
1.4031E+07
1.28218E+07
-8.618
SIXX 45°
1.3094E+07
1.19407E+07
-8.808
SIXX 48°
1.1169E+07
1.07287E+07
-3.942
SIXX 51°
1.0593E+07
9.70591E+06
-8.374

---

13 Modeling
F

13.1 Characteristics of modeling

The symmetry of the problem makes it possible to model of it only half (X 0).

60 finite elements SEG3 are laid out regularly on the initial surface of contact (3 degrees of angle for each one).

The cylinder and circular volume surrounding boring are with a grid with elements QUA8 and TRIA6.

bd4
CONTACT
METHOD = “CONTINUES”
bd3
COULOMB = 0.4

APPARIEMENT=' MAIT_ESCL'
ad2
Master: bcc1
Slave: bcc2
Q/2
NO2 X
ad1
bcc2
cc3
bcc1
ad3
cc4
ad4

Boundary condition:

.
on the GROUP_MA
CC4:
DX = 0, DY = 0.
.
on the GROUP_MA
AD1, AD2, AD3, AD4, BD3, and BD4:
DX = 0.

Loadings:

The symmetry of the problem compared to the plan X = 0 makes it possible to model the force concentrated by one
nodal force Fy = 937.5 103 NR, equivalent to Q/2 for a cylinder length unit, applied to
group nodes O2, center of the cylinder.
This force is applied into 1 increment.

13.2 Characteristics of the grid

A number of nodes:
1603
A number of meshs and types:
88 SEG3
58 TRIA6
456 QUAD8

13.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = “C_PLAN”

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = “CONTINUES”

FRICTION = “COULOMB”
COULOMB = 0.4
PROJECTION =QUADRATIQUE
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-62/06/005/A

---

14 Results of modeling F

14.1 Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification	Reference	Aster	% difference
SIXX for an angle of 0°	1.7813E+07	1.88235E+07	5.673
SIXX 3°	1.7813E+07	1.87386E+07	5.196
SIXX 6°	1.7750E+07	1.85220E+07	4.349
SIXX 9°	1.7688E+07	1.84104E+07	4.084
SIXX 12°	1.7594E+07	1.81071E+07	2.917

SIXX 15°
1.7470E+07
1.78019E+07
1.900
SIXX 18°
1.7312E+07
1.73913E+07
0.458
SIXX 21°
1.7125E+07
1.68233E+07
1.762
SIXX 24°
1.6906E+07
1.65322E+07
-2.211
SIXX 27°
1.6656E+07
1.63678E+07
-1.730
SIXX 30°
1.6343E+07
1.60549E+07
-1.763
SIXX 33°
1.5937E+07
1.56070E+07
-2.071
SIXX 36°
1.5406E+07
1.48829E+07
-3.395
SIXX 39°
1.4781E+07
1.41776E+07
-4.082
SIXX 42°
1.4031E+07
1.29292E+07
-7.852
SIXX 45°
1.3094E+07
1.19737E+07

-8.555
SIXX 48°
1.1169E+07
1.06929E+07
-4.263
SIXX 51°
1.0593E+07
0.96396E+07
-8.999

15 Modeling
H

15.1 Characteristics of modeling

The symmetry of the problem makes it possible to model of it only half (X 0).

60 finite elements SEG2 are laid out regularly on the initial surface of contact (3 degrees of angle for each one).

The cylinder and circular volume surrounding boring are with a grid with elements QUA4 and TRIA3.

bd4
CONTACT
METHOD = "CONTINUES"
bd3
COULOMB = 0.4

APPARIEMENT=' MAIT_ESCL'
ad2
Master: bcc1
Slave: bcc2
Q/2
NO2 X
ad1
bcc2
cc3
bcc1
ad3
cc4
ad4

Boundary condition:

.
on the GROUP_MA
CC4:
DX = 0, DY = 0.
.
on the GROUP_MA
AD1, AD2, AD3, AD4, BD3, and BD4:
DX = 0.

Loadings:

The symmetry of the problem compared to the plan X = 0 makes it possible to model the force concentrated by one
nodal force Fy = 937.5 103 NR, equivalent to Q/2 for a cylinder length unit, applied to
group nodes O2, center of the cylinder.
This force is applied into 1 increment.

15.2 Characteristics of the grid

A number of nodes:
1282
A number of meshs and types:
128 SEG2
162 TRIA3
1106 QUAD4

15.3 Functionalities

tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = “C_PLAN”

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = “CONTINUES”

FRICTION = “COULOMB”
COULOMB = 0.4
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

---

16 Results of modeling H

16.1 Values tested: SIEF_ELNO_ELGA

One tests the efforts of normal pressure generated by contact-friction. These efforts defined in polar co-ordinates are expressed in MPa.

Identification Reference
Aster %
difference
SIXX for an angle of
0°
1.7813E+07
1.79054E+07
0.519
SIXX 3°
1.7813E+07
1.88551E+07
5.850
SIXX 6°
1.7750E+07
1.89952E+07
7.015
SIXX 9°
1.7688E+07
1.88212E+07
6.407
SIXX 12°
1.7594E+07
1.85900E+07
5.661
SIXX 15°
1.7470E+07
1.83361E+07
4.958
SIXX 18°
1.7312E+07
1.78879E+07
3.327
SIXX 21°
1.7125E+07
1.74676E+07
2.001
SIXX 24°
1.6906E+07
1.67457E+07
-0.948

SIXX 27°
1.6656E+07
1.60969E+07
-3.357
SIXX 30°
1.6343E+07
1.56549E+07
-4.211
SIXX 33°
1.5937E+07
1.57323E+07
-1.284
SIXX 36°
1.5406E+07
1.55859E+07
1.168
SIXX 39°
1.4781E+07
1.51202E+07
2.295
SIXX 42°
1.4031E+07
1.42668E+07
1.680
SIXX 45°
1.3094E+07
1.33861E+07
2.230
SIXX 48°
1.1169E+07
1.24518E+07
11.485
SIXX 51°
1.0593E+07
1.11524E+07
5.280

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17 Summary of the results

The results are of good quality if it is considered that they are compared with an analytical solution and
that the grids used are not particularly fine.
The best solutions are given by modelings E and F (algorithms Lagrangien and continuous, respectively) which uses quadratic elements with quadratic projection (without using this projection, the results are false). Then modelings A and H come which, like the preceding one, use the algorithms Lagrangien and continuous, respectively, with main pairing slave. If one uses nodal pairing (modeling B), the solution is good but it is necessary to underline that this technique of pairing is limited to the small slips. Finally modelings C come and D which use the algorithm of penalization and which give acceptable results. Let us note that convergence with these algorithms is much slower and difficult.
If one examines the extent of the surface of contact using the impression of the structure of data VALE_CONT (see file of results), one notes that it is given very precisely (60°). In what relate to adherent surface, the algorithms return an acceptable value about 30° to place of 26.2° analytically.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.128 document

SSNV128 - Plate with contact and friction on a rigid level

Summary:

This problem corresponds to a quasi-static analysis of a problem of mechanics with contact and friction.
A square plate is subjected to compressive forces and is compressed on 1 indeformable plan where it undergoes
forces of contact and friction. This test is based on results 2D suggested by the GRECO in great deformations.

This test comprises 18 modelings making it possible to test:

.
modelings 2D (QUAD4, QUAD8, TRIA3 and TRIA6) and modelings 3D (HEXA8, HEXA20, HEXA27, PENTA6, PENTA15, TETRA4 and TETRA10),
.

methods of treatment of the contact with "LAGRANGIAN" friction, "PENALIZATION" and "CONTINUES" for the order CONTACT,
·
the geometrical reactualization: "AUTOMATIC", "CONTROL" or "WITHOUT",
·
"NODAL" pairing or "MAIT_ESCL",
·
the research of the nodes in contact with "NOEUD_BOUCLE" or "NOEUD_VOISIN",
·
option "MAIT" or "MAIT_ESCL" for the key word NORMAL,
·
the use of key word VECT_Y,
·
the use of key word COEF_MATR_FROT,
·
coefficients of penalization for the elements of contact: E_T and E_N,
·
key words of exclusion of a group of node: SANS_ (GROUP_) NO and VECT_Y.

1
Problem of reference

1.1 Geometry

Z
F
40 mm
before deformation
blocked face
in X = 40 mm
F
40 mm
y
With
X
Surface contact
with friction

Thickness of the plate ep = 1 Misters.

Side of the plate has = 40 Misters.

Position of the points of reference under the surface of contact (mm)

X y Z
To 0 0 0
B 1.25
0 0
C 5. 0 0
D 7.5 0 0
E 11.25 0 0

1.2
Material properties

Plate:

Poisson's ratio: 0.2
11
2
Young modulus: 1.3 10 N/m

Frame (only if it is modelled by of the same elements dimension than the plate):

Poisson's ratio: 0.2
Young modulus: E (1016 N/m2).

The coefficient of friction under the rigid plan is μ = 1.

1.3
Boundary conditions and loadings

The frame, when it is of N-1 dimension compared to the dimension of the plate, is blocked:

·
by a complete embedding.

The frame, when it is of the same dimension than the plate, is blocked:

·
in the plan X = 40 mm for displacements according to X (symmetry of the problem),
·
by an embedding of its lower face,

The plate is blocked:

·
in the plan X = 40 mm for displacements according to X (symmetry of the problem),
·
according to Y, with the node located at the intersection of, the face symmetry plane of contact and plan
Z = 0 to prevent the movements of rigid body,

In 3D, to bring back itself to a problem 2D:

•
displacement following Z is blocked for all the nodes,

The plate is subjected to two pressures distributed:

•
a vertical acting under the face of the top: F = 5 daN/mm2,
•
horizontal acting under the face initially in X = 0, F = 15.daN/mm2.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution comes from results obtained by an average on other computer codes [bib1].

2.2
Results of reference

Tangential displacements (according to X) at points A B C D E of the surface of contact.

2.3 Reference
bibliographical

[1]
R.A. FEIJOO H.J.C. BARBOSA and NR. ZOUAIN "Numerical formulations for contact problems with friction" Newspaper of Theorical and Applied Mechanics GAUTHIER-VILLARS
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-62/06/005/A

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3 Modeling With

3.1 Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION under key word factor CONTACT for elements SEG2.

The plate is with a grid with elements QUAD4 and the frame with elements SEG2.

3.2 Characteristics of the grid

A number of nodes: 396
A number of meshs and types: 352 QUAD4 for the plate and 32 SEG2 for the frame.

3.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT

METHOD
“LAGRANGIAN”
AFFE_CHAR_MECA CONTACT
“NODAL” PAIRING

AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_BOUCLE”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

STAT_NON_LINE NEWTON
“MATRIX”
“TANGENT”

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
“NODAL” PAIRING

AFFE_CHAR_MECA CONTACT
SEEK

“NOEUD_BOUCLE”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

STAT_NON_LINE NEWTON
“MATRIX”
“TANGENT”

4
Results of modeling A

4.1
Values tested by Lagrangian method “MULT_FRONT”

Identification Reference
***Aster** %*
difference

DX at point A
2.86E5
2.846 E5
-0.487
DX at the point B
2.72E5
2.708 E5
-0.439
DX at the point C
2.28E5
2.274 E5
-0.259
DX at the point D
1.98E5
1.972 E5
-0.366
DX at the point E
1.50E5
1.536 E5
2.43

4.2
Values tested by Lagrangian method "LDLT"

Identification Reference
Aster *%*
difference
DX at point A
2.86E5
2.846E5
-0.487
DX at the point B
2.72E5
2.708E5
-0.439
DX at the point C
2.28E5
2.274E5
-0.259
DX at the point D
1.98E5
1.973E5
-0.366

DX at the point E
1.50E5
1.536E5
2.43

4.3
Values tested by penalized method "MULT_FRONT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.871E5
0.398
DX at the point B
2.72E5
2.733E5
0.492
DX at the point C
2.28E5
2.298E5
0.819
DX at the point D
1.98E5
1.998E5
0.936
DX at the point E
1.50E5
1.566E5
4.38

4.4
Values tested by penalized method "LDLT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.871E5
0.398
DX at the point B
2.72E5

2.733E5
0.492
DX at the point C
2.28E5
2.298E5
0.819
DX at the point D
1.98E5
1.998E5
0.936
DX at the point E
1.50E5
1.566E5
4.38

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION under key word factor CONTACT for elements SEG3.

The plate is with a grid with elements QUAD8 and the frame with elements SEG3.

5.2
Characteristics of the grid

A number of nodes: 558
A number of meshs and types: 160 QUAD8 for the plate and 1 SEG3 for the frame.

5.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"CONTROL"
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

STAT_NON_LINE NEWTON
"MATRIX"
"TANGENT"

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T and E_N
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“WITHOUT”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

STAT_NON_LINE NEWTON
“MATRIX”
“TANGENT”

6
Results of modeling B

6.1
Values tested by Lagrangian method "MULT_FRONT"

Identification	***Reference***	***Aster***	*%* ***difference***
DX at point A	*2.86E5*	*2.859 E5*	*-0.005*
DX at the point B	*2.72E5*	*2.720 E5*	*0.028*
DX at the point C	*2.28E5*	*2.283 E5*	*0.118*
DX at the point D	*1.98E5*	*1.979 E5*	*-0.042*
DX at the point E	*1.50E5*	*1.541 E5*	*2.79*

6.2
Values tested by Lagrangian method "LDLT"

Identification	***Reference***	***Aster***	*% difference*
DX at point A	*2.86E5*	*2.859 E5*	*-0.005*
DX at the point B	*2.72E5*	*2.729 E5*	*0.028*
DX at the point C	*2.28E5*	*2.283 E5*	*0.118*
DX at the point D	*1.98E5*	*1.979 E5*	*-0.042*
DX at the point E	*1.50E5*	*1.541 E5*	*2.709*

6.3
Values tested by penalized method "MULT_FRONT"

Identification	***Reference***	***Aster***	*% difference*
DX at point A	*2.86E5*	*2.874 E5*	*0.486*
DX at the point B	*2.72E5*	*2.735 E5*	*0.545*
DX at the point C	*2.28E5*	*2.296 E5*	*0.708*

DX at the point D
1.98E5
1.993 E5
0.667
DX at the point E
1.50E5
1.556 E5
3.767

6.4
Values tested by penalized method "LDLT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.874 E5
0.486
DX at the point B
2.72E5
2.735 E5
0.545
DX at the point C
2.28E5
2.296 E5
0.708
DX at the point D
1.98E5
1.993 E5
0.667
DX at the point E
1.50E5
1.556 E5
3.767

---

7 Modeling C

7.1 Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION under key word factor CONTACT for elements SEG2.

The plate is with a grid with elements TRIA3 and the frame with elements SEG2.

7.2 Characteristics of the grid

A number of nodes: 431
A number of meshs and types: 732 TRIA3 for the plate and 32 SEG2 for the frame.

7.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"WITHOUT"

STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

STAT_NON_LINE NEWTON
"MATRIX"
"TANGENT"

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"PENALIZATION"
E_T and E_N
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT

NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

STAT_NON_LINE NEWTON
“MATRIX”
“TANGENT”

8
Results of modeling C

8.1
Values tested by Lagrangian method “MULT_FRONT”

Identification Reference
Aster *%*
difference
DX at point A
2.86E5
2.848 E5

-0.420
DX at the point B
2.72E5
2.712 E5
-0.300
DX at the point C
2.28E5
2.279 E5
-0.042
DX at the point D
1.98E5
1.978 E5
-0.095
DX at the point E
1.50E5
1.538 E5
2.58

8.2
Values tested by Lagrangian method "LDLT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.848 E5
-0.420
DX at the point B
2.72E5
2.712 E5
-0.300
DX at the point C
2.28E5
2.279 E5
-0.042
DX at the point D
1.98E5
1.978 E5
-0.095
DX at the point E
1.50E5

1.538 E5
2.528

8.3
Values tested by penalized method "MULT_FRONT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.873 E5
0.462
DX at the point B
2.72E5
2.737 E5
0.630
DX at the point C
2.28E5
2.303 E5
1.023
DX at the point D
1.98E5
2.004 E5
1.193
DX at the point E
1.50E5
1.567 E5
4.453

8.4
Values tested by penalized method "LDLT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.873 E5
0.462
DX at the point B
2.72E5
2.737 E5

0.630
DX at the point C
2.28E5
2.303 E5
1.023
DX at the point D
1.98E5
2.004 E5
1.193
DX at the point E
1.50E5
1.567 E5
4.453

---

9 Modeling D

9.1 Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION under key word factor CONTACT for elements SEG3.

The plate is with a grid with elements TRIA6 and the frame with elements SEG3.

9.2
Characteristics of the grid

A number of nodes: 763
A number of meshs and types: 325 TRIA6 for the plate and 32 SEG3 for the frame.

9.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_VOISIN"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"CONTROL"
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"

COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
“NODAL” PAIRING

AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_BOUCLE”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

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10 Results of modeling D

10.1 Values tested by Lagrangian method “MULT_FRONT”

Identification	*Reference*	*Aster*	*% difference*
DX at point A	*2.86E5*	*2.858 E5*	*-0.065*
DX at the point B	*2.72E5*	*2.721 E5*	*0.050*
DX at the point C	*2.28E5*	*2.286 E5*	*0.279*
DX at the point D	*1.98E5*	*1.980 E5*	*0.027*
DX at the point E	*1.50E5*	*1.541 E5*	*2.751*

10.2 Values tested by Lagrangian method “LDLT”

Identification	*Reference*	*Aster*	*% difference*
DX at point A	*2.86E5*	*2.858 E5*	*-0.065*
DX at the point B	*2.72E5*	*2.721 E5*	*0.050*
DX at the point C			

2.28E5
2.286 E5
0.279
DX at the point D
1.98E5
1.980 E5
0.027
DX at the point E
1.50E5
1.541 E5
2.751

10.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.872 E5
0.428
DX at the point B
2.72E5
2.736 E5
0.573
DX at the point C
2.28E5
2.299 E5
0.860
DX at the point D
1.98E5
1.994 E5
0.724
DX at the point E
1.50E5
1.557 E5
3.792

10.4 Values tested by penalized method "LDLT"

Identification Reference
Aster %
difference
DX at point A

2.86E5
2.872 E5
0.428
DX at the point B
2.72E5
2.735 E5
0.573
DX at the point C
2.28E5
2.299 E5
0.860
DX at the point D
1.98E5
1.994 E5
0.724
DX at the point E
1.50E5
1.557 E5
3.792

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11 Modeling
E

11.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD4.

The plate is with a grid with elements HEXA8 and the frame with elements QUAD4.

11.2 Characteristics of the grid

A number of nodes: 792
A number of meshs and types: 320 HEXA8 for the plate and 32 QUAD4 for the frame.

11.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT FRICTION "COULOMB" COULOMB
AFFE_CHAR_MECA CONTACT METHOD "LAGRANGIAN"
AFFE_CHAR_MECA CONTACT COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT "NODAL" PAIRING

AFFE_CHAR_MECA CONTACT SEEK "NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT NORMAL "MAIT"

AFFE_CHAR_MECA CONTACT REAC_GEOM "AUTOMATIC"

STAT_NON_LINE SOLVEUR "MULT_FRONT"

"LDLT"

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"PENALIZATION"
E_T and E_N
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"CONTROL"
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

12 Results of modeling E

12.1 Values tested by Lagrangian method "MULT_FRONT"

Identification	Reference	Aster	% difference
DX at point A	2.86E5	2.846 E5	-0.487
DX at the point B	2.72E5	2.708 E5	-0.439
DX at the point C	2.28E5	2.274 E5	-0.259
DX at the point D	1.98E5	1.973 E5	-0.366
DX at the point E	1.50E5	1.536 E5	2.429

12.2 Values tested by Lagrangian method "LDLT"

Identification	Reference	Aster	% difference

DX at point A
2.86E5
2.846 E5
-0.487
DX at the point B
2.72E5
2.708 E5
-0.439
DX at the point C
2.28E5
2.274 E5
-0.259
DX at the point D
1.98E5
1.973 E5
-0.366
DX at the point E
1.50E5
1.536 E5
2.429

12.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.846 E5
-0.491
DX at the point B
2.72E5
2.708 E5
-0.444
DX at the point C
2.28E5
2.274 E5
-0.262
DX at the point D
1.98E5
1.973 E5
-0.368
DX at the point E

1.50E5
1.536 E5
2.428

12.4 Values tested by penalized method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.846 E5
-0.491
DX at the point B
2.72E5
2.708 E5
-0.444
DX at the point C
2.28E5
2.274 E5
-0.262
DX at the point D
1.98E5
1.973 E5
-0.368
DX at the point E
1.50E5
1.536 E5
2.428

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13 Modeling F

13.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD8.

The plate is with a grid with elements HEXA20 and the frame with elements QUAD8.

13.2 Characteristics of the grid

A number of nodes: 1316
A number of meshs and types: 160 HEXA20 for the plate and 1 QUAD8 for the frame.

13.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT

VECT_Y

AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK

“NOEUD_BOUCLE”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

14 Results of modeling F

14.1 Values tested by Lagrangian method “MULT_FRONT”

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.912 E5
1.817
DX at the point B

2.72E5
2.766 E5
1.680
DX at the point C
2.28E5
2.310 E5
1.330
DX at the point D
1.98E5
2.002 E5
1.135
DX at the point E
1.50E5
1.559 E5
3.996

14.2 Values tested by Lagrangian method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.912 E5
1.817
DX at the point B
2.72E5
2.766 E5
1.680
DX at the point C
2.28E5
2.310 E5
1.330
DX at the point D
1.98E5
2.002 E5
1.135
DX at the point E
1.50E5
1.539 E5
3.996

14.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.911 E5
1.804
DX at the point B
2.72E5
2.765 E5
1.666
DX at the point C
2.28E5
2.309 E5
1.312
DX at the point D
1.98E5
2.002 E5
1.112
DX at the point E
1.50E5
1.559 E5
3.963

14.4 Values tested by penalized method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.911 E5
1.804
DX at the point B
2.72E5
2.765 E5
1.666
DX at the point C
2.28E5
2.309 E5
1.312

DX at the point D
1.98E5
2.002 E5
1.112
DX at the point E
1.50E5
1.559 E5
3.963

15 Modeling G

15.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD8.

The plate is with a grid with elements HEXA27 and the frame with elements QUAD8.

15.2 Characteristics of the grid

A number of nodes: 408
A number of meshs and types: 24 HEXA27 for the plate and 8 QUAD8 for the frame.

15.3 Functionalities

tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“LAGRANGIAN”
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD

“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
“NODAL” PAIRING

AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_BOUCLE”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

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16 Results of modeling G

16.1 Values tested by Lagrangian method “MULT_FRONT”

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.851 E5
-0.330
DX at the point C
2.28E5
2.275 E5
-0.213

16.2 Values tested by Lagrangian method “LDLT”

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.851 E5
-0.330
DX at the point C
2.28E5
2.275 E5
-0.213

16.3 Values tested by penalized method “MULT_FRONT”

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.851 E5
-0.324
DX at the point C
2.28E5
2.275 E5
-0.205

16.4 Values tested by penalized method "LDLT"

Identification	Reference	Aster	% difference
DX at point A	2.86E5	2.851 E5	-0.324
DX at the point C	2.28E5	2.275 E5	-0.205

---

17 Modeling
H

17.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD4.

The plate is with a grid with elements PENTA6 and the frame with elements QUAD4.

17.2 Characteristics of the grid

A number of nodes: 670
A number of meshs and types: 323 PENTA6 for the plate and 1 QUAD4 for the frame.

17.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"CONTROL"
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

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18 Results of modeling H

18.1 Values tested by Lagrangian method “MULT_FRONT”

Identification	*Reference*	*Aster*	*% difference*
DX at point A	*2.86E5*	*2.851 E5*	*-0.320*
DX at the point B	*2.72E5*	*2.716 E5*	*-0.140*
DX at the point C	*2.28E5*	*2.284 E5*	*0.159*
DX at the point D	*1.98E5*	*1.978 E5*	*-0.082*
DX at the point E	*1.50E5*	*1.540 E5*	*2.678*

18.2 Values tested by Lagrangian method “LDLT”

Identification	*Reference*	*Aster*	*% difference*
DX at point A	*2.86E5*	*2.851 E5*	*-0.320*
DX at the point B			

2.72E5
2.716 E5
-0.140
DX at the point C
2.28E5
2.284 E5
0.159
DX at the point D
1.98E5
1.978 E5
-0.082
DX at the point E
1.50E5
1.540 E5
2.678

18.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.851 E5
-0.320
DX at the point B
2.72E5
2.716 E5
-0.140
DX at the point C
2.28E5
2.284 E5
0.159
DX at the point D
1.98E5
1.978 E5
-0.082
DX at the point E
1.50E5
1.540 E5
2.678

18.4 Values tested by penalized method "LDLT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.851 E5
-0.320
DX at the point B
2.72E5
2.716 E5
-0.140
DX at the point C
2.28E5
2.284 E5
0.159
DX at the point D
1.98E5
1.978 E5
-0.082
DX at the point E
1.50E5
1.540 E5
2.678

---

19 Modeling
I

19.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD8.

The plate is with a grid with elements PENTA15 and the frame with elements QUAD8.

19.2 Characteristics of the grid

A number of nodes: 1297
A number of meshs and types: 158 PENTA15 for the plate and 32 QUAD8 for the frame.

19.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
"NODAL" PAIRING

AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT

REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

20 Results of modeling I

20.1 Values tested by Lagrangian method "MULT_FRONT"

Identification	*Reference*	*Aster*	*% difference*
DX at point A	*2.86E5*	*2.865 E5*	*0.179*
DX at the point B	*2.72E5*	*2.727 E5*	*0.277*
DX at the point C	*2.28E5*	*2.290 E5*	*0.453*
DX at the point D	*1.98E5*	*1.983 E5*	*0.164*
DX at the point E	*1.50E5*	*1.543 E5*	*2.871*

20.2 Values tested by Lagrangian method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.865 E5
0.179
DX at the point B
2.72E5
2.727 E5
0.277
DX at the point C
2.28E5
2.290 E5
0.453
DX at the point D
1.98E5
1.983 E5
0.165
DX at the point E
1.50E5
1.543 E5
2.871

20.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.866 E5
0.207
DX at the point B
2.72E5
2.728 E5
0.306
DX at the point C
2.28E5
2.291 E5

0.486
DX at the point D
1.98E5
1.984 E5
0.205
DX at the point E
1.50E5
1.544 E5
2.932

20.4 Values tested by penalized method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.866 E5
0.207
DX at the point B
2.72E5
2.728 E5
0.306
DX at the point C
2.28E5
2.291 E5
0.486
DX at the point D
1.98E5
1.984 E5
0.205
DX at the point E
1.50E5
1.544 E5
2.932

---

21 Modeling J

21.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements TRIA3.

The plate is with a grid with elements TETRA4 and the frame with elements TRIA3.

21.2 Characteristics of the grid

A number of nodes: 441
A number of meshs and types: 980 TETRA4 for the plate and 64 TRIA3 for the frame.

21.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT

“NODAL” PAIRING

AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_BOUCLE”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“PENALIZATION”
E_T
AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”

22 Results of modeling J

22.1 Values tested by Lagrangian method “MULT_FRONT”

Identification	*Reference*	*Aster*	*% difference*
DX at point A	*2.86E5*	*2.831 E5*	*-1.005*
DX at the point B	*2.72E5*	*2.698 E5*	*-0.794*
DX at the point C	*2.28E5*	*2.277 E5*	*-0.096*
DX at the point D	*1.98E5*	*1.977 E5*	*-0.125*

DX at the point E
1.50E5
1.539 E5
2.624

22.2 Values tested by Lagrangian method "LDLT"

Identification Reference
***Aster** %*
difference
DX at point A
2.86E5
2.831 E5
-1.005
DX at the point B
2.72E5
2.698 E5
-0.794
DX at the point C
2.28E5
2.270 E5
-0.096
DX at the point D
1.98E5
1.977 E5
-0.125
DX at the point E
1.50E5
1.539 E5
2.624

22.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.831 E5
-1.007
DX at the point B
2.72E5
2.698 E5

-0.796
DX at the point C
2.28E5
2.278 E5
-0.098
DX at the point D
1.98E5
1.977 E5
-0.126
DX at the point E
1.50E5
1.539 E5
2.624

22.4 Values tested by penalized method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.831 E5
-1.007
DX at the point B
2.72E5
2.698 E5
-0.796
DX at the point C
2.28E5
2.278 E5
-0.098
DX at the point D
1.98E5
1.977 E5
-0.126
DX at the point E
1.50E5
1.539 E5
2.624

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23 Modeling K

23.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements TRIA6.

The plate is with a grid with elements TETRA10 and the frame with elements TRIA6.

23.2 Characteristics of the grid

A number of nodes: 1236
A number of meshs and types: 526 TETRA10 for the plate and 32 TRIA6 for the frame.

23.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT

COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"AUTOMATIC"

STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"PENALIZATION"
E_T and E_N
AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
"NODAL" PAIRING

AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT

NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“CONTROL”
NB_REAC_GEOM
STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

---

24 Results of modeling K

24.1 Values tested by Lagrangian method “MULT_FRONT”

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.876 E5
0.551
DX at the point C
2.28E5
2.289 E5

0.435

24.2 Values tested by Lagrangian method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.875 E5
0.551
DX at the point C
2.28E5
2.289 E5
0.435

24.3 Values tested by penalized method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.876 E5
0.581
DX at the point C
2.28E5
2.291 E5
0.469

24.4 Values tested by penalized method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.876 E5
0.581
DX at the point C
2.28E5
2.291 E5

---

25 Modeling L

25.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD4.

The plate is with a grid with elements HEXA8 and the frame with elements QUAD4. 32 finite elements
QUAD4 are laid out on the faces of contact (2D) of the plate and the frame. The plate is tilted with 45° (rotation around the axis Y).

25.2 Characteristics of the grid

A number of nodes: 792
A number of meshs and types: 320 HEXA8 for the plate and 32 QUAD4 for the frame.

25.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“LAGRANGIAN”
AFFE_CHAR_MECA CONTACT
VECT_Y

AFFE_CHAR_MECA CONTACT
COEF_MATR_FROT

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL
“MAIT”

AFFE_CHAR_MECA CONTACT
REAC_GEOM
“AUTOMATIC”

STAT_NON_LINE SOLVEUR
“MULT_FRONT”
“LDLT”

04/05/06
Author (S):
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:
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26 Results of modeling L

26.1 Values tested by Lagrangian method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.02E5
2.012 E5
-0.377
DX at the point B
1.92E5
1.915 E5
-0.271
DX at the point C
1.61E5
1.608 E5
-0.126
DX at the point D
1.40E5
1.395 E5
-0.363
DX at the point E
1.06E5
1.086 E5
2.492

26.2 Values tested by Lagrangian method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.02E5

2.012 E5
-0.377
DX at the point B
1.92E5
1.915 E5
-0.271
DX at the point C
1.61E5
1.608 E5
-0.126
DX at the point D
1.40E5
1.395 E5
-0.363
DX at the point E
1.06E5
1.086 E5
2.492

27 Modeling M

27.1 Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION of the key word *factor CONTACT for elements SEG2.*

The plate is with a grid with elements QUAD4 and the frame with elements SEG2.

27.2 Characteristics of the grid

A number of nodes: 396
A number of meshs and types: 352 QUAD4 for the plate and 32 SEG2 for the frame.

27.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“CONTINUES”

AFFE_CHAR_MECA CONTACT
INTEGRATION “NODE”

AFFE_CHAR_MECA CONTACT
MODL_AXIS
“NOT”

AFFE_CHAR_MECA CONTACT
SEUIL_INIT
0

AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
1

AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
4

AFFE_CHAR_MECA CONTACT
ITER_FROT_MAXI

10

AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
1

AFFE_CHAR_MECA CONTACT
COEF_REGU_FROT
1

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_VOISIN"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

STAT_NON_LINE COMP_ELAS RELATION
"ELAS"

STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

TEST_RESU
VALE_CONT

---

28 Results of modeling M

28.1 Values tested by the method continues “MULT_FRONT”

Identification	Reference	Aster	% difference
DX at point A	2.86E5	2.846 E5	-0.484
DX at the point B	2.72E5	2.708 E5	-0.436
DX at the point C	2.28E5	2.274 E5	-0.255
DX at the point D	1.98E5	1.973 E5	-0.365
DX at the point E	1.50E5	1.536 E5	2.429

Identification	Reference	Aster	% difference
PLAY in N365	0.0	-1.6156E-27	
CONT in N365	1	1	
RN in N365			

1.0486E5
1.0486E5
-6.04E-4

28.2 Values tested by the method continues "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.846 E5
-0.484
DX at the point B
2.72E5
2.708 E5
-0.436
DX at the point C
2.28E5
2.274 E5
-0.255
DX at the point D
1.98E5
1.973 E5
-0.365
DX at the point E
1.50E5
1.536 E5
2.429

---

29 Modeling NR

29.1 Characteristics of modeling

Modeling: 3D to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements QUAD4.

The plate is with a grid with elements HEXA8 and the frame with elements QUAD4. 32 finite elements QUAD4 are laid out on the faces of contact (2D) of the plate and the frame.

29.2 Characteristics of the grid

A number of nodes: 792
A number of meshs and types: 320 HEXA8 for the plate and 32 QUAD4 for the frame.

29.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"

AFFE_CHAR_MECA CONTACT
INTEGRATION "NODE"

AFFE_CHAR_MECA CONTACT
MODL_AXIS
"NOT"

AFFE_CHAR_MECA CONTACT

SEUIL_INIT
0

AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
1

AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
4

AFFE_CHAR_MECA CONTACT
ITER_FROT_MAXI
8

AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
100

AFFE_CHAR_MECA CONTACT
COEF_REGU_FROT
100

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_VOISIN"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

STAT_NON_LINE COMP_ELAS RELATION
"ELAS"

STAT_NON_LINE SOLVEUR
"MULT_FRONT"
"LDLT"

30 Results of modeling NR

30.1 Values tested by the method continues "MULT_FRONT"

Identification	***Reference***	***Aster***	***% difference***
DX at point A	***2.86E5***	***2.922 E5***	***2.174***
DX at the point B	***2.72E5***	***2.775 E5***	***2.024***
DX at the point C	***2.28E5***	***2.319 E5***	***1.727***
DX at the point D	***1.98E5***	***2.012 E5***	***1.617***
DX at the point E	***1.50E5***	***1.569 E5***	***4.652***

30.2 Values tested by the method continues "LDLT"

Identification	Reference	Aster	% difference
DX at point A	2.86E5	2.922 E5	2.174
DX at the point B	2.72E5	2.775 E5	2.024
DX at the point C	2.28E5	2.319 E5	1.727
DX at the point D	1.98E5	2.012 E5	1.617
DX at the point E	1.50E5	1.569 E5	4.652

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-62/06/005/A

Code_Aster ®
Version
8.2

Titrate:
SSNV128 - Plate with contact and friction on a rigid level
Date:
04/05/06
Author (S):
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:
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31 Modeling
O

31.1 Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements SEG2.

The plate is with a grid with elements QUAD4 and the frame with elements SEG2.

31.2 Characteristics of the grid

A number of nodes: 396
A number of meshs and types: 352 QUAD4 for the plate and 32 SEG2 for the frame.

31.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"LAGRANGIAN"
AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_VOISIN"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

AFFE_CHAR_MECA CONTACT
REAC_GEOM
"WITHOUT"

STAT_NON_LINE COMP_ELAS RELATION
"ELAS"

32 Results of modeling O

32.1 Values tested by Lagrangian method "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.846 E5
-0.492
DX at the point B
2.72E5
2.708 E5
-0.444
DX at the point C
2.28E5
2.274 E5
-0.262
DX at the point D

1.98E5
1.973 E5
-0.369
DX at the point E
1.50E5
1.536 E5
2.427

32.2 Values tested by Lagrangian method "LDLT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.846 E5
-0.492
DX at the point B
2.72E5
2.708 E5
-0.444
DX at the point C
2.28E5
2.274 E5
-0.262
DX at the point D
1.98E5
1.973 E5
-0.369
DX at the point E
1.50E5
1.536 E5
-0.427

---

33 Modeling P

33.1 Characteristics of modeling

Modeling: D_PLAN to test the operand "COULOMB" of the key word FRICTION of the key word factor CONTACT for elements SEG3.

The plate is with a grid with elements QUAD8 and the frame with elements SEG3.

33.2 Characteristics of the grid

A number of nodes: 620
A number of meshs and types: 160 QUAD8 for the plate and 106 SEG3 for the frame.

33.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
"COULOMB"
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
"CONTINUES"

AFFE_CHAR_MECA CONTACT INTEGRATION "NODE"

AFFE_CHAR_MECA CONTACT MODL_AXIS "NOT"

AFFE_CHAR_MECA CONTACT SEUIL_INIT *100.*

AFFE_CHAR_MECA CONTACT ITER_GEOM_MAXI *3*

AFFE_CHAR_MECA CONTACT ITER_CONT_MAXI *1*

AFFE_CHAR_MECA CONTACT ITER_FROT_MAXI *10*

AFFE_CHAR_MECA CONTACT COEF_REGU_CONT *100.*

AFFE_CHAR_MECA CONTACT COEF_REGU_FROT *100.*

AFFE_CHAR_MECA CONTACT PAIRING "MAIT_ESCL" AFFE_CHAR_MECA CONTACT SEEK "NOEUD_VOISIN"

AFFE_CHAR_MECA CONTACT NORMAL "MAIT"

STAT_NON_LINE COMP_ELAS RELATION "ELAS"

STAT_NON_LINE SOLVEUR

---

34 Results of modeling P

34.1 Values tested by the method continues "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.866 E5
-0.013
DX at the point B
2.72E5
2.720 E5
-0.020
DX at the point C
2.28E5
2.282 E5
-0.109
DX at the point D
1.98E5
1.979 E5

-0.054
DX at the point E
1.50E5
1.54 E5
2.692

---

35 Modeling
Q

35.1 Characteristics of modeling

Modeling: D_PLAN to test key words SANS_GROUP_NO (or SANS_NO) and VECT_Y of key word factor CONTACT for elements SEG2.

The plate is with a grid with elements QUAD4 and the frame with elements SEG2.
Vector VECT_Y gives the direction of the slip, whose direction is given compared to normal vector NR (directed towards the interior of the main field) and so that doublet (VECT_Y, nv) form a direct base.

35.2 Characteristics of the grid

A number of nodes: 396
A number of meshs and types: 352 QUAD4 for the plate and 32 SEG2 for the frame.

35.3 Functionalities
tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“CONTINUES”

AFFE_CHAR_MECA CONTACT
INTEGRATION “NODE”

AFFE_CHAR_MECA CONTACT
CONTACT_INIT “YES”

AFFE_CHAR_MECA CONTACT
SANS_GROUP_NO
“PPS”

AFFE_CHAR_MECA CONTACT
VECT_Y
(-1.,0.,0.)
AFFE_CHAR_MECA CONTACT
SEUIL_INIT
0.1

AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
2

AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
4

AFFE_CHAR_MECA CONTACT
ITER_FROT_MAXI
10

AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
1.

AFFE_CHAR_MECA CONTACT
COEF_REGU_FROT
1.

AFFE_CHAR_MECA CONTACT
PAIRING "MAIT_ESCL"
AFFE_CHAR_MECA CONTACT
SEEK
"NOEUD_BOUCLE"

AFFE_CHAR_MECA CONTACT
NORMAL
"MAIT"

STAT_NON_LINE COMP_ELAS RELATION
"ELAS"

STAT_NON_LINE SOLVEUR
"MULT_FRONT"

36 Results of modeling Q

36.1 Values tested by the method continues "MULT_FRONT"

Identification Reference

Aster %
difference
PLAY at the point F
0
2.832 E27
2.83 E27
CONTACT at the point F
1.
1.
0
RN at the point F
1.486 E+5
1.48 E+5
-2.16 E4
DX at point A
2.86E5
2.845 E5
-0.492
DX at the point B
2.72E5
2.707 E5
-0.444
DX at the point C
2.28E5
2.274 E5
-0.262
DX at the point D
1.98E5
1.972 E5
-0.369
DX at the point E
1.50E5
1.536 E5
2.427

Titrate:

37 Modeling R

37.1 Characteristics of modeling

Modeling: D_PLAN to test key words SANS_GROUP_NO (or SANS_NO) and VECT_Y of key word factor CONTACT for elements QUAD4.

The plate and the frame are with a grid with elements HEXA8. A line of 32 finite elements QUAD4 is laid out on each face of contact (2D) of the plate and the frame.
Vector VECT_Y gives the direction of the slip, corresponding to one of the vectors
tangentsr
, where the trihedron (v v
, nv form a direct base. It is given here
1
2
)
I
I,
1
= 2
automatically.

37.2 Characteristics of the grid

A number of nodes: 792
A number of meshs and types: 320 HEXA8 for the plate and the frame and 64 QUAD4 for the contact between
plate and the frame.

37.3 Functionalities tested

Orders

AFFE_CHAR_MECA CONTACT
FRICTION
“COULOMB”
COULOMB
AFFE_CHAR_MECA CONTACT
METHOD
“CONTINUES”

AFFE_CHAR_MECA CONTACT
INTEGRATION “NODE”

AFFE_CHAR_MECA CONTACT
SANS_GROUP_NO
“PP”

AFFE_CHAR_MECA CONTACT
ITER_GEOM_MAXI
1

AFFE_CHAR_MECA CONTACT
ITER_CONT_MAXI
4

AFFE_CHAR_MECA CONTACT
ITER_FROT_MAXI
12

AFFE_CHAR_MECA CONTACT
COEF_REGU_CONT
100

AFFE_CHAR_MECA CONTACT
COEF_REGU_FROT
100

AFFE_CHAR_MECA CONTACT
PAIRING “MAIT_ESCL”
AFFE_CHAR_MECA CONTACT
SEEK
“NOEUD_VOISIN”

AFFE_CHAR_MECA CONTACT
NORMAL

"MAIT"

STAT_NON_LINE COMP_ELAS RELATION
"ELAS"

STAT_NON_LINE SOLVEUR
"MULT_FRONT"

38 Results of modeling R

38.1 Values tested by the method continues "MULT_FRONT"

Identification Reference
Aster %
difference
DX at point A
2.86E5
2.97E5
3.846
DX at the point B
2.72E5
2.82E5
3.676
DX at the point C
2.28E5

2.36E5
2.330
DX at the point D
1.98E5
2.06E5
3.340
DX at the point E
1.50E5
1.62E5
8.000

The relative error increases slightly in comparison with modeling NR, in particular for not E.

---

39 Summary of the results

The results obtained on the whole of modelings of this case test are satisfactory, as well in 2D that in 3D. On points A, B, C and D, one obtains a relative error lower than 1% compared to results of the GRECO. On the other hand, for the point E, the relative error, about 2,5%, remains acceptable.

From a time point of view computing, one notes that the method by penalization is in general more rapid that Lagrangian method. One notes, on the other hand, an ease of use of the method Lagrangian (cf Doc. [R5.03.01]) compared to the penalized method, since convergence and quality of the results obtained by this last method are conditioned by the coefficient of *penalization which is automatically given in the Lagrangian method.*

From a qualitative point of view:

.
in 2D, one notes a positive effect on the results of the quadratic grid compared to linear grid (cf modelings A and B),
.
in 3D, one notes that calculations with quadratic grid does not improve the results. This is explained by the fact why one decreased by 50% the number of meshs compared to linear grid to have a number of nodes are equivalent.

As regards modeling L, inclined plate, one notes a good convergence and results satisfactory.

Lastly, for the method continues (modelings M, NR, P and Q), one obtains in 3D results with relative errors slightly more important than those obtained by the methods Lagrangian and penalized. These errors can come from the choice of the coefficients (cf the documentation of use orders AFFE_CHAR_MECA and AFFE_CHAR_MECA_F for more information on these coefficients). In 2D, one notes a convergence slower than the methods Lagrangian and penalized. Lastly, the exclusion of the nodes rubbing in redundancy with the boundary conditions imposed (pivot no one) using SANS_GROUP_NO and VECT_Y functions correctly in 2D (modeling Q) but increase the level of error in 3D (modeling R).

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.129 document

SSNV129 - Contact of 2 simple bearing plates
of which is subjected to pressure

Summary:

A rectangular plate is subjected to a uniform compressive force and is compressed on a plate identical where it undergoes forces of contact.

This test comprises two modelings (linear elements QUAD4 with modeling DKT - elements quadratic QUAD9 with modeling COQUE_3D). Calculations of reference were carried out without contact.
The results of Code_Aster with contact are obtained in nonregression and are analyzed compared to the results
obtained without contact.

Titrate:

SSNV129 - Contact of 2 simple bearing plates

Date:
19/08/02
Author (S):
P. Key MASSIN, R. FERNANDES
:
V6.04.129-A Page:
2/10

1
Problem of reference

1.1 Geometry

Pressure
L
D
C
L
Z
With
B
E
y
X

Thickness of the plate: E = 0,5 cm.
Width of the plate: L = 5 cm.
Length of the plate: L = 10 cm.

Co-ordinates of the points of reference (cm)

X y Z
To 0 2.5
0
B 10.2.5 0
C 10.2.5 0
D 0.2.5 0

1.2
Material properties

Plates:

Poisson's ratio: 0.3
15
Young modulus: 2. 10 N/m2

1.3
Boundary conditions and loadings

The plate is blocked:

· on AB and CD for displacements according to X and Z,
· on BC and DA for displacements according to y and Z,
· on AB and CD for rotations according to y,
· on AB and CD for rotations according to X.

One also blocks the central node of each plate to leave him the only possibility of to move along axis Z.

The plate is subjected to a vertical pressure distributed on the higher plate:

·
12
Pressure: p = 2.5 10 N/m2,

2
Reference solution

2.1 Reference
Bibliographical

The reference solution comes from the results obtained in "Formulated for Stress and Strain" of ROARK' S (6th edition - McGraw-Hill International Editions)

2.2
Analytical results of reference without contact

The results obtained were calculated on a simple bearing plate subjected to a pressure vertical (not of contact).

· Calcul of the arrow in the center of the plate:
- pb4
max
y
=

Et3

· Calcul of the constraint in the center of the plate according to the width of the plate:
2

- Pb
=

B
T 2

· p indicates the pressure applied to the plate,
· E the Young modulus,
· with the length,
· B the width,
· T the thickness,
·
, being two coefficients obtained starting from the a/b report/ratio.

= 0.1110

= 0.6102

That is to say:

y =

cm
0.69375

= 1.5255 1010

N/cm2

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

2.3
Results obtained without contact with Code_Aster

2.3.1 Modeling
DKT

Modeling: DKT to test the contact between two plates.

256 finite elements QUAD4 are laid out on the initial surface of contact. The grid has only one elements in the thickness of the plate sleep.

2.3.2 Characteristics of the grid

A number of nodes: 289 nodes
A number of meshs and type: 256 QUAD4

2.3.3 Values of reference Aster

Identification Reference
Aster (DKT) Error
DZ in the center of the plate
0.69375
0.69138
0.35 %
in the center of the plate
1.5255 E+10
1.5298 E+10
0.28 %

2.3.4 Modeling COQUE_3D

Modeling: COQUE_3D to test the contact between two plates.

256 finite elements QUAD9 are laid out on the initial surface of contact. The grid has only one elements in the thickness of the plate sleep.

2.3.5 Characteristics of the grid

A number of nodes: 578 nodes
A number of meshs and type: 256 QUAD9

2.3.6 Values of reference Aster

Identification Reference
Aster (COQUE_3D) Error
DZ in the center of the plate
0.69375
0.65927
4.97 %
in the center of the plate
1.5255 E+10
1.41316 E+10
7.36 %

2.4 Comments

It is noted that the results obtained without contact are very satisfactory for a modeling of type DKT. The error obtained for a modeling of the type COQUE_3D can be explained by the catch in count effects of transverse shearing which should not be negligible for this plate relatively thick since the l/e report/ratio is worth 1/10.
Moreover, the effect of the size of the grid would be also to analyze by taking grids 100x100 with place of grid 16x16.

SSNV129 - Contact of 2 simple bearing plates

Date:
19/08/02
Author (S):
P. Key MASSIN, R. FERNANDES
:
V6.04.129-A Page:
5/10

3 Modeling
With

3.1
Characteristics of modeling

Modeling: DKT to test the contact between two plates.

256 finite elements QUA4 are laid out on the initial surface of contact. The grid has only one elements in the thickness of the plate sleep.

C

D
***
B
With

*where * indicates the node medium of the plate.*
With = DR1 or DR21,
B = DR2 or DR22,
C = DR3 or DR23,
D = DR4 or DR24.

The nodes to which one applies the boundary conditions are the nodes N177 and N466 located in the center of each plate.

3.2
Characteristics of the grid

A number of nodes: 289 nodes
A number of meshs and type: 256 QUA4

3.3 Functionalities tested

3.3.1 Calculation 1

Orders

AFFE_MODELE
MODELING
"DKT"

CONTACT
METHOD
"FORCED"

CONTACT
REAC_GEOM_INTE

STAT_NON_LINE
COMP_INCR
RELATION

"ELAS"

Calculation by the method of the active constraints is carried out without geometrical reactualization and on
only one step of time.

3.3.2 Calculation
2

Orders

AFFE_MODELE
MODELING
"DKT"

CONTACT
METHOD
"LAGRANGIAN"

CONTACT
REAC_GEOM_INTE

STAT_NON_LINE
COMP_INCR
RELATION
"ELAS"

Calculation by the method of Lagrangian is carried out with two geometrical reactualizations for each of the 5 steps of time.

4
Results of modeling A

4.1
Values of reference Aster

4.1.1 Calculation
1

Identification of the central node
Aster without contact
Aster Error
(/2)
DZ
3.4569 E-01
3.42675 E-01
0.87%

7.6491 E+09
7.67191 E+09
0.30%

One also tests the following values in nonregression:

Identification
Aster
DZ with the N132 node
2.86558 E01
DZ with the N204 node
2.74507 E01
DZ with the N211 node
2.45747 E01
with the N132 node
6.57215 E+09
with the N204 node

6.28349 E+09
with the N211 node
5.71108 E+09

4.1.2 Calculation
2

Identification of the central node
Aster without contact
Aster Error
(/2)
DZ
3.4569 E-01
3.47470 E-01
0.51%

7.6491 E+09
7.5768 E+09
0.94%

One also tests the following values in nonregression:

Identification
Aster
Error Calcul2/Calcul1
DZ with the N132 node
2.90536 E01
1.4%
DZ with the N204 node
2.81684 E01
2.6%
DZ with the N211 node
2.48085 E01
1.0%
with the N132 node
6.67510 E+09
1.6%
with the N204 node
6.50562 E+09
3.5%
with the N211 node
5.76723 E+09
1.0%

4.2 Parameters of execution

Version:
6.1.10
Machine:
SGI - Origin 2000
Time CPU To use:
214 seconds

4.3 Comments

The results obtained with contact are very satisfactory since one obtains, with less than 1% of error, results obtained without contact except for a factor of 2. It is indeed the result awaited since to add the contact between two plates identical to that of paragraph 2 returns to to suppose a plate subjected to pressure with a rigidity twice higher.

---

5 Modeling B

5.1 Characteristics of modeling

Modeling: COQUE_3D to test the contact between two plates.

256 finite elements QUA9 are laid out on the initial surface of contact. The grid has only one elements in the thickness of the plate sleep.

C

D
****
B
With

where * indicates the node medium of the plate.
With = DR1 or DR21,
B = DR2 or DR22,
C = DR3 or DR23,
D = DR4 or DR24.

The nodes to which one applies the boundary conditions are the nodes N241 and N1074 located in the center of each plate.

5.2
Characteristics of the grid

A number of nodes: 578 nodes
A number of meshs and type: 256 QUA9

5.3 Functionalities
tested

Orders

AFFE_MODELE
MODELING
"COQUE_3D"

CONTACT
METHOD
"FORCED"

CONTACT
REAC_GEOM_INTE

STAT_NON_LINE
COMP_INCR

RELATION
"ELAS"

Orders

AFFE_MODELE
MODELING
"COQUE_3D"

CONTACT
METHOD
"LAGRANGIAN"

CONTACT
REAC_GEOM_INTE

STAT_NON_LINE
COMP_INCR
RELATION
"ELAS"

6
Results of modeling B

6.1
Values of reference Aster

Identification of the central node
Aster without contact
Aster Error
(/2)
DZ
3.29636 E-01
3.27176 E-01
0.75%

7.06580 E+09
7.03945 E+09
0.37%

One also tests the following values in nonregression:

Identification
Aster
DZ with the N192 node
2.07642 E01
DZ with the N246 node
2.05704 E01
DZ with the N314 node
1.73742 E01
with the N192 node
4.71388 E+09
with the N246 node
4.57802 E+09
with the N314 node
4.07646 E+09

6.2 Parameters
of execution

Version:
6.1.10
Machine:
SGI Origin 2000
Time CPU To use:

280 seconds

6.3 Comments

The results obtained with contact are very satisfactory since one obtains, with less than 1% of error, results obtained without contact except for a factor of 2. It is indeed the awaited result since to add the contact between two plates identical to that of paragraph 2 amounts supposing one plate subjected to pressure with a rigidity twice higher.

7
Summary of the results

One notes very good results in the presence of contact for two modelings.

Modeling A (DKT) has very satisfactory results compared to the analytical results (1% of error with or without contact). When one replaces a plate under pressure by two plates from which one comes to be stuck to the other, the multiplication of rigidity by two results in one division by two of the maximum arrow as well as constraint in the center of the plates.

Modeling B (COQUE_3D) gives a behavior are equivalent to that met for modeling A in DKT when one replaces a plate under pressure by two plates in contact. One observes a division by two of the maximum arrow as well as constraint in the center of plates. Moreover, the value of the arrow obtained is rather satisfactory (~7% of error) compared to

analytical results. This difference can be explained by the taking into account of shearing transverse for the COQUE_3D for a plate which is altogether relatively thick since l/e = 1/10.

Organization (S): EDF/IMA/MMN

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.133

SSNV133 - Uniaxial traction and compression.
Mixed work hardening

Summary:

The purpose of this test is to validate elastoplastic behaviors VMIS_ECMI_TRAC and VMIS_ECMI_LINE, which combine an isotropic work hardening (linear or given by a traction diagram) and a work hardening linear kinematics.

The geometrical and mechanical data make it possible to be in uniaxial situation (uniform constraints, one only nonnull component). The reference solution is simple, analytical. This test allows simply to check that the integration of the model of behavior is correct.

3 modelings make it possible to check the uniaxiality of the constraints: 3D, AXIS, C_PLAN.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

---

1 Problem of reference

1.1 Geometry

y
1
2

1 mm
3
4
X
1 mm

1.2
Material properties

Elastoplastic law of behaviour to mixed work hardening (isotropic linear and kinematic linear).

C
= 20000
MPa

AND
E
= 200000
y
MPa

= 0 3
.
Y

= 400
MPa
E
1.5C
E
= 40000
MPa

T

1.3
Boundary conditions and loadings

The plate is blocked according to OY along the side [3,4], following OX along the side [1,3] while being

subjected to a displacement imposed in y: U D along the side [1,2].
y

The way of loading is as follows:

T
U D (mm)
y
1 2.
10-3
2.4.5d3
3.0.1d3
4 -2.
10-3

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is obtained by an analytical calculation.

D
uy

Displacement imposed U D provides the deformation immediately
=
. Only this
y
yy
1
component (corresponding to the nonnull component of the tensor of the constraints) interests us here.
In addition, to calculate the behavior, it is necessary to extract from the data the function of work hardening
isotropic R (p):

With
T (p)
y
3C 2

p = - E
With
C (p)

T
E.E
= F () =
T
y +
p
E - AND

E.E
3
R (p) =
T
y +
- C. p
E - AND 2

2.1.1 T = 1: elastic behavior

Indeed, the behavior is elastic until t=1. For t=1,
=

yy
E yy = 400MPa reaches just it
threshold of plasticity.

2.1.2 T = 2: elastoplastic load

When one reaches the criterion of plasticity (in load or discharge), one a:

3
-

C p = R (p)
2

= E (- p)

T
E.E
E.E
T
T

For the load, it is necessary to solve T = F () = +
p = +
(-
)
y
y
E - E
E - E
E
T
T

y
what gives again: T = + E (-
): one moves on the traction diagram up to the point such
y
T
E
that:

T = (- p
E

With
With
With)

2.1.3 T = 3: discharge elastic

The discharge is elastic up to the A' point:

3
- A' +
p
C
=
With
R (Pa)
2

A' = E (A' - p
With)

2.1.4 T = 4: elastoplastic load in compression

3
C =
p
C
- R (p)
2

2.2
Results of Reference

T
U D (mm)
(MPa)
y
yy
1 2.
10-3 400
2.4.5d3 500
3.0.1d3 380
4 -2.
10-3 -464

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibiographic

[1]
Relation of behaviour to linear and isotropic work hardening kinematic nonlinear. Note
[R5.03.16].
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling AXIS

3.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4

3.3 Functionalities
tested

Orders

Keys
DEFI_MATERIAU TRACTION
SIGM

[U4.23.01]
PRAGER
C

STAT_NON_LINE COMP_INCR RELATION
VMIS_ECMI_TRAC
[U4.32.01]

4
Results of modeling A

4.1 Values
tested

Identification Moments Reference
Aster %
difference
yy
1
400 400 0
yy
2
500 500 0
yy
3
-380 -380 0
yy
4
-464 -464 0

4.2 Parameters
of execution

Version: 5.1

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
128 Mo
Time CPU To use:
5 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X

5.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8 + 4 QUAD4 (faces)

5.3 Functionalities

tested

Orders

Keys
DEFI_MATERIAU ECRO_LINE D_SIGM_EPSI
[U4.23.01]

SY

PRAGER
C

STAT_NON_LINE COMP_INCR RELATION
VMIS_ECMI_LINE
[U4.32.01]

6
Results of modeling B

6.1 Values
tested

Identification Moments
Reference
Aster %
difference
yy
1
400 400 0
yy
2
500 500 0
yy
3
-380 -380 0
yy
4
-464 -464 0

6.2 Parameters of execution

Version: 5.1

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
128 Mo
Time CPU To use:
5 seconds

---

7 Modeling C

7.1 Characteristics of modeling

Modeling C_PLAN

7.2 Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4

7.3 Functionalities
tested

Orders

Keys
DEFI_MATERIAU TRACTION
SIGM

[U4.23.01]
PRAGER
C

STAT_NON_LINE COMP_INCR RELATION
VMIS_ECMI_TRAC
[U4.32.01]

8
Results of modeling C

8.1 Values
tested

Identification Moments Reference
Aster %
difference
yy
1
400 400 0
yy
2
500 500 0
yy
3
-380 -380 0
yy

4
-464 -464 0

8.2 Parameters
of execution

Version: 5.1

Machine: SGI - ORIGIN 2000 - R12000

Obstruction memory:
128 Mo
Time CPU To use:
6 seconds

9
Summary of the results

The results provided by Code_Aster coincide with the values of reference, because the test is uniaxial, and the stress and strain state is homogeneous.

Code_Aster ®
Version
5.0

Titrate:
SSNV135 triaxial Compression test drained with model CJS (level 1)
Date:
05/02/02
Author (S):
C. CHAVANT, pH. Key AUBERT
:
V6.04.135-A Page:
1/8

Organization (S): EDF/AMA, CNEPE/GC

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.135

SSNV135 - Triaxial compression test drained with model CJS
(level 1)

Summary

This test makes it possible to validate level 1 of model CJS. It is about a triaxial compression test in drained condition. Three levels of containment are simulated: 100, 200, then 400 kPa.

By reason of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test.

The results obtained with model CJS1 are compared with the analytical solution.

1
Problem of reference

1.1 Geometry

Z
E
height:
H = 1 m
width:
L = 1 m
thickness: E = 1 m
C
H

With
y
B
X
L

Co-ordinates of the points (in meters):

With
B
C
X 0. 0.
0.5
y 0. 1.
0.5
Z 0. 0.
0.5

1.2
Material property

E = 22,4 103 kPa
= 0,3

Parameters CJS1: = 0,03
= 0,82
Rm = 0,289
Pa = 100 kPa

1.3
Initial conditions, boundary conditions, and loading

Phase 1:
One brings the sample in a homogeneous state: 0 = 0 = 0
xx
yy
zz, by imposing the pressure of
containment corresponding on the front, side right-hand side and higher faces. Displacements are blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0), as well as the confining pressure on the front faces and side right-hand side. One apply a displacement imposed to the higher face: U (T)

Z
, in order to obtain a deformation
zz = -20% (counted starting from the beginning of phase 2).

2
Reference solution

2.1
Development of the analytical solution for CJS1

One has permanently:
= = 0
xx
yy
xx

where 0
you
xx = C represents the confining pressure.

Remain to determine zz.

Elastic phase:

By writing the elastic law simply, one a:

0 = 0 + + (+ 2 μ) +

xx
xx
zz
xx
xx
= 0 + (+ 2 μ) + 2
zz
zz
zz
xx

where here and μ is the coefficients of Lamé.

By eliminating xx between these two equations, one finds:

μ (3 + 2 μ)
= 0 +
(

zz
zz

+ μ)
zz
Plastic phase:

One a:

I
0
0
you
1 = zz + 2 xx where xx = C represents the confining pressure.

One deduces some for the components from the diverter S:

1
0
1
S = 2
I
zz
- xx

and S
= 0 - I
3 1

xx
xx
1
3

1
3
0

1
0
that is to say: S
= 6 - I
II
xx

and det (S) = 2
I -

3 1
xx

3 1

1/6
Consequently: (
H S) = (1 -)

In addition, when one reaches the criterion of the mechanism déviatoire: S
(H) + R I
II
S
m
=
1
0
from where the relation:

0
6
I
xx
1 =

2
Rm
-
3
(1 -) 1/6

---

and finally, one has for the vertical constraint:

6 0

xx
=
- 2 0
zz
xx
2
Rm
-
3 (1 -) 1/6

Moreover, one can calculate that the transition enters the states rubber band and perfectly plastic is done
for an axial deformation equalizes with:

μ (3 + 2 μ)
6 0

xx
=
0
(

- 2
zz

+ μ)
xx
2
R

m
-

3
1/6

(1-)

2.2
Results of reference

Constraints xx, yy and zz at points A, B and C.

2.3
Uncertainty on the solution

Analytical solution for CJS1.

---

3 Modeling
With

3.1
Characteristics of modeling

3D:

Z
B
y
X

Cutting: 2 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 0 = 0 = 0
xx
yy
zz: successively 100 kPa, 200 kPa and 400 kPa.
Level 1 of model CJS

3.2
Characteristic of the grid

A number of nodes: 27
A number of meshs and types: 8 HEXA8 and 24 QUA4

3.3 Functionalities
tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
"CJS"

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

4
Results of modeling A

4.1 Values
tested

For 0 = 0 = 0
xx
yy
zz: 100 kPa

Localization Number deformation
constraint
Reference
Aster *%*
difference
of order axial
(kPa)
zz (%)
Not A, B and C
10 -0.8
% xx
-100.0 -100.0
<
10-5
100
-20.0
%
xx

-100.0 -100.0
< 10-5

10 -0.8
% yy
-100.0 -100.0
< 10-5
100
-20.0
%
yy
-100.0 -100.0
< 10-5

10 -0.8
% zz
-279.2
-279.2 <
10-5
20
-1.6
%
zz
-367.159
-367.1587 <
10-5
40
-3.2
%
zz
-367.159
-367.1587 <
10-5
60
-7.2
%
zz
-367.159
-367.1587 <
10-5
100
-20.0
%

zz
-367.159
-367.1587 <
10-5

For 0 = 0 = 0
xx
yy
zz: 200 kPa

Localization Number deformation
constraint Reference
***Aster** %*
difference
of order
axial
(kPa)
zz (%)
Not A, B and C
10
-0.8 %
xx
-200.0 -200.0
<
10-5
100
-20.0
%
xx
-200.0 -200.0
< 10-5

10 -0.8
% yy
-200.0 -200.0
< 10-5
100
-20.0
%
yy
-200.0 -200.0
< 10-5

10 -0.8

% zz
-379.2
-379.2 <
10-5
20
-1.6
%
zz
-558.4
-558.4 <
10-5
40
-3.2
%
zz
-734.317
-734.3174 <
10-5
60
-7.2
%
zz
-734.317
-734.3174 <
10-5
100
-20.0
%
zz
-734.317
-734.3174 <
10-5

For 0 = 0 = 0
xx
yy
zz: 400 kPa

Localization Number deformation
constraint Reference
Aster %
difference
of order

axial
(kPa)
zz (%)
Not A, B and C
10
-0.8 %
xx
-400.0 -400.0
<
10-5
100
-20.0
%
xx
-400.0 -400.0
< 10-5

10 -0.8
% yy
-400.0 -400.0
< 10-5
100
-20.0
%
yy
-400.0 -400.0
< 10-5

10 -0.8
%
zz
-579.2
-579.2 <
10-5
20
-1.6
%
zz
-758.4
-758.4 <
10-5
40
-3.2

%
zz
-1116.8
-1116.8 <
10-5
60
-7.2
%
zz
-1458.6348
-1468.6348 <
10-5
100
-20.0
%
zz
-1458.6348
-1468.6348 <
10-5

4.2 Parameters
of execution

Version: 5.03.08

Machine: SGI - ORIGIN 2000 - R12000
System: IRIX 64

Obstruction memory: 16 Mo
Time CPU To use: 120 S
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNV135 triaxial Compression test drained with model CJS (level 1)
Date:
05/02/02

5
Summary of the results

The values of Code_Aster are in triad with the values of the analytical solution of reference.

Intentionally white left page.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNV136 - Triaxial compression test drained with model CJS (level 2)
Date:
05/02/02
Author (S):
***C. CHAVANT**, pH. Key AUBERT*
:
V6.04.136-A Page:
1/6

Organization (S): EDF/AMA, CNEPE

Document: V6.04.136

SSNV136 - Triaxial compression test drained with model CJS (level 2)

Summary

This test makes it possible to validate level 2 of model CJS. It is about a triaxial compression test in drained condition.
calculations are carried out only on the solid part of the ground, without hydraulic coupling. The level of
containment is of 100 kPa.
By reason of symmetry, one is interested only in the eighth of a sample 3D subjected to a triaxial compression test.
It is about a test of nonregression. Nevertheless, results obtained with Code_Aster for model CJS2 are compared with those obtained with a private version of software FLAC 2D.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

Z
E
height:
H = 1 m
width:
L
= 1 m
thickness:
E = 1 m
C
H
With
B
y
X
L

Co-ordinates of the points (in meters):

With
B
C
X 0. 0.
0.5
y 0. 1.
0.5
Z 0. 0.
0.5

1.2
Material property

E = 35,6616541 103 kPa
= 0,15037594

Parameters CJS2:
= - 0,55
= 0,82
Rm = 0,289
Rc = 0,265
N = 0,6

K p

O = 25,5 103 kPa
With = 0.25 kPa
Pa = -100 kPa

1.3
Initial conditions, boundary conditions, and loading

Phase 1:
One brings the sample in a homogeneous state: 0 = 0 = 0
xx
yy
zz, by imposing the pressure of
containment corresponding on the front, side right-hand side and higher faces. Displacements are blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0), as well as the confining pressure on the front faces and side right-hand side. One apply a displacement imposed to the higher face: U (T)
Z
, in order to obtain a deformation
zz = -20% (counted starting from the beginning of phase 2).

2
Reference solution

2.1 Method of calculation used for the reference solution

The results obtained with the software a private version of the software Flac-2D are used as reference.

2.2 Results of reference

Constraints xx, yy and zz at points A, B and C.

2.3 Uncertainty on the solution

Uncertainty related to the software Flac-2D.

2.4 Bibliography

[1]
Board, "FLAC (Fast Lagrangian Analysis of Continua) Version 2.20. U.S. NRC", NUREG/CR-5430, October 1989.
[2]
"Flac Fast Lagrangian Analysis of Continua. Theory and Background. " Itasca Consulting Group.

---

3 Modeling
With

3.1
Characteristics of modeling

3D:
Z
B
y
X

Cutting: 2 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 0 = 0 = 0
xx
yy
zz: successively 100 kPa, 200 kPa and 400 kPa.
Level 2 of model CJS

3.2
Characteristic of the grid

A number of nodes: 27
A number of meshs and types: 8 HEXA8 and 24 QUA4

3.3 Functionalities
tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
“CJS”

4
Results of modeling A

4.1 Values
tested

For 0 = 0 = 0
xx
yy
zz: 100 kPa

Localization Number deformation
constraint
Reference
Aster %
difference
of order
axial
(kPa)
zz (%)
Not A, B and C

-0.8 %

xx
100.0

-100.013 <
0.05

-20.0
%
xx
-100.0 -100.020
< 0.05

-0.8 %
yy
-100.0
-100.013 <
0.05

-20.0
%
yy
-100.0 -100.020
< 0.05

-0.8 %
zz
-286.8
-286.838 <
0.05

-1.6
%
zz
-332.9
-332.965 <
0.05

-3.2
%
zz
-350.8
-350.894 <
0.05

-7.2

%
zz
-356.1
-356.144 <
0.05

-20.0
%
zz
-358.8
-358.849 <
0.05

4.2 Parameters of execution

Version:
5.02.16

Machine:
SGI-ORIGIN 2000-R12000

Obstruction memory: 128 MO
Time CPU To use: 172s

5
Summary of the results

The values of the constraints obtained with Aster coincide with those of software FLAC with one lower deviation than 0,05%.

SSNV137 - Cable of prestressed in a beam
concrete right-hand side

Summary

One considers a right concrete beam, of square section, crossed over his length by a cable of prestressed out of steel. In at-rest state, the cable is parallel to fibre average of the beam and excentré by
report/ratio in the two principal plans. The beam and the cable are embed-free. The cable is put in traction at
its loose lead, in order to prestress the beam in inflection-compression. Losses of tension along cable are neglected.

The goal of this case-test is to validate the method of calculation of the state of balance of a concrete structure
prestressed, when this structure is modelled by elements 3D, associated the basic elements representing the cable of prestressing.

The functionalities particular to test are as follows:

.
operator DEFI_CABLE_BP: determination of the relations kinematics between the DDL of the nodes of one
cable and the DDL of the nodes "close" to a concrete structure modelled by elements 3D;
.
operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance.

The results obtained are validated by comparison with an analytical solution of reference.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

The concrete beam is right, of square section.
Its dimensions are L × has × has = 3 m × 0,4 m × 0,4 Mr.
The cable crosses the beam parallel with average fibre and it is excentré compared to the two plans principal. The eccentricities according to directions y and Z are worth respectively
ey = -0,12 m and ez = -0,16 Mr.
The surface of the cross-section of the cable is worth Its = 2,5.103 m2.

Z

y

has

X

has

L

Z

ey
y

has

ez

has

1.2
Properties of materials

Material concrete constituting the beam: Young modulus Eb = 4,5.1010 Pa
Material steel constituting the cable: Young modulus Ea = 1,85.1011 Pa
The Poisson's ratio is taken equal to 0 for two materials. One thus cancels the effects of Poisson in directions y and Z.
Losses of tension in the cable being neglected, the various parameters being used for their estimate are fixed at 0.

1.3
Boundary conditions and loadings

The nodes of the beam located on the face x=0 are blocked in translation according to the three directions.
Among these nodes are the "neighbors" of the left node end of the cable, which is thus blocked in translation by the relations kinematics. One thus should not impose conditions on additional limits in this node, which would be redundant with the relations kinematics and would make impossible the resolution in displacements (singular matrix).

One applies to the node right end of the cable a normal effort of traction (F0; 0; 0), with F0 = 106 NR.

2
Reference solution

The analytical solution of reference is determined by the theory of the beams. One is considered embed-free beam. The geometrical characteristics are those defined in paragraph [§2.1].
One applies at the loose lead a normal effort of compression (F; 0; 0) and a bending moment (0; ez. F; ey. F).

The solution of this problem is as follows:

Tensor of the constraints:

xx 0
0
F
12th
12

E
=
y
0
0
0
Z
with xx = -
1+
y +
Z
2
2
2

éq 2-1

has
has
has

0
0
0

Displacements: by neglecting the effects Poisson one obtains

12
12
(
F
ey
E
U X, y, Z) = -
1 +
y
Z
+
Z X
E

2
2
2
B has
has
has

6Fey
v
(X, y, Z) =
x2

éq 2-2
E

4
B has

6

(
Fe
W X, y, Z)
Z
=
x2
E

4
B has
U
= v = W = 0

with the boundary conditions v
W

in X = 0
=
= 0

X X

In the expressions above, F indicates the residual normal effort in the cable afterwards elastic shortening of the beam, which can be clarified according to the initial tension F0.

The axial rate of deformation of the concrete on the level of the cable is written

12e2
2
concrete
xx
F
y
12ez
1

xx
=
= -
+
+

E

2
2
2
B
Eb has
has
has

The residual normal effort in the cable results from the initial tension F
concrete
steel
=
0 by the relation

xx
xx

F - F0
and steel
xx
=
; from where:
Ea Its
F
F = F
0
0 + E has Its xx F =

éq 2-3
E

2
2
12

S has
E
has
y
12ez

1 +
1+
+

E
2
2
2
B has
has
has

The numerical values of reference are calculated using the formulas [éq 2-1], [éq 2-2] and [éq 2-3].

---

3 Modeling
With

3.1
Characteristics of modeling

The concrete beam is represented by 60 elements MECA_HEXA20, supported per as many meshs hexahedrons with 20 nodes. The figure below gives a simplified representation of the grid of beam.

A material concrete is affected with the elements, for which behaviors ELAS are defined (Young modulus Eb = 4,5.1010 Pa) and BPEL_BETON: parameters characteristic of this relation are fixed at 0 bus one neglects the losses of tension along the cable of prestressing.

The DDL DX, DY, and DZ of the nodes of the face x=0 are blocked.

The cable is represented by 30 elements MECA_BARRE, supported per as many meshs segments to 2 nodes. The ends left and right-hand side are respectively nodes NC000001 and NC000031.

A surface of cross-section Its = 2,5.103 m2 is assigned to the elements, as well as a material steel for which are defined behaviors ELAS (Young modulus Ea = 1,85.1011 Pa) and BPEL_ACIER: parameters characteristic of this relation are fixed at 0 (neglected losses of tension), except stress ultimate elastic for which a zero value is illicit (fprg = 1,77.109 Pa).

To avoid any redundancy with the relations kinematics, no blocking is forced on the node NC000001 (cf notices paragraph [§2.3]).

The F0 tension = 106 NR is applied to node NC000031. This value of tension is coherent with values of section and yield stress, for a cable of prestressed of strand type.

The calculation of the state of balance of the beam unit and cable is carried out in only one step, it behavior being elastic. One carries out then a complementary calculation allowing to determine constraints with the nodes of the elements of the beam.

3.2
Stages of calculation and functionalities tested

The principal stages of calculation correspond to the functionalities which one wishes to validate:

- *operator DEFI_MATERIAU: definition of the relations of behavior BPEL_BETON and BPEL_ACIER, in the particular case where losses of tension along the cable of prestressed are neglected (default values of the parameters);*
- *operator DEFI_CABLE_BP: determination of a constant profile of tension along the cable of prestressing, losses being neglected ; calculation of the coefficients of the relations kinematics between the DDL of the nodes of the cable and the DDL of the nodes "close" to beam out of concrete, in the case of a beam modelled by elements 3D;*
- *operator AFFE_CHAR_MECA: definition of a loading of the type RELA_CINE_BP;*
- *operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account loading of the type RELA_CINE_BP, in the case of a beam modelled by elements 3D.*

One uses finally operator CALC_ELEM option SIGM_ELNO_DEPL in order to calculate the constraints with nodes of the elements of the beam.

4
Results of modeling A

4.1 Values tested

4.1.1 Displacements of the nodes of the beam

One compares the values extracted field DEPL resulting from STAT_NON_LINE with the theoretical values from reference. The tolerance of relative variation compared to the reference is worth:

- *3% for node NB010527;*
- *1% for nodes NB030127, NB050127 and NB050527;*
- *0,1% for the other nodes.*

Node	*Component*	*Value of reference*	*Computed value*	*Relative variation*
NB010105	*DX*	*2,298342.104 m*	*2,298342.104 m*	*+2,35.10-7 %*
NB010305	*DX*	*1,237569.104 m*	*1,237569.104 m*	*+4,91.10-8 %*
NB010505	*DX*	*1,767956.105 m*	*1,767956.105 m*	*-1,13.10-7 %*
NB030105	*DX*	*1,502762.104 m*	*1,502762.104 m*	*+2,87.10-7 %*

NB030305 DX 4,419890.105 m
4,419890.105 m
-1,12.10-7 %
NB030305 DY 7,955801.105 m
7,955801.105 m
+1,31.10-8 %
NB030305 DZ 1,060773.104 m
1,060773.104 m
+4,53.10-7 %
NB030505 DX +6,187845.105 m
+6,187845.105 m
+4,91.10-8 %
NB050105 DX 7,071823.105 m
7,071823.105 m
+2,84.10-8 %
NB050305 DX +3,535912.105 m
+3,535912.105 m
-1,13.10-7 %
NB050505 DX +1,414365.104 m
+1,414365.104 m
-2,54.10-7 %

NB010116 DX 8,618785.104 m
8,618783.104 m
-1,87.10-7 %
NB010316 DX 4,640884.104 m
4,640884.104 m
+5,86.10-8 %
NB010516 DX 6,629834.105 m
6,629837.105 m
+4,12.10-7 %
NB030116 DX 5,635359.104 m
5,635360.104 m
+1,15.10-7 %
NB030316 DX 1,657459.104 m
1,657459.104 m
-8,23.10-8 %
NB030316 DY 1,118785.103 m
1,118785.103 m
-4,18.10-7 %

NB030316 DZ 1,491713.103 m
1,491713.103 m
-1,95.10-7 %
NB030516 DX +2,320442.104 m
+2,320442.104 m
+5,66.10-8 %
NB050116 DX 2,651934.104 m
2,651934.104 m
-5,31.10-8 %
NB050316 DX +1,325967.104 m
+1,325967.104 m
+3,21.10-8 %
NB050516 DX +5,303867.104 m
+5,303869.104 m
+2,95.10-7 %

NB010127 DX 1,493923.103 m
1,494742.103 m
+0,055 %
NB010327 DX 8,044199.104 m
8,039511.104 m
-0,058 %
NB010527 DX 1,149171.104 m
1,123172.104 m
-2,262 %
NB030127 DX 9,767956.104 m
9,755085.104 m
-0,132 %
NB030327 DX 2,872928.104 m
2,870992.104 m
-0,067 %
NB030327 DY 3,361326.103 m
3,361041.103 m
-0,008 %
NB030327 DZ 4,481768.103 m
4,481603.103 m
-0,004 %
NB030527 DX +4,022099.104 m
+4,021519.104 m
-0,014 %

NB050127 DX 4,596685.104 m
4,599190.104 m
-0,598 %
NB050327 DX +2,298343.104 m
+2,296287.104 m
-0,089 %
NB050527 DX +9,193370.104 m
+9,167311.104 m
-0,283 %

4.1.2 Normal constraint in the beam

One compares the values extracted field SIGM_ELNO_DEPL resulting from CALC_ELEM with the values
theoretical of reference.
The component to which the tests relate is SIXX.
The tolerance of relative variation compared to the reference is worth 0,1%.

Node
Net
Value of reference
Computed value
Relative variation
NB010116 HX010115 2,585635.107 Pa
2,585622.107 Pa
-4,97.10-6 %

NB010316 HX010115 1,392265.107 Pa
1,392266.107 Pa
+9,60.10-7 %
NB010516 HX010315 1,988950.106 Pa
1,989086.106 Pa
+0,007 %
NB030116 HX010115 1,690608.107 Pa
1,690605.107 Pa
-1,66.10-6 %
NB030316 HX010115 4,972376.106 Pa
4,972387.106 Pa
+2,39.10-6 %
NB030516 HX010315 +6,961326.106 Pa
+6,961321.106 Pa
-6,61.10-7 %
NB050116 HX030115 7,955801.106 Pa
7,955959.106 Pa
+0,002 %
NB050316 HX030115 +3,977901.106 Pa
+3,977883.106 Pa
-4,46.10-6 %
NB050516 HX030315 +1,591160.107 Pa
+1,591176.107 Pa
+0,001 %

4.1.3 Displacements of the nodes of the cable of prestressing

One compares the values extracted field DEPL resulting from STAT_NON_LINE with the theoretical values from
reference. The tolerance of relative variation compared to the reference is worth:

·
1% for node NC000031, component DZ;
·
0,1% for the other nodes.

Node
Component
Value of reference
Computed value
Relative variation
NC000006 DY 1,243094.104 m
1,243094.104 m

-6,24.10-8 %
NC000006 DZ 1,657459.104 m
1,657459.104 m
-2,64.10-7 %
NC000011 DY 4,972376.104 m
4,972376.104 m
-5,90.10-8 %
NC000011 DZ 6,629834.104 m
6,629834.104 m
+3,99.10-8 %
NC000016 DY 1,118785.103 m
1,118785.103 m
-3,13.10-7 %
NC000016 DZ 1,491713.103 m
1,491713.103 m
-7,49.10-8 %
NC000021 DY 1,988950.103 m
1,988946.103 m
-1,96.10-6 %
NC000021 DZ 2,651934.103 m
2,651929.103 m
-1,74.10-6 %
NC000026 DY 3,107735.103 m
3,107026.103 m
-0,023 %
NC000026 DZ 4,143646.103 m
4,142654.103 m
-0,024 %
NC000031 DY 4,475138.103 m
4,475186.103 m
+0,001 %
NC000031 DZ 5,966851.103 m
6,010387.103 m
+0,730 %

4.1.4 Normal effort in the cable of prestressing

One compares the value extracted field SIEF_ELNO_ELGA resulting from STAT_NON_LINE with the value
theoretical of reference.
The component to which the test relates is NR.
The tolerance of relative variation compared to the reference is worth 0,1%.

Node
Net
Value of reference
Computed value
Relative variation
NC000016 SG000015
+7,955801.105 NR
+7,955805.105 NR
+5,42.10-7 %

5
Summary of the results

The computed values correspond indeed to those theoretically awaited. One obtains well a state of inflection-compression for the concrete beam.
The more important variations observed in certain nodes closer to the loose lead can to be explained by the more or less good adequacy of a modeling 3D for a structure of the type beam. Thus the grid remains enough coarse not to increase the cost of calculation. One recalls finally that the reference solution is established under the assumptions of the theory of the beams.

5.0

Titrate:
SSNV137 - Cable of prestressed in a right concrete beam
Date:
09/04/02
Author (S):
C. CHAVANT, Key Mr. LAINET
:
V6.04.137-A Page:
10/10

Intentionally white left page.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
6.4

Titrate:
SSNV138 - Plate Cantilever in great rotations subjected to one Date moment
:
17/06/03

Author (S):
P. MASSIN, Mr. Al MIKDAD, J.M.PROIX Key
:
V6.04.138-C Page:
1/12

Organization (S): EDF-R & D /AMA, SAMTECH

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.138

SSNV138 - Plate Cantilever in great rotations
subjected to one moment

Summary:

Quasi-static calculation of an elastic plate embedded on a side and subjected to one bending moment to the other
side, leading to great rotations of the plate.

Interest:

To test nonlinear finite elements geometrical COQUE_3D (modelings A and C) and POU_D_T_GD (modeling B) using the algorithm of update of great rotations 3D GREEN_GR in STAT_NON_LINE.

Note:

This test is the version plates case test of beam SSNL103. The mechanical characteristics were modified in order to support a surface modeling.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

1
Problem of reference

1.1 Geometry

y
Z
L=10 m
4
P
3
P
B = 1 m
X
m
1
P
H = 0.1 m
2
P

Rectangular plate embedded into 1
P 4
P and subjected into 2
P 3
P with a linear couple:

m *= - me*
; m
y
> 0

1.2
Properties of materials and characteristic of section

Elastic behavior:

E = 12 ×106 Pa; = 0

The fact that the Poisson's ratio is null makes the solution of plate identical to that of beam.
I is there the inertia of the section with a model of beam:

3
B
1
-3
I y = H =
×10
12
12

1.3
Boundary conditions and loading

Embedding in 1
P 4
P. One seeks the successive states of balance under the loading made up of
linear couple in 2
P 3
P:

m (T) = 100 T; T pseudo-time.

One is interested particularly in displacements horizontal and vertical and rotation of the line
2
P 3
P.

2
Reference solution

2.1
Method of calculation used for the reference solution

With a kinematics of beam and a model in resulting efforts, curve (in great rotations) cantilever subjected to the bending moment M = mb is, with the preceding numerical data:

D
mb
T
=
=
dx
I.E.(internal excitation)
L
y

It is the solution of Euler.

2.2
Results of reference

L

R =
Rsin
R 1

(- cos)
L

According to the solution of Euler, the deformation is an arc of circle. With section 2
P 3
P (X = L), rotation
is worth:

(X = L) = T.

In the absence of normal effort, average surface remains inextensible and the radius of curvature is given
by:

D -1

L
R =
=
dx
T
Horizontal displacement is then

sin
U =
T
R sin - L = L (
-)
1
T

and vertical displacement is

L
v = R 1
(- cos) =
1
(- cost)
T

2.3 References bibliographical

[1]
Mr. Al MIKDAD: Statics and Dynamics of the Beams in Great Rotations and Resolution of Problems of Nonlinear Instability. Thesis of Doctorate, University of Technology of Compiegne (1998).
[2]
J.C. SIMO and L. CONSIDERING QUOC: In Three-dimensional Finite Strain Rod Model. Leaves II: Computational Aspects. Comput. Meth. Appl. Mech. Engrg. 58, 79-116 (1986).
[3]
J.C. SIMO, D.D. FOX and M.S. RIFAI: There are Resulting Stress Geometrically Exact Shell Model. Leaves III: Computational Aspects of the Nonlinear Theory. Comput. Meth. Appl. Mech. Engrg. 79, 21-70 (1990).

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3 Modeling With

3.1 Characteristics of modeling

Modeling COQUE_3D

3.2 Characteristics of the grid

1 element
10 elements

A number of nodes: 54
A number of meshs and type: 10 QUAD9 and 1 SEG3

3.3 Functionalities tested

· Modeling COQUE_3D into nonlinear geometrical.
· The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

Orders

STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"
COQUE_NCOU: 1
DEFORMATION: "GREEN_GR"

4
Results of modeling A

4.1 Values tested

The incremental analysis is carried out in the interval of pseudo-time [0: 2.4] in fourteen steps of charge.

4.1.1 History of horizontal rotation DRY to the nodes charged

Moment
M couples
Aster
Reference
% difference
DRY (radians)
DRY (radians)

0.6 60.
0.6000E+00
0.6000E+00
+0.000
1.2 120
1.20003E+00
1.2000E+00
+0.003
1.8 180
1.80011E+00
1.8000E+00
+0.006
2.4 240
2.40021E+00

2.4000E+00
+0.009

4.1.2 History of horizontal displacement DX to the nodes charged

Moment
M couples
Aster
Reference
% difference

0.6 60.
5.89343E-01
5.8929E-01
+0.009
1.2 120
2.23316E+00
2.23300E+00
+0.012
1.8 180
4.59041E+00
4.58973E+00
+0.015
2.4 240
7.1866E+00
7.18557E+00
+0.015

4.1.3 History of vertical displacement DZ to the nodes charged

Moment
M couples
Aster
Reference
% difference

0.6 60.
2.91108E+00
2.91107E+00
+0.000
1.2 120
5.31370E+00

5.31368E+00
+0.000
1.8 180
6.817704E+00
6.81778E+00
-0.001
2.4 240
7.2386
E+00
7.23914E+00
-0.007

We present hereafter a visualization of the deformation during 14 step of load:

4.2 Remarks

One uses COEF_RIGI_DRZ = 0.001. The value of the angle swing reached is 135 degrees.

---

5 Modeling
B

5.1
Characteristics of modeling

POU_D_T_GD (beam 3D in great rotations).

modeling POU_D_T_GD.

5.2 Characteristics of the grid

10 elements

A number of nodes: 11
A number of meshs and type: 10 SEG2

5.3 Functionalities tested

· Nonlinear element geometrical POU_D_T_GD.
· The static algorithm of update of great rotations ELAS_POUTRE_GD of STAT_NON_LINE.

Orders

STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS_POUTRE_GD"
DEFORMATION: "GREEN_GR"

6
Results of modeling B

6.1 Values tested

The incremental analysis is carried out in the interval of pseudo-time [0: 6] in 60 steps of load.

6.1.1 History of horizontal rotation DRY (radians) to the nodes charged

Moment
Moment m
Aster
Reference
% difference

0.3 30.
0.3000E+00
0.3000E+00
+0.000
0.6 60.
0.6000E+00
0.6000E+00
+0.000
3.0 300.
3.0000E+00
3.0000E+00
+0.000
6 600 -6
-6 0

6.1.2 History of horizontal displacement DX (m) to the nodes charged

Moment
Moment m
Aster
Reference
% difference

0.3 30.
1.4895E-01

1.4932E-01
-0.247
0.6 60.
5.8788E+01
5.8934E+01
-0.240
3.0 300. -9.5278 -9.5296
-0.02
6 600
-10.4729
-10.4657
0.07

6.1.3 History of vertical displacement DZ (m) to the nodes charged

Moment
Moment m
Aster
Reference
% difference

0.3 30.
1.4888E+01
1.4887E+01
+0.004
0.6 60.
2.9115E+00
2.9110E+00
+0.015
3.0 300.
6.6582 6.6333 0.38
6 600
6.74377
6.638286
1.6

7 Modeling C

7.1 Characteristics of modeling

Modeling COQUE_3D

7.2 Characteristics of the grid

1 element
10 elements

A number of nodes: 64
A number of meshs and type: 20 TRIA7 and 1 SEG3

7.3 Functionalities tested

· Modeling COQUE_3D into nonlinear geometrical.
· The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

Orders

STAT_NON_LINE
COMP_ELAS
RELATION: “ELAS”
COQUE_NCOU: 1
DEFORMATION: “GREEN_GR”

8
Results of modeling C

8.1 Values tested

The incremental analysis is carried out in the interval of pseudo-time [0: 2.2] in eight step of load.

8.1.1 History of horizontal rotation DRY to the nodes charged

Moment	M couples	Aster	Reference	% difference
0.6	60	0.5993E+00	0.6000E+00	-0.107
1.2	120	1.1950E+00	1.2000E+00	-0.411
1.8	180			

1.7843E+00
1.8000E+00
-0.868
2.2 220
2.2000E+00
2.1728E+00
-1.235

8.1.2 History of horizontal displacement DX to the nodes charged

Moment
M couples
Aster
Reference
% difference

0.6 60
5.88149E-01
5.8929E-01
-0.194
1.2 120
2.21699E+00
2.23300E+00
-0.717
1.8 180
4.52666E+00
4.58973E+00
-1.374
2.2 220
6.21278E+00
-6,3250163463
-1.774

8.1.3 History of vertical displacement DZ to the nodes charged

Moment
M couples
Aster
Reference
% difference

0.6 60

2.90827E+00
2.91107E+00
-0.096
1.2 120
5.29785
E+00
5.31368E+00
-0.298
1.8 180
6.79264E+00
6.81778E+00
-0.369
2.2 220
7.207771E+00
7,22046E+00
-0.176

We present hereafter a visualization of the deformation during 8 steps of load:

8.2 Remarks

One uses COEF_RIGI_DRZ = 0.001. The value of the angle swing reached is 125 degrees.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

9
Summary of the results

One notices difficulties of convergence which disappear by multiplying the thickness by 3 or 4.

It is necessary to increase the value of the COEF_RIGI_DRZ which allots a rigidity around normal of the elements of hull which is worth by defect 105 (the smallest rigidity of inflection around directions in the plan of the hull) in order to be able to increase the value of the swing angle that one can reach. Values of this coefficient up to 103 remain licit.

During the iterations of Newton, deformations of membrane appear and are cancelled with convergence.

Speeds of convergence of the algorithms of NEWTON are comparable for modelings POU_D_T_GD and COQUE_3D.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

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Titrate:
SSNV139 - Plate Skews

Date:
09/02/00
Author (S):
***P. MASSIN,** Key Mr. Al MIKDAD*
:
V6.04.139-A Page:
1/8

Organization (S): EDF/MTI/MMN, SAMTECH

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.139

SSNV139 - Plate skews

Summary:

Quasi static calculation of a horizontal oblique elastic plate embedded on a side and subjected to a force
concentrated vertical. The results are compared with those of software the SAMCEF software.

The interest is to test the finite element of COQUE_3D into nonlinear geometrical COQUE_3D while using
the algorithm of update of great rotations 3D GREEN_GR in STAT_NON_LINE.

Rotations are 3D and slightly higher than 1 radian.

1
Problem of reference

1.1 Geometry

y
Z
L = 100
P
P2
F
B = 20
O
= 20
X
H = 0.5
X

P1
P

Oblique plate embedded out of P P
1 2 and subjected out of P to a concentrated vertical force:

F = - F E
F
Z
;
> 0

1.2
Material properties

Elastic behavior:

1
E = 2100000; =
3

1.3
Boundary conditions and loadings

Embedding out of P P
1 2. One seeks the successive states of balance under the loading made up of the force:

F (T) = T

out of P, T being pseudo time.

One is interested particularly in displacements horizontal and vertical in P.

2
Reference solution

This solution [bib4] is that which is obtained with software the SAMCEF software [bib1]. Modeling is based on a theory of hull in resulting efforts with a Co-rotational formulation [bib3] and a discretization DSQ [bib2].

4 elements
20 elements

The grid considered is 20 × 4 elements quadrilateral with 4noeuds each one.

2.1 References bibliographical

[1]
The SAMCEF software, Handbook of reference V7.1 Elements Volume, 1998
[2]
J-L. BATOZ, G.DHATT: "Modeling of the Structures by Finite elements: Beams and Plates ", Hermès, Paris, 1992
[3]
M.A. CRISFIELD: "Non-linear Finite Element Analysis of Solids and Structures", Volume 1: Essentials, John Wiley, Chichester, 1994
[4]
PH. JETTEUR: Nonlinear kinematics of the Hulls. Report/ratio SAMTECH, Contract PP/GC-134/96, 1998

---

3 Modeling
With

3.1
Characteristics of modeling

Element MEC3QU9H (voluminal hull)

Modeling COQUE_3D

4 elements
15 elements

3.2
Characteristics of the grid

A number of nodes: 387

A number of meshs and types: 60 QUAD9

3.3 Functionalities
tested

· Modeling COQUE_3D into nonlinear geometrical.

· The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

COMP_ELAS:
(RELATION
: "ELAS"
COQUE_NCOU
: 1
DEFORMATION: "GREEN_GR"
)

4
Results of modeling A

4.1 Values
tested

History of horizontal displacement DX to the node charged

Moment
Force F
Aster
Reference
% difference
250. 250.

3.902E+01
3.807E+01
+2.514
500. 500.
5.432E+01
5.200E+01
+4.470

History of vertical displacement DZ to the node charged

Moment
Force F
Aster
Reference
% difference
250. 250.
7.218E+01
7.240E+01
-0.307
500. 500.
8.103E+01
-8.073E+01
+0.371

4.2 Remarks

One uses the default value of COEF_RIGI_DRZ = 0.00001.

4.3 Parameters
of execution

Version: 5.01.18

Machine: SGI

System:
CLASTER
Obstruction memory:
8 Mo

Time CPU To use total:
756.59 seconds

---

5 Modeling B

5.1 Characteristics of modeling

Element MEC3TR7H (voluminal hull)

Modeling COQUE_3D

4 elements
15 elements

5.2 Characteristics of the grid

A number of nodes: 507

A number of meshs and types: 120 TRIA7

5.3 Functionalities tested

· Modeling COQUE_3D into nonlinear geometrical.
· The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

STAT_NON_LINE:
(
COMP_ELAS:
(
RELATION
: "ELAS"
COQUE_NCOU
: 1
DEFORMATION: "GREEN_GR"
)
)

---

6 Results of modeling B

6.1 Values

tested

History of horizontal displacement DX to the node charged

Moment
Force F
Aster
Reference
% difference
250. 250.
3.744E+01
3.807E+01
-1.648
500. 500.
5.227E+01
5.200E+01
+0.517

History of vertical displacement DZ to the node charged

Moment
Force F
Aster
Reference
% difference
250. 250.
7.044E+01
7.240E+01
-2.705
500. 500.
7.917E+01
8.073E+01
-1.930

6.2 Remarks

One uses the default value of COEF_RIGI_DRZ = 0.00001.

6.3 Parameters
of execution

Version: 5.01.18

Machine: SGI

System:
CLASTER
Obstruction memory:
8 Mo
Time CPU To use total: 762.78 seconds

7
Summary of the results

The model used for the reference solution is based on a theory in resulting efforts with Co-rotational formulation [bib3], whereas that of Code_Aster uses a voluminal approach with a formulation in Lagrangian total [R3.07.04].

For this thin hull, the triangle and the quadrangle give good results.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.140

SSNV140 - Embedded cylindrical panel

Summary:

One presents in this test a quasi static calculation of embedded elastic cylindrical panel subjected to one surface force data either in the total reference mark, or in the local reference mark. This force is constant in first case and following in the second case. Nonlinear modeling COQUE_3D thus is tested geometrical by using the algorithm of update of great rotations 3D GREEN_GR of STAT_NON_LINE, as well as the treatment of the following pressures for modeling COQUE_3D. The reference solution which is numerical is obtained with software the SAMCEF software.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/05/005/A

1
Problem of reference

1.1 Geometry

The lengths are expressed in meters.

P3
P4
P2
F Z
1
P
L =10
2
H = 0 125
.
R = 100
2 = 2
.
0 rad
Z
y
X

The cylindrical panel is embedded along its 4 sides and subjected to a surface force.

.

data in the total reference mark for modeling a:

***F** = **-** F **E**; F >*
Z
Z
Z
0

.
data in the local reference mark for modeling b:

***F** = **-** F **N**; F > 0*
Z
Z

*who leads to the membrane compression of the panel, accompanied by localised inflections. In case of modeling B, **N** is the normal with the reactualized geometry of the panel.*

Because of the geometrical and physical symmetry of the problem, only the quarter P P P P
1 2 3 4 of the panel

is modelled, by taking account of the conditions of symmetry.

1.2
Material properties

Elastic behavior:

E = 450000 Pa; = 0 3
.

1.3 Boundary conditions and loadings

C.L. :
P2P3: DX=0.
DY=0.
DZ=0.
DRX=0
DRY=0
DRZ=0

P3P4: DX=0.
DY=0.
DZ=0.
DRX=0
DRY=0
DRZ=0

Symmetry: P1P2:
DY=0.

DRX=0.

DRZ=0.

P4P1: DX=0.

DRY=0.
DRZ=0.

One seeks the successive states of balance under the loading made up of the surface force *data in the total reference mark:*

F (T)
T
Z
=

T being pseudo time.
One is only interested in the component vertical of displacement in P1.

2
Reference solution

2.1
Method of calculation used for the reference solution

This solution [bib4] is that which is obtained with software the SAMCEF software [bib1]. Modeling is based on a theory of hull in resulting efforts with a Co-rotational formulation [bib3] and a discretization DSQ [bib2].

16 elements
16 elements

The grid considered in the calculation of reference is a regular grid of 16 × 16 elements quadrilateral with 4 nodes each one.

2.2
Results of reference

History of vertical displacement DZ in meters with the node charged P1

Moment	Surface force fz (NR)	DZ in P1 (m)
0.2	0.2	1.043E01
0.4	0.4	3.935E01
0.7	0.7	5.13E01

2.3 References

bibliographical

[1]
The SAMCEF software, Handbook of reference V7.1 Elements Volume, 1998
[2]
J-L. Batoz, G.Dhatt, "Modeling of the Structures by Finite elements: Beams and Plates", Hermès, Paris, 1992
[3]
Crisfield M.A., "Non-linear Finite Element Analysis of Solids and Structures", Volume 1: Essentials, John Wiley, Chichester, 1994
[4]
PH. JETTEUR, Nonlinear Kinematics of the Hulls. Report/ratio SAMTECH, Contract PP/GC-134/96, 1998

---

3 Modeling With

3.1 Characteristics of modeling

Modeling COQUE_3D

Element MEC3QU9H (voluminal hull 3D) - regular Grid

8 elements

8 elements

3.2
Characteristics of the grid

A number of nodes: 320

A number of meshs and type: 64 QUAD9

The grid is twice less fine than that of the reference solution.

3.3 Functionalities
tested

.
Modeling COQUE_3D into nonlinear geometrical.
.
The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

Order Mots
keys

STAT_NON_LINE
COMP_ELAS
RELATION: "elas"

COQUE_NCOU: 1

DEFORMATION: "green_gr"

---

4 Results of modeling A

4.1 Values tested

History of vertical displacement DZ to the node charged

Moment	***Force surface fz***	***Aster***	***Reference***	***% difference***
0.2	*0.2*	*1.040E01*	*1.043E01*	*-0.351*
0.4	*0.4*	*3.920E01*	*3.935E01*	*-0.362*

4.2 Remarks

The default value of COEF_RIGI_DRZ = 0.00001 was selected (value generally used in analyze linear).

5 Modeling B

It is identical to modeling A, except for loading which is following: it is reactualized according to the geometry. One goes until moment 0.7 per step of time of 0.1. There are thus 7 steps of charge.

5.1 Characteristics of modeling

Modeling COQUE_3D

Element MEC3QU9H (voluminal hull 3D) - regular Grid

8 elements
8 elements

5.2 Characteristics of the grid

A number of nodes: 320

A number of meshs and type: 64 QUAD9

The grid is twice less fine than that of the reference solution.

5.3 Functionalities tested

.
Modeling COQUE_3D into nonlinear geometrical.
.
The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

The following loading is obtained in the following way:

Order Mots keys

STAT_NON_LINE
COMP_ELAS
RELATION: "elas"

COQUE_NCOU: 1

DEFORMATION: "green_gr"

EXCIT
TYPE_CHARGE: SUIV

6
Results of modeling B

6.1 Values
tested

The values of reference come from software the SAMCEF software. They are given as an indication.

History of vertical displacement DZ to the node charged

Moment	Force surface fz	Aster	Reference (The SAMCEF software)	% difference
0.4	0.4	3.92E01	3.93E01	-0.25%
0.7	0.7	5.11E01	5.13E01	-0.28%

6.2 Remarks

Rotations not being very large, it is enough to use the default value of COEF_RIGI_DRZ = 0.00001 (value generally used in linear analysis).

7.4

Titrate:
SSNV140 - Embedded cylindrical panel

Date:
02/11/05
Author (S):
***P. MASSIN,** Key Mr. Al MIKDAD*
:
V6.04.140-B Page:
8/10

7 Modeling C

It is identical to modeling A, except for the functionality tested, COMP_INCR instead of COMP_ELAS. As in both cases, one remains in the elastic range, one must thus find them same results.

7.1 Characteristics of modeling

Modeling COQUE_3D

Element MEC3QU9H (voluminal hull 3D) - regular Grid

8 elements
8 elements

7.2 Characteristics of the grid

A number of nodes: 320

A number of meshs and type: 64 QUAD9

The grid is twice less fine than that of the reference solution.

7.3 Functionalities

tested

.
Modeling COQUE_3D into nonlinear geometrical.
.
The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

The following loading is obtained in the following way:

Order Mots
keys

STAT_NON_LINE
COMP_INCR
RELATION: "elas"

COQUE_NCOU: 1

DEFORMATION: "green_gr"

EXCIT
TYPE_CHARGE: SUIV

---

8 Results of modeling C

8.1 Values tested

History of vertical displacement DZ to the node charged

Moment	***Force surface fz***	***Aster***	***Reference***	***% difference***
0.2	*0.2*	*1.040E01*	*1.043E01*	*-0.352*
0.4	*0.4*	*3.921E01*	*3.935E01*	*-0.360*

8.2 Remarks

The default value of COEF_RIGI_DRZ = 0.00001 was selected (value generally used in analyze linear).

9
Summary of the results

H
The facts of the case correspond to a thin hull
= 0 625%
.
what is severe for
L
the finite element triangle MEC3TR7H (not presented here bus presenting a case of blocking at shearing transverse). The deformation is primarily membranous and rotations remain moderate.

The reference solution obtained by software the SAMCEF software is numerical and its grid twice more end that that used here. Its model finite elements rests on an approach in resulting efforts with a rotational formulation [bib3]. The approach chosen in Code_Aster is 3D forced plane with a formulation Lagrangian total [R3.07.04]. The quality of the results obtained is good. The variation compared to this solution is lower than 0.5% for the vertical displacement of the central point.

***P. MASSIN**, Key Mr. Al MIKDAD*
:

Organization (S): EDF/AMA, SAMTECH

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.141

SSNV141 - Segment of a sphere pinch

Summary:

One presents in this case-test a geometrical nonlinear quasi static calculation of segment of a sphere pinch. It allows to test modeling COQUE_3D into nonlinear geometrical and the algorithm of update of great rotations 3D (key Word GREEN_GR of operator STAT_NON_LINE). This popular example in analysis linear watch capacity of the element of hull to representing well the inflection without extension and them movements of rigid body. Moreover the thinness of the hull compared to its radius of curvature allows to test the treatment of blocking in transverse shearing. Deformations obtained by Code_Aster different from 0.1 to 1.25% compared to those of Code the SAMCEF software, taken for reference.

HT-66/02/001/A

1
Problem of reference

1.1 Geometry

Z
18°
P4
P3
H = 0.04
R = 10
F
F
P7
P6
F
F
X
y
1
P
P2
P5

Cap pinch:

In P1 F = Fex

In P6 F = - Fex
In P2 F = - Fey
In P7 F = Fey
With F > 0

1.2
Material properties

Elastic behavior:

E = 6.825 × 107
.
; = 0 3
.

1.3
Boundary conditions and loadings

One seeks the successive states of balance under the loading

F (T) = T

applied into 1

P
P6
P2
P7

Because of the geometrical and physical symmetry of the problem, only the quarter P P P P 1 2 3 4 is modelled,

by taking account of the conditions of symmetry. These conditions eliminate 5 movements from body rigid. The last movement of rigid body is eliminated by blocking displacement according to Z. with not P5,

C.L. :
P5:
DZ=0
Symmetry:
P2P3:
DY=0.
DRX=0.
DRZ=0.
P4P1:
DX=0.

DRY=0. DRZ=0.

One is interested particularly in displacements of items 1
P and 3
P following the directions of
loading.

2
Reference solution

This solution [bib4] is that which is obtained with software the SAMCEF software [bib1]. Modeling is based on a theory of hull in resulting efforts with a Co-rotational formulation [bib3] and one discretization DSQ [bib2].

20 elements
20 elements
20 elements
20 elements

The grid considered is 20 × 20 elements quadrilateral.

The strategy of Newton with level of force imposed illustrates a difficulty of convergence. One pushes calculation to F = 100.

2.1 References bibliographical

[1]
The SAMCEF software, Handbook of reference V7.1 Elements Volume, 1998
[2]
J-L. Batoz, G.Dhatt, "Modeling of the Structures by Finite elements: Hulls", Hermès, Paris, 1992
[3]
Crisfield M.A., "Non-linear Finite Element Analysis of Solids and Structures", Volume 1: Essentials, John Wiley, Chichester, 1994
[4]
PH. JETTEUR, Nonlinear Kinematics of the Hulls. Report/ratio SAMTECH, Contract PP/GC-134/96, 1998

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3 Modeling With

3.1 Characteristics of modeling

Element MEC3QU9H (voluminal hull)
Modeling COQUE_3D

10 elements
10 elements
10 elements
10 elements

3.2
Characteristics of the grid

A number of nodes: 441

A number of meshs and types: 100 QUAD9

3.3 Functionalities
tested

· Modeling COQUE_3D into nonlinear geometrical.
· The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

STAT_NON_LINE:
(
COMP_ELAS:
(
RELATION
: "elas"
COQUE_NCOU
: 1
DEFORMATION: "green_gr"
)
)

4
Results of modeling A

4.1 Values
tested

The incremental analysis is carried out in the interval of pseudo-time [0: 100.] in 10 steps of load.

History of horizontal displacement DX at the P1 point

Moment	*Force F*	*Aster*	*Reference*	*% difference*
020.	*020.*	*+1.486E+00*	*+1.484E+00*	*+0.107*
050.	*050.*	*+2.571E+00*	*+2.578E+00*	*-0.262*
100.	*100.*	*+3.362E+00*	*+3.390E+00*	*-0.827*

History of horizontal displacement DY at the P2 point

Moment
Force F

Aster
Reference
% difference

020. 020.
1.816E+00
1.799E+00
+0.954
050. 050.
3.779E+00
-3.759E+00
+0.543
100. 100.
5.780E+00
-5.802E+00
-0.300

4.2 Remarks

One uses as value for COEF_RIGI_DRZ: 0.001.

One presents the curve displacement charges at the requested points.

EDF
Mechanical department and Digital Models
Electricity
HEMISPHERE GRIPS. CURVES DEPLACEMENT-CHARGE
from France
4
them displacements are about
size of the hemisphere (R=10)
- Contrary to the linear solution,
the modules of displacements are
2
different
0
T
NR
E
M
E
AC

-2
PL
CURVE DX (F) in P1
OF
CURVE DY (F) in P2
-4
-6
-8
0
20
40
60
80
100
CHARGE
agraf 16/02/99 (c) EDF/DER 1992-1998

---

5 Modeling B

5.1 Characteristics of modeling

Element MEC3TR7H (voluminal hull)

Modeling COQUE_3D

10 segments
20 segments
20 segments
20 segments

5.2
Characteristics of the grid

A number of nodes: 1541

A number of meshs and type: 734 TRIA7

5.3 Functionalities
tested

· Modeling COQUE_3D into nonlinear geometrical.
· The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE.

STAT_NON_LINE:
(
COMP_ELAS:
(
RELATION
: “elas”
COQUE_NCOU
: 1
DEFORMATION: “green_gr”
)
)

6 Results of modeling B

6.1 Values tested

The incremental analysis is carried out in the interval of pseudo-time [0: 100.] in 10 steps of load.

History of horizontal displacement DX at the P1 point

Moment	*Force F*	*Aster*	*Reference*	*% difference*
020.	*020.*	*+1.486E+00*	*+1.479E+00*	*-0.345*
050.	*050.*	*+2.559E+00*	*+2.578E+00*	*-0.748*
100.	*100.*	*+3.348E+00*	*+3.390E+00*	*-1.250*

History of horizontal displacement DY at the P2 point

Moment
Force F
Aster

Reference
% difference

020. 020.
1.801E+00
1.799E+00
+0.09
050. 050.
3.739E+00
-3.759E+00
-0.528
100. 100.
5.731E+00
-5.802E+00
-1.222

6.2 Remarks

One uses as value for COEF_RIGI_DRZ: 0.001.

7
Summary of the results

H
The facts of the case correspond to a thin hull
= 0 4
. %. It is necessary
R
to increase the value of the COEF_RIGI_DRZ which allots a rigidity around the normal of the elements
of hull which is worth by defect 105 the smallest rigidity of inflection around the directions in the plan of
the hull in order to be able to increase the value of the swing angle which one can reach.
values of this coefficient up to 103 remain licit.

The Code_Aster solution is close to the reference solution the SAMCEF software for two modelings.

This test thus shows the correct operation of modeling COQUE_3D in great displacements
and great rotations, without revealing of blocking in shearing.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNV142 - Clean creep test (Granger model)

Date:
23/09/02
Author (S):
J. EL GHARIB *Key*
:
V6.04.142-B Page:
1/6

Organization (S): EDF/AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal systems
Document: V6.04.142

SSNV142 - Clean creep test: Granger model

Summary:

This case-test of nonlinear quasi-static mechanics relates to a creep test on a cylinder axisymmetric. It aims to validate the relation of behavior of "Granger", relation of behavior which one introduced into Code_Aster to model the clean creep of the concretes. This model is a linear viscoelastic model (grouping of rheological models of Kelvin in series) which allows to take into account the history of the constraint, the temperature and the hygroscopy.

In this test, the constraint, the temperature and the hygrometrical state are constant.

The cylinder is modelled by four elements quadrangles with 8 nodes.

The results obtained by Code_Aster are compared with the analytical solution of reference.

1
Problem of reference

1.1 Geometry

Cylindrical test-tube

Z
D
C
D
a=1 m
has
R
With
B
has

1.2
Material properties

Isotropic elasticity
Relation of clean behaviour of creep
E = 31000 MPa
"Granger".
= 0.2
J1 = 0.2 MPa1

1 = 4320000 S
J2 = 0.1 MPa1
2 = 2160000 S

One does not take account of the phenomenon of ageing in the relation of behavior of Granger.

1.3
Boundary conditions and loadings

On side AB: uz = 0

One uniformly imposes on the structure a constant temperature of T = 20°C and a hygroscopy constant h=1.

Loading: one charges in traction of 0 to 20 MPa into 10 S. And one maintains the loading during 1 year.

D
1
T (S)
t0=0
t1=10

2
Reference solution

2.1
Method of calculation used for the reference solution

Being given the nature of the requests, the solution (forced, deformations) is homogeneous.

0
0
0

That is to say the loading: 0 () 0

D T

0
0
0

The clean model of creep of Granger is such as the viscoelastic deformation corresponding to the case of a constant loading 0 applied to the moment t0 is worth: (cf [R7.01.01])

K =8
T - T
fl (T) =
0
0 Jk (1 - exp-)
K =1
S

The model also depends on the temperature and the hygroscopy in the following way:

K
-
=8
248
T - T
fl
T
(T) =
0
0 H
Jk (1 - exp-

45

)
K =1
S

but in this test the fields of temperature and hygroscopy are selected constant and such as H and T - 248 are worth 1 respectively.
45

When the constraint evolves/moves with time then:

K =8 T
T -

D
fl (T) = Jk (1 - exp-)

K =1
S
D
=0

one thus has for the case present:

T
2 =t
K =
1
fl
T -

1
yy =
Jk (1 - exp-) D
K =1
S
T
T =
1
0

the loading remaining constant beyond T1.

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That is to say:

K =2
fl

T - T
1

T

K
1
yy = 1 Jk 1 - exp-

1 - exp-

K =1
S T1
S
1442
4 443
4
~1

A longitudinal deflection of creep is accompanied by a transverse deformation such as:

fl

fl
xx =
- yy

2.2
Results of reference

One will be interested in the values of the deformations of creep in 45 days, 245 days and 365 days.

---

3 Modeling
With

3.1
Characteristics of modeling

Y
D3
N2
N5
N7
N3
N6
N4

N8
N1
N17
D4
N15
D2
N10 N11
N16
N9
N14
N21
N13 N12
N20
N19 N18
X
D1

The loading and the boundary conditions are modelled by:

FACE_IMPO: (GROUP_MA: D1, DY: 0.)
PRES_REP: (GROUP_MA: D3, NEAR: function)

One imposes moreover one uniform and constant temperature of 20°C and a uniform field of drying and constant of 1 on the structure using operator AFFE_CHAM_NO. The curve of sorption-desorption (user datum) makes it possible to pass from the variable drying to the hygroscopy.

3.2
Characteristics of the grid

A number of nodes:
21
A number of meshs and types: 4 HEXA8

3.3 Functionalities
tested

Orders
Key word factor
Simple key word
Argument
DEFI_MATERIAU
GRANGER_FP

AFFE_CHAM_NO
AFFE_CHAR_MECA
FACE_IMPO
PRES_REP
TEMP_CALCULEE
SECH_CALCULE
STAT_NON_LINE
COMP_INCR
RELATION
GRANGER_FP
CALC_ELEM
OPTION
EPGR_ELNO
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4
Results of modeling A

4.1 Values tested

One tests the values with the sequence numbers corresponding to 45, 245 and 365 days

Variables number

of order
Reference
***Aster** %*
difference
flxx
5 -0.80862 -0.80862 0.
fl
5 4.04313 4.04313 0.
yy
fl
50 5.9701 -1.19402 0.
xx
fl
50
-1.19402
5.9701
0.
yy
flxx
74 -1.19946 -1.19946 0.
fl
74 5.99730 5.99730 0.
yy

5
Summary of the results

The results obtained with Code_Aster are close to those of the reference solution (variations < 0.05%)

:
23/09/02
Author (S):
***C. CHAVANT**, B. CIREE Key*
:
V6.04.143-A Page:
1/14

Organization (S): EDF/AMA, CS IF

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.143 document

SSNV143 - Biaxial traction with the law of behavior BETON_DOUBLE_DP

Summary:

This case of validation is intended to check the model of behavior 3D BETON_DOUBLE_DP formulated in tally of thermoplasticity, for the description of the nonlinear behavior of the concrete, in traction, and in compression, with the taking into account of the irreversible variations of the thermal characteristics and mechanics of the concrete, particularly sensitive at high temperature.

The description of cracking is treated within the framework of plasticity, using an energy equivalence, by identifying the density of energy of cracking in mode I, with the plastic work of a homogeneous medium
equivalent, where the plastic deformation is uniformly distributed, in an "elementary" zone. This approach
preserve the continuity of the formulation of the model, on the whole of its behavior, and contributes to avoid
possible numerical difficulties during the change of state of material.
Pathological sensitivity of the numerical solution to the space discretization (grid), generated by the introduction of a softening behavior of the concrete in traction and compression, is partially solved
by introducing an energy of cracking or rupture, dependent a characteristic length lc, related to cut elements.

The case test includes/understands two modelings 3D, the loading consists of a load followed by a discharge.

---

1 Problem of reference

1.1 Geometry

It is about a cube with 8 nodes, whose two faces have a normal displacement no one, and the two faces

opposed have an imposed normal displacement, different one from the other of a coefficient 2. The cube makes 1 mm on side. The cases tests are composed of a load, followed by a discharge. In modeling A, the cube is directed according to the Oxyz reference mark. In modeling B, it is turned of 30°
by around axis OY.

U2

Face1xy

Modeling A

Face1yz

U1

Faceyz

Ux = 0

Z

y Uz = 0

N1
X
N2

Facexy
Modeling B

U2

Face1yz

U1

Face1xy

One = 0
Faceyz

Facexy
Z

NR
y
One = 0
2

X

NR

1
U2 = 2.U1

3/14

1.2
Material properties

To test the evolution of the mechanical characteristics in an irreversible way with the temperature, one
apply a field of temperature decreasing. Certain variables depend on the temperature,
others of drying. Lastly, one applies a coefficient of withdrawal of desiccation not no one, equal to
thermal dilation coefficient, to test "data-processing" operation. Deformations
thermics thus equal and will be opposed to the deformations of withdrawal of desiccation. These
dependences intervene only for checks purely data-processing, the characteristics
mechanics can be regarded as constants.

For the usual linear mechanical characteristics:

Young modulus:
E = 32.000 MPa
of
0°C with 20°C

E = 15.000 MPa
with
400°C (linear decrease)

E = 5.000 MPa
with
800°C (linear decrease)
Poisson's ratio:
= 0.18

Thermal dilation coefficient:
= 10-5

Coefficient of withdrawal of desiccation: = 10-5

For the nonlinear mechanical characteristics of model BETON_DOUBLE_DP:

Resistance in uniaxial pressing:
f' C = 40 N/mm ²

of 0°C with 400°C

f' C = 15 N/mm ²
with
800°C (linear decrease)
Resistance in uniaxial traction:
f' T = 4 N/mm ²
of 0°C with 400°C

f' T = 1.5 N/mm ²
with
800°C (linear decrease)
Report/ratio of resistances in compression = 1.16

biaxial/uniaxial pressing:
Energy of rupture in compression:
Gc =10 Nmm/mm ²

Energy of rupture in traction:
WP =0.1 Nmm/mm ²

Report/ratio of the limit elastic to resistance 30%

in uniaxial pressing:

1.3
Boundary conditions and loadings mechanical

Field of temperature decreasing of 20°C with 0°C.
Lower face of the cube (facexy):
blocked according to OZ.
Higher face of the cube (face1xy):
displacement 0.30 mm imposed followed by a discharge of 0.1 mm
Left face of the cube (faceyz):
blocked according to OX.
Right face of the cube (face1yz):
displacement 0.15 mm imposed followed by a discharge of 0.05 mm
Lower nodes front face (N1, N2):
blocked according to OY (Suppression of the movements of solid body).

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is calculated in an semi-analytical way, knowing that in traction, only the criterion of traction is activated. It is thus necessary to solve a system of an equation to an unknown factor, which allows to obtain by dichotomy for example, plastic deformation cumulated in traction. This one allows to calculate strains and stresses then. This is possible, knowing displacement, and thus deformation in the two imposed directions. Displacement in the third direction is then an unknown factor of the problem.
The reference solution is calculated only in traction. The solution is determined by one program resolution by dichotomy in independent FORTRAN. In compression, discharge, exact solution was not recomputed, and constitutes a solution of nonregression of the code, been dependent on version 5.02.14.
For modeling B, the results result by rotation from the tensor from constraint from modeling A, of the intrinsic reference mark of the cube to the reference mark user, the stress field of both configurations being identical in the intrinsic reference mark of the cube.

2.2 Calculation of the reference solution of reference

For more details on the notations and the setting in equation, one will refer to the document of reference. Only, the principal equations are pointed out here.
One notes "has", imposed displacement following direction X, and "2.a" following imposed displacement
direction Z. The tensor of deformation is form (has, y, 2.a, 0. , 0. , 0.) by taking the notations usual of Code_Aster (three principal components, three components of shearing).
The tensor of constraint is form (X, 0. , Z, 0. , 0. , 0.), in modeling A.
The criterion of traction is expressed in the form:

+ C.
2
C
F
Oct.
Oct.
=
- F
eq
=
+ -

T (T)
F
trac
H
T (T)
D
D
3
D

The constitutive equations are written by distinguishing the isotropic part of the deviatoric part of tensors of constraints and deformations.

1
1
1
1
=

= -

=
~
= - tr
H
tr
H
tr () S
tr () I
( )
() I
3
3
3
3
= S + I
H

= ~ + H I
3
The equivalent constraint is written then: eq =
tr ()
S
2
In the case of an incremental formulation, and of a variable law of behavior, while noting with one exhibitor "E" the elastic components of the constraint and the deformation, one obtains:
+
μ
K +
=
S +
+
2μ

E
-
+
-
~
=
+ 3K
μ
and H

The criteria in compression and traction are expressed in the following way:

+ A.
2
has
F
Oct.
Oct.
=
- F
eq
=
+ -

C (c)
F
comp
H
C (c)
B

B
3
B
+ C.
2
C
F
Oct.
Oct.
=
- F
eq
=
+ -

T (T)
F
trac
H
T (T)
D
D
3
D

The plastic deformations in traction and compression are expressed:

S
has
p

~

C
p
C =

H =
C

2 eq
B
C

B
3

S
C
p

~

T
p
T =

H =
T

2 eq
D
T
D
3

One obtains for the constraint:

S = -
+
2μ (~ p
~ p

E
+
p
p
C +

T)
=
- 3

+
H
H
K (H C

H T)

1
+
has
C
S
+
C
T
1 2μ

= -
+
E

=
- 3

+
H
H
K
C

T
B
2
2D eeq

B
3
D
3

eq
E eq

+
C

for the equivalent constraint:
=
- 2µ
T
+

B
2
2D

The two criteria lead then to a system of two equations to two unknown factors C and T with to solve:

2
has
2 +
+ 2
µ
K has
2µ+ K+ac
E eq
E

+
-

+
-

+
- F - +

=
H
C
2

2
T
C (C
c)
0
3b
B
3b
B

3bd
data base

2
C
2

μ+ K +ac
2 +
+ 2
μ
K C
E eq
E

+
-

+
-

+
- F - +

=
H
C
T
2
2
T

(T
T)

0
3D
D
3bd
data base
3D
D

In a similar way, in the case of the only criterion of traction activated, configuration of the case test, one
obtains a system of an equation to an unknown factor T to be solved:

2
C
2 +
+ 2
µ
K C
E eq
E

+
-
+
- F -

+

=
H
T

2
2
T (T
T)
0
3D
D
3D
D

One thus seeks to solve this system, by using the particular shape of the tensors of constraints and of deformations, uniforms on the structure.
On the basis of = (has.
2 A
y
) .0
.,
0
.,
0
,
and of = (X. ,
0
, Z
).
0
.,
0
.,
0
,

. one obtains:

X = has (+ 2μ) + y + 2 A
.

The elastic tensor of constraint

y = has
. + y (+ 2μ) + 2a
.

Z = has
. + y + 2a (. + 2μ)

2
S = -

μ
X
. y

3

4
The elastic diverter of constraint S = -2.μ.a +
μ
y
. y

3

2
S = 2.μ.a -
μ
Z
. y

3

1

The hydrostatic constraint elastic E H = (
3 + 2μ) has + .y

3

The equivalent constraint elastic E
2
2
eq = μ 4
- 12. . +
y
y 12.a has
In the case of a curve of linear work hardening post-peak in traction, the expression of the parameter of work hardening is as follows:
p

2.G F ()
F (
p
,) = (,) = F
T
1-

=
U
T
T
T ()
with ()

U ()
lc. ft ()
One thus seeks to solve the equation:

2
C
2 +
+ 2
μ
K C

L. F
E eq
E

+
-

+
- F 1
C
T
-

= 0
éq
2.2-1
3
D H
T3 2
2
D
D
D
T
T

2.G

T

Knowing that the constraint in the direction is null there, one second equation is obtained:

+

1

T
E
E

=
+
= 0 = 1 - 2

+
y
sy H
µ
S y H

D eeq

1
+
.
T
4

C
E

T
= 0 = 1 - 2

-
y
µ
µ
2.µ.a

K

D eeq
y
H
3

+
-
D
4 µ

E
-
y
2.µ.a
H

3

+
From where: =
T
that one can substitute in the expression of the criterion
2µ 4 µ

- 2.µ
C
.a
K
D. eeq
y

3

+ D
[éq 2.2-1].
Knowing has, imposed displacement, one obtains a nonlinear equation with an unknown factor, that one can solve simply by dichotomy, and which makes it possible to calculate the deformation y, then the unit unknown factors of the system.

2.3
Uncertainty on the solution

It is negligible, about the precision machine.

2.4 References
bibliographical

The model was definite starting from the théses following:

[1]
J.F. GEORGIN, at the time of its thesis "Contribution to the numerical modeling of the behavior concrete concrete and structures reinforced under thermomechanical requests with high temperature ",
[2]
G. HEINFLING, at the time of its thesis "Contribution to the modeling of the concrete under request of
fast dynamics. The taking into account of the effect speed by viscoplasticity ", and is described in the report/ratio of specification:
[3]
SCSA/128IQ1/RAP/00.034 Version 1.2, Development of a model of behavior 3D concrete with double criterion of plasticity in Code_Aster - Specifications ".

---

3 Modeling
With

3.1
Characteristics of modeling

3D (HEXA8)

1 element, stress field and uniform deformation.

U2

U1

Ux = 0

Z

y

Uz = 0

X

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and type: 1 HEXA8

3.3 Functionalities tested

Orders Options

AFFE_MODELE
"MECHANICAL"
"3D"
DEFI_MATERIAU
"BETON_DOUBLE_DP"
DEFI_MATERIAU
"ELAS_FO"
"K_DESSIC"
AFFE_CHAR_MECA
"SECH_CALCULEE"
STAT_NON_LINE
"BETON_DOUBLE_DP"

4
Results of modeling A

4.1 Values
tested

The nonnull components of the stress field SIEF_ELNO_ELGA (component were tested
xx and zz), the component yy of the field of deformation EPSI_ELNO_DEPL, which constitutes an unknown factor
system (deformations in the two other directions being imposed), deformation
figure cumulated in traction (second variable internal, second component of the field
VARI_ELNO_ELGA), and finally, only for the fourth case of loading (discharge),
plastic deformation cumulated in compression, (first internal variable, first component of
field VARI_ELNO_ELGA).

The first three loadings correspond to the load, and have results of reference.
The fourth loading corresponds to the discharge, and constitutes a result of nonregression of
code.

Component field SIEF_ELNO_ELGA SIXX

Identification Reference
Aster
% difference
For a displacement imposed in
0.1235611 0.1235380 0.019
charge U1=0.1 and U2= 0.05
For a displacement imposed in
6.882374.10-2 6.878218.10-2 0.060
charge U1=0.2 and U2= 0.10
For a displacement imposed in
1.408764.10-2 1.402639.10-2 0.435
charge U1=0.3 and U2= 0.15
For a displacement imposed in
(*) -4.195092.10-5 -

discharge U1=0.1 and U2= 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field SIEF_ELNO_ELGA SIZZ

Identification Reference
Aster
% difference
For a displacement imposed in
0.239212 0.239174 0.016
charge U1=0.1 and U2 = 0.05
For a displacement imposed in
0.133243 0.133165 0.059
charge U1=0.2 and U2 = 0.10
For a displacement imposed in
2.727403.10-2 2.725569.10-2 0.434
charge U1=0.3 and U2 = 0.15
For a displacement imposed in
(*) -4.959258.10-5 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field EPSI_ELNO_DEPL EPYY

Identification Reference
Aster
% difference
For a displacement imposed in
-3.419463.10-3 -3.419464.10-3 2.10-7
charge U1=0.1 and U2 = 0.05
For a displacement imposed in
-6.835813.10-3 -6.835815.10-3 2.10-7
charge U1=0.2 and U2 = 0.10
For a displacement imposed in
-1.025216.10-2 -1.025216.10-2 2.10-7
charge U1=0.3 and U2 = 0.15
For a displacement imposed in
(*) -4.357498.10-1 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field VARI_ELNO_ELGA VARI_2 (plastic deformation cumulated in traction)

Identification Reference
Aster
% difference
For an imposed displacement
1.085728.10-2 1.085728.10-2 5.10-9
U1=0.1 and U2 = 0.05
For an imposed displacement
2.171556.10-2 2.171556.10-2 5.10-9
U1=0.2 and U2 = 0.10
For an imposed displacement
3.257385.10-2 3.257385.10-2 4.10-9
U1=0.3 and U2 = 0.15
For an imposed displacement
3.257385.10-2 3.257385.10-2 4.10-9
U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field VARI_ELNO_ELGA VARI_1 (plastic deformation cumulated in compression)

Identification Reference
Aster
% difference
For a displacement imposed in
(*) 3.528401.10-1 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

5 Modeling B

5.1 Characteristics of modeling

3D (HEXA8)

1 element, stress field and uniform deformation.

U2

U

1

One = 0

Z
One = 0

y

X

5.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and type: 1 HEXA8

5.3
Functionalities tested

Orders Options

AFFE_MODELE
“MECHANICAL”
“3D”

DEFI_MATERIAU
“BETON_DOUBLE_DP”

DEFI_MATERIAU
“ELAS_FO”

"K_DESSIC"

AFFE_CHAR_MECA
"SECH_CALCULEE"

STAT_NON_LINE
"BETON_DOUBLE_DP"

6
Results of modeling B

The nonnull components of the stress field SIEF_ELNO_ELGA (component were tested xx, zz and xz), plastic deformation cumulated in traction (second variable internal, second component of field VARI_ELNO_ELGA), and finally, only for the fourth case of loading (discharge), plastic deformation cumulated in compression, (first internal variable, first component of field VARI_ELNO_ELGA).

The first three loadings correspond to the load, and have results of reference.
The fourth loading corresponds to the discharge, and constitutes a result of nonregression of code.

6.1 Values tested

Component field SIEF_ELNO_ELGA SIXX

Identification Reference
Aster
% difference
For a displacement imposed in
0.152474 0.1524472 0.018
charge U1=0.1 and U2 = 0.05
For a displacement imposed in
8.492877.10-2 8.487797.10-2 0.060
charge U1=0.2 and U2 = 0.10
For a displacement imposed in
1.732484.10-2 1.730871.10-2 0.434
charge U1=0.3 and U2 = 0.15
For a displacement imposed in
(*) -4.386134.10-5 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field SIEF_ELNO_ELGA SIZZ

Identification Reference
Aster
% difference
For a displacement imposed in
0.210300 0.210265 0.016
charge U1=0.1 and U2 = 0.05
For a displacement imposed in
0.117138 0.117069 0.059
charge U1=0.2 and U2 = 0.10
For a displacement imposed in
2.397743.10-2 2.387336.10-2 0.434
charge U1=0.3 and U2 = 0.15
For a displacement imposed in
(*) -4.768217.10-5 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field SIEF_ELNO_ELGA SIXZ

Identification Reference
Aster
% difference
For a displacement imposed in
-5.007871.10-2 -5.007226.10-2 0.013
charge U1=0.1 and U2 = 0.05
For a displacement imposed in
-2.789472.10-2 -2.787871.10-2 0.057
charge U1=0.2 and U2 = 0.10
For a displacement imposed in
-5.709873.10-3 -5.685155.10-3 0.433
charge U1=0.3 and U2 = 0.15
For a displacement imposed in
(*) -3.308936.10-6 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no analytical solution.

Component field VARI_ELNO_ELGA VARI_2 (plastic deformation cumulated in traction)

Identification Reference
Aster
% difference
For a displacement imposed in
1.085728.10-2 1.085728.10-2 5.10-9

charge U1=0.1 and U2 = 0.05
For a displacement imposed in
2.171556.10-2 2.171556.10-2 5.10-9
charge U1=0.2 and U2 = 0.10
For a displacement imposed in
3.257385.10-2 3.257385.10-2 4.10-9
charge U1=0.3 and U2 = 0.15
For a displacement imposed in
3.257385.10-2 3.257385.10-2 4.10-9
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

Component field VARI_ELNO_ELGA VARI_1 (plastic deformation cumulated in compression)

Identification Reference
Aster
% difference
For a displacement imposed in
(*) 3.528401.10-1 -
discharge U1=0.1 and U2 = 0.05

(*) discharges some, one carries out a test of nonregression. There is no calculated analytical solution.

7
Summary of the results

This case test offers satisfactory results compared to the results of reference, lower than 0.06% for the first two cases of loading, more important for the third, which is explained by one relatively low level of constraint (one reaches the end of the curve of work hardening in traction).

The test discharges some (fourth loading) makes it possible to check nonthe regression of the code.

The iteration count is relatively important with the first step of calculation, about 13, then drop to 7, 4 and 1, which is explained by the passage of the plastic threshold to the first step of calculation, for
to reach a quasi linear behavior thereafter (curved post-peak linear).
One obtains also a more significant number of iterations to step 31 (beginning of the fourth case of loading), then an iteration count dropping up to 1, because of the passage in discharge, with one change of behavior, follow-up of a quasi linear behavior thereafter (curved post-peak linear).

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.144 document

SSNV144 - Bend in inflection into large
displacements

Summary:

This test validates the modeling of the phenomena of inflection of hull in great displacements in the field
rubber band or elastoplastic: an elbow of piping, prolonged by right pipes is subjected to an inflection in its plan. Piping is thick (of size similar to the elbows of the primary education circuits).
reference solution is numerical: it is obtained with Code_Aster using a grid 3D of the elbow.

Modeling is carried out with elements COQUE_3D in great displacements or elastoplasticity.

:

07/11/05
Author (S):
J.M. PROIX, Key P. MASSIN
:
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1
Problem of reference

The elbow has as a radius of curvature: Rc = 1.25m

With
L
B
Rc
L
Y
Mz
C
D
X

The tubular section has for average radius R = 395.5mm and a thickness E = 77mm.

1.1
Properties of materials

The material is elastoplastic with isotropic linear work hardening.
E = 2.E11 Pa
= 0.3
Elastic limit SIGY = 200.106 Pa
Modulate work hardening D_SIGM_EPSI = 2.1010 Pa

1.2
Boundary conditions and loadings

Embedding of A (corresponding to the section of named piping CERCLE1).

Moment MZ imposed in D (correspondent with CERLCE2) growing until:

Increment 1
Mz = 308670215.2 Nm

In the case of calculation into large displacement, Mz is reached in 10 equal increments

1.3 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

In linear elasticity, cf [V6.02.117] one carries out a comparison with other numerical results obtained with Code_Aster on a grid 3D of the elbow and right parts, connected at the ends to

right beams. This grid 3D comprises 1024 meshs HEXA20. A modeling COQUE_3D give close results.

2.2
Results of reference

For one moment applied Mz in D, displacement DY of the same point D is worth:

Moment
Dy not D (m) (3D)
Dy not D (m) (COQUE_3D)
3.08670D+08 1.09349D02
1.08875D02

2.3
Uncertainty on the solution

Owing to the fact that the reference solution is numerical, one can evaluate the precision according to [§2.2] to 2% by comparison of the 3D solutions and COQUE_3D.

3 Modeling With

3.1 Characteristics of modeling

COQUE_3D

3.2 Characteristics of the grid

A number of nodes: 1480
A number of meshs and type: 360 QUAD9

3.3 Functionalities tested

Orders Options

"MECHANICAL" AFFE_MODELE
"COQUE_3D"

DEFI_MATERIAU "ECRO_LINE"

DEFI_MATERIAU "ELAS"

AFFE_CARA_ELEM HULL

STAT_NON_LINE VMIS_ISOT_LINE

STAT_NON_LINE DEFORMATION GREEN_GR

4 Results of modeling A

4.1 Values tested

To compare the results of the linear elastic design (MECA_STATIQUE) with the solution of reference, one compares displacements of 4 nodes of the section of the tube corresponding to the point D
(CIRCLE 2).

Increment of load
DY of the point D
1: Mz =3.08670D+06Nm

DY (m)

Linear calculation:

Node
Reference
Aster
% diff
(COQUE_3D)
N1157 1.08875D03
1.08154D-03
0.6
N1104 1.08875D03
1.09424D-03 0.5
N1109 1.08875D03
1.08427D-03 0.4
N1099 1.08875D03
1.08427D-03 0.4

The tests of nonlinear calculations are tests of nonregression.

Elastoplastic calculation (not regression)

Node
Aster
N1157 1.079288D-03
N1104 1.09199D-03
N1109 1.082028D-03
N1099 1.082028D-03

Calculation great displacements (not regression):

Node
Aster
N1157 1.079777D-03
N1104 1.09299D-03
N1109 1.082769D-03
N1099 1.082769D
-03

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/05/005/A

5
Summary of the results

This test makes it possible to validate elements COQUE_3D into linear and nonlinear geometrical for one
real geometry having two curves. The results are close (less than 1%) to the reference
numerical in elasticity.

Organization (S): EDF/MTI/MMN, SAMTECH

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.145

SSNV145 - Plate cantilever in great rotations
subjected to a following pressure

Summary

One presents a quasi-static calculation of elastic plate embedded on a side and subjected to a pressure following. The following loading implies modifications of the system of equations linearized. The system
equations solved by the method of NEWTON is nonsymmetrical. The tangent matrix of rigidity (forces interior) and the contribution of the compressive forces according to the deformation of the structure are nonsymmetrical.
This modeling makes it possible to test the nonlinear objects finite elements geometrical COQUE_3D using
the algorithm of update of great rotations 3D GREEN_GR in STAT_NON_LINE in the presence of one pressure of the following type. The reference solution is obtained by the software finite elements the SAMCEF software.

Version
5.0

Titrate:
SSNV145 - Plate cantilever in great rotations with following pressure Date:
19/10/01
Author (S):
***P. MASSIN**, Key P. LATRUBESSE*
:
V6.04.145-A Page:
2/10

1 Problem of reference

1.1 Geometry

y
Z
p
4
P
3
P
B = 1
X
1
P
H = 0.1
2
P

L = 10

The lengths are given in meters.
Rectangular plate thickness 0.1m embedded out of P P and subjected to a pressure:
1
4

p = - p E
p >
Z
0

1.2
Properties of materials and characteristic of section

Elastic behavior:

E = 12 × 106 Pa; = 0 3
.

1.3
Boundary conditions and loading

Embedding out of P P. One seeks the successive states of balance under the loading made up of
1
4
pressure:

p = T; T pseudo-time.

One is interested particularly in displacements horizontal and vertical and rotation in the center of line P P.
2
3

2
Reference solution

2.1
Method of calculation used to obtain the reference solution

The reference solution [bib4] is that which is obtained with software the SAMCEF software [bib1]. modeling is based on a theory of hull in resulting efforts with a formulation Co-rotational [bib3] and a discretization DSQ [bib2] regular.

1 element
20 elements

The grid considered is a regular grid of 20x1 quadrilateral elements to 4 nodes each one.

2.2
Results of reference

One tests the pseudo-temporal evolution of DX, DZ, DRY at the point medium of segment P1P2.

2.3 References bibliographical

[1]
The SAMCEF software, Handbook of reference V7.1 Elements Volume, 1998
[2]
J-L. Batoz, G.Dhatt, "Modeling of the Structures by Finite elements: Beams and Plates", Hermès, Paris, 1992
[3]
Crisfield M.A., "Non-linear Finite Element Analysis of Solids and Structures", Volume 1: Essentials, John Wiley, Chichester, 1994
[4]
PH. JETTEUR, Nonlinear Kinematics of the Hulls. Report/ratio SAMTECH, Contract PP/GC-134/96, 1998
[5]
Mr. Al MIKDAD, following Pressure for the elements COQUE_3D, N° Report/ratio 99020-1 1999
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/01/010/A

Code_Aster ®
Version
5.0

3 Modeling
With

3.1
Characteristics of modeling

MEC3QU9H (hull 3D degenerated)

1 element
10 elements

modeling COQUE_3D - regular grid.

3.2
Characteristics of the grid

A number of nodes: 33

A number of meshs and type: 10 QUAD9

3.3 Functionalities
tested

.
Nonlinear element geometrical COQUE_3D,
.
The static algorithm of update of great rotations GREEN_GR of
STAT_NON_LINE,
.
The use of a following pressure.

STAT_NON_LINE:
(

COMP_ELAS:
(
RELATION: "elas"
COQUE_NCOU: 1
DEFORMATION: "green_gr"
)
EXCIT (
TYPE_CHARGE: SUIV
)
)

4
Results of modeling A

4.1 Values
tested

History of horizontal displacement DX (m) in the middle of P1P2

Moment
Pressure
Aster
Reference
% difference
p
(The SAMCEF software)

13. 13.
8.85391E+00
9.03743E+00 2.026%
26. 26.
1.40311E+01
1.41513E+01 0.841%

History of vertical displacement DZ (m) in the middle of P1P2

Moment
Pressure
Aster
Reference
% difference
P
(The SAMCEF software)

13. 13.
8.40991E+00
8.42753E+00 0.203%
26. 26.
4.54734E+00
4.43375E+00 2.554%

History of horizontal rotation DRY in the middle of P1P2

Moment
Pressure
Aster
Reference
% difference
p
(The SAMCEF software)

13. 13.
1.92061E+00
1.94328E+00 1.153%
26. 26.
3.07026E+00
3.09814E+00 0.896%

4.2 Remarks

The number of meshs of the reference solution is 2 times larger than that of the solution of modeling A.

One uses the value of COEF_RIGI_DRZ = 0.001.

The following figures, illustrate the solution obtained with a nonfollowing and following pressure. They
acts of the components of translation of the medium of the loose lead.

Nonfollowing pressure

Following pressure

It is seen that in the case of a following pressure, displacement DZ decreases after having reached one
maximum. The beam tends to be rolled up. This phenomenon is not representable with nonfollowing pressures.

4.3 Parameters
of execution

Version: 5.03.06

Machine: Claster

System:
CLASTER
Record length:
819200 bytes
Time CPU To use total:
1655 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

MEC3TR7H (hull 3D degenerated)

1 element
20 elements - 10 subdivisions

modeling COQUE_3D - regular but nonsymmetrical grid.

H
The facts of the case correspond to a thin hull
=

%
625
.
0
what is severe for
L
the finite element MECQTR7H (case of blocking to transverse shearing).

5.2
Characteristics of the grid

A number of nodes: 33

A number of meshs and type: 20 TRIA7

5.3 Functionalities
tested

.
Nonlinear element geometrical COQUE_3D,
.
The static algorithm of update of great rotations GREEN_GR of STAT_NON_LINE,
.
The use of a following pressure.

STAT_NON_LINE:
(
COMP_ELAS:
(
RELATION: "elas"
COQUE_NCOU: 1
DEFORMATION: "green_gr"
)
EXCIT (
TYPE_CHARGE: SUIV
)
)

6
Results of modeling B

6.1 Values
tested

History of horizontal displacement DX (m) in the middle of P1P2

Moment
Pressure
Aster
Reference
% difference
p
(The SAMCEF software)

11.
11.
-6.96406 E+00
-7.36640 E+00
5.45%
22.
22.
-1.31300 E+01
-1.35098 E+01
2.81%

History of vertical displacement DZ (m) in the middle of P1P2

Moment

Pressure
Aster
Reference
% difference
P
(The SAMCEF software)

11.
11.
-8.37020 E+00
-8.44920 E+00
0.93%
22.
22.
-6.17548 E+00
-5.78828 E+00
6.69%

History of horizontal rotation DRY in the middle of P1P2

Moment
Pressure
Aster
Reference
% difference
p
(The SAMCEF software)

11.
11.
1.63965 E+00
1.69200 E+00
3.09%
22.
22.
2.73405 E+00
2.82168 E+00
3.12%

6.2 Remarks

The grid of modeling B is a regular but nonsymmetrical grid. Grid of reference solution is built with 20 quadrangles with 4 nodes each one.

One uses the value of COEF_RIGI_DRZ = 0.001.

H
Although the studied problem is a mean problem of hull
=
%
625
.
0
, elements of triangles
L
reach a high level of load: 22 step for 26 with the quadrangles. The solution with elements triangle is thus very satisfactory.

6.3 Parameters
of execution

Version: 5.03.06

Machine: Claster

System:
CLASTER
Record length:
819200 bytes
Time CPU To use total: 3355 seconds

7
Summary of the results

The solutions obtained by Code_Aster are very close to the reference solution of the software The SAMCEF software, with a grid twice less refined. Values of displacement at the end of the beam differ from to the more 2,5% for the first modeling in quadrangle and of to the more 6,7% for the second modeling in triangle.

Intentionally white left page.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/01/010/A

Code_Aster ®
Version
5.0

Titrate:
SSNV146 - Analyze regularized limit. Spherotoric bottom tank
Date:
06/11/01
Author (S):
F. VOLDOIRE Key
:
V6.04.146-A Page:
1/6

Organization (S): EDF/RNE/AMV

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.146

SSNV146 - Analyze regularized limit.
Spherotoric bottom tank

Summary

This test makes it possible to qualify the operators used analyzes regularized limit of it. One calculates the load limits by
a kinematic approach regularized by the method of Norton-Hoff-Friaâ.

One considers an axisymmetric spherotoric bottom tank (modeling A). The constitutive material checks it
criterion of von Mises and the structure is subjected to an internal pressure. Calculation makes it possible to obtain the load
limit in the direction of the loading.

The structure is modelled by incompressible elements and the loading is standardized.

The resolution by the regularized method of Norton-Hoff-Friaâ is carried out in the order
STAT_NON_LINE. A postprocessing in order POST_ELEM makes it possible to obtain the value of a terminal
higher of the limiting load, as well as an estimate of the lower limit.

The reference solution results from a European benchmark, carried out within the framework of a project Brite EuRam
BE97-4547 "LISA", in 1998, and the results are in perfect agreement with the values of reference.

1
Problem of reference

1.1 Geometry

The internal ray of the cylindrical part is: 49mm, while the thickness is: 2mm. The ray of spherical part with the apex is 98mm, while the ray of the torus of connection is of 20mm.

p

1.2
Material properties

The material is homogeneous:
Young modulus: E
=
200.000 MPa.
Poisson's ratio: = 0.5
Elastic limit: y = 100 MPa.
Coefficient of the law of Norton-Hoff: N = 21.101.

1.3
Boundary conditions and loadings

The boundary conditions are: axial displacement no one on the end of the cylindrical part (conditions of symmetry).

Conditions limit in AXIS:

.
on BORD_INF: DY = 0.

The loading parameterized by is:

.
in AXIS:

Close = 1. on internal wall B_D.

2
Reference solution

2.1
Method of calculation used for the reference solution

This test of benchmark is referred: case-test LA6 and was carried out within the framework of a European project
Brite EuRam BE97-4547 "LISA", in 1998, partly financed by the EC. This test was carried out with even grid by the three participating organizations. By considering a pipe of same dimensions, the limiting load is: 4,0005MPa, and for the sphere of same dimensions: 4,04MPa.

2.2
Results of reference

One gives hereafter the results provided by EDF at the time of the benchmark, for three values of the parameter of
regularization N, as those provided by organizations LTAS in Liege (which uses another regularized kinematic method, in the university software dedicated "ELSA") and ForschungZentrum of Jülich (which use a static method approximate by finite elements in displacements, and one reduced representation of the fields of auto-contraintes, using the Permas code, supplemented of one algorithm of optimization).

Modeling case
sup
inf
lim
lim estimated

EDF N =21
2D axis
3,9514 MPa
3,6049 MPa
EDF N =31
2D axis
3,9456 MPa
3,7090 MPa
EDF N =71 2D
axis
3,9404 MPa
3,8372 MPa
Univ. of Liège/LTAS
2D axis
3,931 MPa
nothing
Research center FZJ
2D axis
nothing 3,997
MPa

The methods regularized kinematics of EDF and the LTAS give very nearby results. One note an anomaly however: the lower limit of the FZJ is higher on the higher terminal of ULg and EDF, which is impossible.

The convergence of the method suggested by Code_Aster is visualized on the diagram below.
Pressure tank
4,5
4
3,5
3
2,5
F_sup (MPa)
2
F_inf (MPa)
1,5
Charge limit
1
0,5
0 1 11 21 31 41 51 61 71
Order N (Norton-Hoff)

2.3 References
bibliographical

[1]
Voldoire F.: Calculation of load limits with Code_Aster and benchmark of Brite EuRam
“LISA”. Note HI-74/98/026/A.
[2] Heitzer
Mr. “
Traglast- und Einspielanalyse zur Bewertung der Sicherheit to passivate
Komponenten. ” Thesis., RWTH Aachen (1999).
[3]
Direct Yan A.M. “Contributions to the limit state analysis of plastified and cracked
structures”. Thesis, Univ. Liege, (1999).
Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
HT-62/01/012/A

---

3 Modeling
With

3.1
Characteristics of modeling

One considers a cylinder modelled by axisymmetric elements QUAD8 of the incompressible type:
miaxqu8, according to a regulated grid. The required precision is 10 5
- on balance.

3.2
Characteristics of the grid

The grid contains two Q8 elements in the thickness, and in all there are 34 elements, and 141 nodes. Here a sight of the grid and deformation for N =31.

Z
R

3.3 Functionalities tested

Orders
Key word factor
Single-ended spanner word
Argument
DEFI_MATERIAU NORTON-HOFF
NR

SY
MACRO_CHAR_F_U CHARGES

STAT_NON_LINE
COMP_INCR RELATION
"NORTON_HOFF"

RECH_LINEAIRE

ETAT_INIT
EVOL_NOLI

SOLVEUR
METHOD
"LDLT"
POST_ELEM CHAR_LIMITE
ALL
"YES"
TEST_TABLE
COUNT
"CHAR_LIMI_SUP"
"CHAR_LIMI_ESTIM"

4
Results of modeling A

4.1 Values tested

Identification Reference
Aster %
difference
Tolerance
N = 21

Charge higher limit
3,9514 3,9514 0.05% 0.1%
Charge estimated limit
3,6049 3,6049 0.05% 0.1%
N = 31

Charge higher limit
3,9456 3,9456 0.05% 0.1%

Charge estimated limit
3,7090 3,7090 0.05% 0.1%
N = 51

Charge higher limit
3,9417 3,9417 0.05% 0.1%
Charge estimated limit
3,7978 3,7978 0.05% 0.1%
N = 71

Charge higher limit
3,9404 3,9404 0.05% 0.1%
Charge estimated limit
3,8372 3,8372 0.05% 0.1%
N = 101

Charge higher limit
3,931 3,9396 0.2% 0.3%
Charge estimated limit
3,90
3,8673
0.8%
0.9%

4.2 Parameters of execution

Version: STA 5.06
Machine: Claster

System:
IRIX 64
Obstruction memory: 64 MO
Time CPU To use:
12.15 seconds
Handbook of Validation

5
Summary of the results

The numerical results Code_Aster are in concord with the numerical values of reference.

Organization (S): EDF/MMC

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.148

SSNV148 - Models of Weibull and Rice-Tracey
in 3D and discharge

Summary:

This test of nonlinear quasi-static mechanics makes it possible to validate the models of Weibull and Rice and Tracey
in 3D for nonmonotonous cases of mechanical loadings (cf POST_ELEM [U4.61.04]).

At the temperature of 50°C, a cylindrical test-tube smoothes is first of all deformed up to 10%. After having it
slightly discharged, one maintains constant the level of deformation reaches while decreasing way homogeneous the temperature of the test-tube until 150°C.A this new temperature, one applies one additional deformation to reach 15% on the whole. Probability of rupture per cleavage as well as the rate of
growth of the cavities of the test-tube are calculated for the whole of the way of loading.

The modeling of the test-tube is carried out with elements 3D (HEXA20, PENTA15).

1
Problem of reference

1.1 Geometry

One considers a half - cylindrical test-tube smooth.

1.2
Properties of material

One adopts an elastoplastic law of behavior of Von Mises with linear isotropic work hardening "VMIS_ISOT_LINE". The deformations used in the relation of behavior are them linearized deformations.

And
Y
E

The Young modulus E, the tangent module And as well as the Poisson's ratio do not depend on temperature. One takes: E=200 GPa, And = 2000 MPa and = 0,3.

The evolution of the elastic limit with the temperature is given in the following table:

Temperature [°C]
-150
-100
-50

Y [MPa]
750 700 650

Lastly, thermal dilation is neglected (thermal dilation coefficient taken equal to 0).

1.3
Boundary conditions and loadings

While referring to the figure [§1.1] boundary conditions are as follows:

· on surface SSUP BC (Y=L0) displacement L imposed following direction OY,
· on surface SINF OA (Y=0) displacements blocked according to direction OY,
· blocked displacements of A following X and Z,
· blocked displacements of B following Z.

Evolution temporal of the temperature (presumedly homogeneous in the test-tube) and of lengthening L are deferred in the following table:

Time
[S]
10 20 30 40
Temperature [°C]
-50
-50
-150
-150

Displacement L - 0
L [mm]
20,35 20,30 20,30 32,525

1.4 Conditions
initial

Null constraints and deformations.

2
Reference solutions

2.1
Method of calculation

In simple traction and with the assumption of the small deformations, the tensile stress (U) like the plastic multiplier p& (U) at the moment U is given in the case considered by:

L U
() - L0
p

Y (- °
50 C)
· if
p
0 U T
U
() = E
p& U
() = 0l T
() = L
1
0 1 +
1 :

L0

E

L (U) - L E - E

E

T
H T (
& U
· if T p U 10
0
)
(U) = E
+
(- 50 C
°) p

& (U) = 1

1
:
T
Y
,

0
L
E

E 0
L
L (U =10) - L (U)
· if 10 U 20: (U) = (U =10) - E
p& (U) = 0

,

L0

· if 20 U 30: (U) = (U = 20) p& (U) = 0,
L (U) - L (U = 20)

And L (&u)
· if 30 U 40: (U) = (U = 20) + E
p

& (U) = 1
T
-

L

0

E L0

2.2 Weibull

The probability of cumulated rupture PF at the moment T is given by (cf POST_ELEM [U4.61.04]):

m

U
( )

I
FD
PF T () = 1

exp - max (
)
.
p

(U
( ))
V
FD T C
U

0

The summation relates to volumes of matter I
V plasticized (as from the moment T p), (U)
I
and (U)
indicating the maximum principal constraint and the temperature in each one of these volumes with various moments (U). Here, volume 0
V of reference is equal to (50 µm) 3. The module of Weibull m is equal to 24 while the constraint of cleavage U depends on the temperature according to:

Temperature [°C]
-50
-100
-150
U [MPa]
2800 2700 2600

The probability of cumulated rupture varies according to ((T), L (T)) according to:

m

(U) V
P (T)

F
= 1 - exp - max

.

p

T C ((U))
U

0
V

2.3 Rice and Tracey

In simple traction, the Napierian logarithm of the growth rate of the cavities at the moment T is given by
(cf POST_ELEM [U4.61.04]):

R T ()
T
Log
= ,
0.283× exp (
)
5
,
0
×

p& U () of
R0
0

2.4
Sizes and results of reference

R
PF and
for the couples (temperature, displacements = (l-l0)) following: (50,0°C, 20,35 mm);
0
R
(50,0°C, 20,30 mm); (150,0°C, 20,30 mm) and (150,0°C, 32,53 mm).

2.5
Uncertainties on the solution

Analytical solution.

3 Modeling
With

3.1
Characteristics of the grid

A number of nodes: 1137
A number of meshs and types: 64 (PENTA15), 192 (HEXA20)

3.2 Functionalities tested

Orders

DEFI_MATERIAU
WEIBULL_FO
M
VOLU_REFE
SIGM_REFE
SIGM_CONV
STAT_NON_LINE
COMP_INCR
RELATION
VMIS_ISOT_LINE
DEFORMATION
SMALL
CALC_ELEM
OPTION
EPSG_ELGA_DEPL
POST_ELEM
WEIBULL
COEF_MULT
OPTION
SIGM_ELMOY
POST_ELEM
RICE_TRACEY
OPTION
SIGM_ELMOY

3.3
Sizes tested and results

Reference
Code_Aster
Reference
Code_Aster
T [°C]
lL0 [mm]
P
% diff.
F
PF
% diff.
R
R

0
R
0
R
-50 20,35
0,01465
0,01481
1,1
1,0447
1,0458
0,1
-50 20,30
0,01465
0,01481
1,1
1,0447

1,0458
0,1
-150 20,30
0,01465
0,01481
1,1
1,0447
1,0458
0,1
-150 32,525 1,0 1,0 0,0
1,068
1,0701
0,2

3.4 Parameters of execution

Version: 6.2

Machine: SGI - ORIGIN 20 00 - R12000

Obstruction memory: 64 Mo
Time CPU To use: 201,81s

4 Summary of the results

The results obtained by Code_Aster are very close to the analytical solutions of reference.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.149

SSNV149 - Test of ENDO_ISOT_BETON

Summary:

One presents in this test two quasi static calculations of an element of volume in homogeneous deformation with
the law of behavior ENDO_ISOT_BETON.

Version
7.1

Titrate:
SSNV149 - Test of ENDO_ISOT_BETON

Date:
28/10/03
Author (S):
P. BADEL, V. GODARD Key
:
V6.04.149-B Page:
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1
Problem of reference

1.1
Geometry and boundary conditions

P
Blockings
8
P7
P1P2P3P4: dz=0
P1P5P8P4: dx=0
P1P5: dy=0
P2P6: dy=0
P4
P3
Traction/compression
P
P2P6P7P3: dx imposed
5
P6
{dx, Dy, dz} are displacements of
nodes according to the three directions.
P1
P2
y
X

Z

Appear 1.1-a: Geometry and boundary conditions of the uniaxial tests

The boundary conditions adopted ensure a homogeneous deformation in the element.

1.2 Material properties

Elastic behavior:

E = 300000 MPa; = 0 3
.

Damaging behavior:

Y = 3 MPa; AND = -6000 MPa

2 Reference solution

This test is a test of nonregression.

3 Modeling

With

3.1 Characteristics of modeling

Modeling 3D

Element MECA_HEXA8.

3.2 Characteristics of the grid

A number of nodes: 8

A number of meshs and types: 1 HEXA8

3.3 Functionalities tested

The law of behavior ENDO_ISOT_BETON.

4 Results of modeling A

4.1 Properties of material

Damaging behavior:

T

= MPa
3
;
threshold
C

=
MPa
225
.

11
;
threshold
E = -
MPa
6000
T

4.2
Way of loading

The element is subjected to a uniaxial traction followed by a discharge and a uniaxial pressing.

4.3 Values
tested

Moment
Name of the field
Component
Place
Aster
24
DEPL
DX N2 8.006E+06
24
SIEF_ELGA
SIXX
M1, point 1
2.03628E+07
24
VARI_ELGA
V1
M1, point 1
8.14067E-01

Titrate:
SSNV149 - Test of ENDO_ISOT_BETON

Date:
28/10/03
Author (S):
P. BADEL, V. GODARD Key
:
V6.04.149-B Page:
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5
Results of modeling B

5.1
Properties of material

Damaging behavior:

T

= MPa
3
;
threshold
C

= 40MPa;
threshold
E = -
MPa
6000
T

5.2
Way of loading

The element is subjected to a uniaxial pressing.

5.3 Values

tested

Moment
Name of the field
Component
Place
Aster
25
DEPL
DX N2 1.28E-05
25
SIEF_ELGA
SIXX
M1, point 1
3.84E+07
25
VARI_ELGA
V1
M1, point 1
0.00E+00
27
DEPL
DX N2 1.37E-05
27
SIEF_ELGA
SIXX
M1, point 1
4.06405E+07
27
VARI_ELGA
V1
M1, point 1
2.90913 E-02
37
DEPL
DX N2 1.82E-05
37
SIEF_ELGA
SIXX
M1, point 1
4.55227E+07
37

VARI_ELGA
V1
M1, point 1
1.00E+00

6
Summary of the results

The objective of modeling A is to show refermeture of crack in compression after one phase of damaging traction. Modeling B shows the effects of the parameter C

threshold
(constraint threshold in an unconfined compression test). It should be noted that the constraint threshold
does not correspond in calculation exactly to the constraint of initiation of the damage in compression, this is due to the fact that the criterion is evaluated starting from the deformations with the step of time
precedent and not with the step of current time. The error observed thus depends on the size of the steps on
time.

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Code_Aster *®*
Version
5.0

Titrate:
SSNV150 - Tractiontriaxiale with law BETON_DOUBLE_DP

Date:
22/01/02
Author (S):
C. CHAVANT*, B. CIREE Key*
:
V6.04.150-A Page:
1/10

Organization (S): EDF/AMA, IPSN

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
V6.04.150 document

SSNV150 - Triaxial traction with the law
of behavior BETON_DOUBLE_DP

Summary

This case of validation is intended to check the model of behavior 3D BETON_DOUBLE_DP

formulated in
tally of thermoplasticity, for the description of the nonlinear behavior of the concrete, in traction, and in
compression, with the taking into account of the irreversible variations of the thermal characteristics and
mechanics of the concrete, particularly sensitive at high temperature.
The description of cracking is treated within the framework of plasticity, using an energy equivalence,
by identifying the density of energy of cracking in mode I, with the plastic work of a homogeneous medium
equivalent, where the plastic deformation is uniformly distributed, in an "elementary" zone. This approach
preserve the continuity of the formulation of the model, on the whole of its behavior, and contributes to avoid
possible numerical difficulties during the change of state of material.
Pathological sensitivity of the numerical solution to the space discretization (grid), generated by
the introduction of a softening behavior of the concrete in traction and compression, is partially solved
by introducing an energy of cracking or rupture, dependent a characteristic length lc, related to
cut elements.
The resolution of the equations constitutive of the model is carried out by an implicit scheme.

It is about a cube with 8 nodes subjected to a triaxial traction, in imposed displacement. This led loading
with the particular case of a hydrostatic state of stress, solved by projection at the top of the cone of traction,
when one places oneself in a hydrostatic diagram forced equivalent/forced. It is about a case test
with analytical solution.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

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1
Problem of reference

1.1 Geometry

It is about a cube with 8 nodes, whose three faces have a normal displacement no one and the three faces
opposed an imposed and identical normal displacement.
The cube makes 1 mm on side. In modeling A, the cube is directed according to the Oxyz reference mark.

Modeling A

U2

Face1xy

Face1xz

Face1yz

U1
U

Faceyz
3

Ux = 0

Z

y

Uz = 0

N1
N2

X
Facexy

U
Facexz
2 = U1= U3

1.2
Material properties

To test the irreversible evolution of the mechanical characteristics with the temperature, one applies a field of temperature decreasing. Certain variables depend on the temperature, others of drying. Lastly, one applies a coefficient of withdrawal of desiccation not no one, equal to the coefficient of
thermal dilation, to test "data-processing" operation. The thermal deformations will be thus equal and opposed to the deformations of withdrawal of desiccation. These dependences intervene only for purely data-processing checks, the mechanical characteristics can be regarded as constants.

For the usual linear mechanical characteristics:

Young modulus:
E = 32.000 MPa
of
0°C with 20°C

E = 15.000 MPa
with
400°C (linear decrease)

E = 5.000 MPa
with
800°C (linear decrease)
Poisson's ratio:
N = 0.18

Thermal dilation coefficient:
has = 105/°C

Coefficient of withdrawal of desiccation: K = 105

For the nonlinear mechanical characteristics of model BETON_DOUBLE_DP:

Resistance in uniaxial pressing f' C = 40 N/mm ²
of
0°C with 400°C
:

f' C = 15 N/mm ²
with
800°C (linear decrease)
Resistance in uniaxial traction:
f' T = 4 N/mm ²
of
0°C with 400°C

f' T = 1.5 N/mm ²
with
800°C (linear decrease)

Report/ratio of resistances in compression

biaxial/uniaxial pressing:
B = 1.16

Energy of rupture in compression:
Gc =10 Nmm/mm ²

Energy of rupture in traction:
WP =0.1 Nmm/mm ²

Report/ratio of the limit elastic to resistance

in uniaxial pressing:
30%

1.3
Boundary conditions and loadings mechanical

Field of temperature decreasing of 20°C with 0°C.
Lower face of the cube (facexy):
blocked according to OZ.
Higher face of the cube (face1xy):
Uz displacement = 0,15 mm
Left face of the cube (faceyz):
blocked according to OX.
Right face of the cube (face1yz):
Ux displacement = 0,15 mm
Front face of the cube (facexz):
blocked according to OY.
Face postpones cube (face1xz):
Uy displacement = 0,15 mm

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is calculated in an analytical way, knowing that in traction, only the criterion of traction is activated, and that in the case of a hydrostatic loading, one is projected at the top of cone of traction. It is thus necessary to solve a linear system of an equation to an unknown factor, which allows to obtain the plastic deformation cumulated in traction. This one makes it possible to calculate then strains and stresses.

2.2
Calculation of the reference solution of reference

For more detail on the notations and the setting in equation, one will refer to the reference document [R7.01.03]. Only, the principal equations are pointed out here.
One notes "has", imposed displacement following directions X, y and Z. The tensor of deformation is form (has, has, has, 0. , 0. , 0.) by taking the usual notations of Code_Aster (three components principal, three components of shearing).
The tensor of constraint is form (, 0. , 0. , 0.), in modeling A.

General equations of the model:

The equations constitutive of the model are written by distinguishing the isotropic part of the part deviatoric of the tensors of constraints and deformations.

1
1

1
1
=
()
= -

=
~
= - tr
H
tr
S
tr () I
( )
() I
3
3
H
tr
3
3
= S + I
= ~ +
H
and
H I
3

The equivalent constraint is written then: eq =
tr (s2)
2

In the case of an incremental formulation, and of a variable law of behavior, while noting with one exhibitor "E" the elastic components of the constraint and the deformation, one obtains:

+
µ
K +
=
S +
+
2µ

~
E =
- +

+
-
3K
μ
and

H
-
H
H
K

The criteria in compression (fcomp) and traction (ftrac) are expressed in the following way:

+ A.
2
has
F
Oct.
Oct.
=
- F
eq
=
+ -

C (c)
F
comp
H
C (c)
B
B
3
B
+ C.
2
C
F
Oct.
Oct.
=
- F

eq
=
+ -

T (T)
F
trac
H
T (T)
D
D
3
D

---

tr (s2)
with Oct. =
3

tr ()
Oct. =
3
C: plastic multiplier in compression
T: plastic multiplier in traction
and has, B, C, D the coefficients of the model

The plastic deformations in traction and compression are expressed:

S
has
~
p
C
p
C =

H =

2 eq
B
C
C
B
3

S
C
~
p
T
p
T =

H =

2 eq
D
T
T
D
3

One obtains for the constraint:

S = -
+
2µ (~ p
~ p

E
+
p
p
C +

T)
=
- *3K (*

C +

H
H
H
H T)

1
+
has
C
S
+
C
T
1 2μ

=
-
+
E

=
- *3K*

+

H
H
C
T
B
2
2D eeq

B
3
D
3

for the equivalent constraint:
eq = eeq - 2μ +
C
T
+

B
2
2D
The two criteria lead then to a system of two equations to two unknown factors C and T with to solve:

2
has
2 +
+ 2
μ
K has
2μ+ K +ac
E eq
E

+
-

+
-

+
- *F* - +

=
H
C
2
2
T
C (C
c)
0
3b
B
3b
B

3bd
data base

2
C
2µ + K +ac
2 +
+ 2
µ
K C

E eq
E

+
-

+
-

+

- F - +

=
H
C
T
2
2
T (T
T)
0
3D
D
3bd
data base
3D
D

In a similar way, in the case of the only criterion of traction activated, ***configuration of the case test****, one*
obtains a system of an equation to an unknown factor T to be solved:

2
C
2 +
+ 2
μ
K C
E eq
E

+
-
+
- F -

+

=
H
T

2
2
T (T
T)
0
3D
D
3D
D

Resolution with projection at the top of the cone of traction:
One thus seeks to solve this system, by using the particular shape of the tensors of constraints and of deformations, uniforms on the structure.
On the basis of = (has, has, has, 0. , 0. , 0.) and of = (, 0. , 0. , 0.). one obtains:

= 3 +
X
has (2µ)

The elastic tensor of constraint

= 3 +
y
has (2μ)

= 3 +
Z
has (2μ)
S =
X
0

The elastic diverter of constraint S =
y
0
S =
Z
0
The hydrostatic constraint elastic E H = (
3 + 2μ) (A) = has
3 K
The elastic equivalent constraint eeq = 0
In the case of a curve of linear work hardening post-peak in traction, the expression of the parameter of work hardening is as follows:

p

2.G ()
F
F
p
T
,
= , = 1-

=
T (
T
) () F ()
T

() with ()

U

U

L. F ()
C
T

where the maximum of temperature during the history of loading indicates, F ()
T

resistance in traction.

~
p
C
p
+
C
T = 0

E
H
=
T
T

=
- *3K*

D
3
H
H
T

D
3

The equation characterizing projection at the top of the cone of traction is as follows:

C
K +c2

L. F
E

-

- F
C
T
1-

= 0
éq
2.2-1
D H
T

D 2
T
T

2.G
T

WP being the energy of rupture in traction (characteristic of material).

What makes it possible to obtain the plastic multiplier:

C E
C
- F
(aK
3
) -
H
T
ft

D
D

=
=
T

2
2
K +c2
L.

+ 2
.

C (F T)
K C
lc (ft)
-
-
D 2
2.G
2
T
D
2.Gt

+

C

C
Then the constraint:
= E - 3K

K 3.a

H
H
T
T

D
3 =
-

D
Knowing has, imposed displacement, one obtains all the unknown factors of the problem.

2.3
Uncertainty on the solution

The solution being analytical, uncertainty is negligible, about the precision of the machine.

2.4 References
bibliographical

The model was defined starting from the following theses and is described in the report/ratio of specification:

[1]
G. Heinfling, at the time of its thesis "Contribution to the numerical modeling of the behavior of concrete and of the concrete structures reinforced under thermomechanical requests with high temperature ",
[2]
J.F. Georgin, at the time of its thesis "Contribution to the modeling of the concrete under request of fast dynamics. The taking into account of the effect speed by viscoplasticity ".
[3]

SCSA/128IQ1/RAP/00.034 Version 1.2, Development of a model of behavior 3D concrete with double criterion of plasticity in Code_Aster - Specifications “.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

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3 Modeling
With

3.1
Characteristics of modeling

3D (HEXA8)

1 element, stress field and uniform deformation.

U2

Face1xy

Face1xz

Face1yz

U1
U

Faceyz
3

Ux = 0

Z

y

Uz = 0

N1
N2

X
Facexy

Facexz

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and type: 1 HEXA8

3.3
Functionalities tested

Orders Options

“MECHANICAL” AFFE_MODELE
“3D”

DEFI_MATERIAU “BETON_DOUBLE_DP”

DEFI_MATERIAU “ELAS_FO”
“K_DESSIC”

AFFE_CHAR_MECA "SECH_CALCULEE"

STAT_NON_LINE "BETON_DOUBLE_DP"

4
Results of modeling A

4.1 Values tested

Components xx and zz of the stress field SIEF_ELNO_ELGA were tested, and plastic deformation cumulated in traction (second variable internal, second component of field VARI_ELNO_ELGA). Displacement being imposed, field EPSI_ELNO_DEPL is not tested.

The three moments correspond to a displacement of 0.005, 0.01 and 0.015 Misters.

Component field SIEF_ELNO_ELGA SIXX

Identification Reference

Aster *%*
difference
For an imposed displacement
1.9182065 1.9182066 7.10-6
in load U1= U2= U3= 0.005
For an imposed displacement
1.161
1.1616769 3.10-6
in load U1= U2= U3= 0.010
6770
For an imposed displacement
0.4051470 0.4051473 7.10-5
in load U1= U2= U3= 0.015

Component field SIEF_ELNO_ELGA SIZZ

Identification Reference
Aster *%*
difference
For an imposed displacement
1.9182065 1.9182066 7.10-6
in load U1= U2= U3= 0.005
For an imposed displacement
1.1616770 1.1616769 3.10-6
in load U1= U2= U3= 0.010
For an imposed displacement
0.4051470 0.4051473 7.10-5
in load U1= U2= U3= 0.015

Component field VARI_ELNO_ELGA V2 (plastic deformation cumulated in traction)

Identification Reference
Aster *%*
difference
For an imposed displacement
0.0099232717 0.0099232717 4.10-7
in load U1= U2= U3= 0.005
For an imposed displacement
0.0199535329 0.0199535329 1.10-7
in load U1= U2= U3= 0.010
For an imposed displacement
0.0299837941 0.0299837941 3.10-8

in load U1= U2= U3= 0.015

4.2 Parameters of execution

Version: 5.04.22

Machine: Claster

Obstruction memory: 32 Mo
Time CPU To use: 17.66 seconds
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

5
Summary of the results

This case test offers very satisfactory results compared to the analytical solution, lower than 7.10- 5% with a low iteration count (1 or 2 iterations). The solution is obtained from one linear equation in the case of a linear curve of work hardening in traction, but the resolution uses an algorithm of Newton within a framework plus general.
One can note the work hardening of the criterion of traction which takes place during the loading, involving one reduction in the constraint (component xx, yy and zz) in addition equalizes with the hydrostatic constraint.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.151

SSNV151 - Traction/Compression with the law of behavior BETON_DOUBLE_DP

Summary

This case of validation is intended to check the model of behavior 3D BETON_DOUBLE_DP formulated in tally of thermoplasticity, for the description of the nonlinear behavior of the concrete in traction and in compression, with the taking into account of the irreversible variations of the thermal characteristics and mechanics of the concrete, particularly sensitive at high temperature.
The description of cracking is treated within the framework of plasticity, using an energy equivalence, by identifying the density of energy of cracking in mode I, with the plastic work of a homogeneous medium equivalent, where the plastic deformation is uniformly distributed in an "elementary" zone. This approach preserve the continuity of the formulation of the model, on the whole of its behavior, and contributes

*to avoid
possible numerical difficulties during the change of state of material.
Pathological sensitivity of the numerical solution to the space discretization (grid), generated by
the introduction of a softening behavior of the concrete in traction and compression, is partially
solved
by introducing an energy of cracking or rupture, dependent a characteristic length lc, related to
cut elements.
The resolution of the equations constitutive of the model is carried out by an implicit scheme.*

*It is about a cube with 8 nodes subjected to a uniaxial pressing, in imposed displacement to which is
added
a biaxial traction when one reached an important work hardening in traction. This loading led to the
case
private individual of a hydrostatic state of stress, solved by projection at the top of the cone of traction,
when
one places oneself in a hydrostatic diagram forced equivalent/forced. It is about a case test of not
regression.*

---

1 Problem of reference

1.1 Geometry

*It is about a cube with 8 nodes, whose three faces have a normal displacement no one, and the three
faces
opposed have an imposed and identical normal displacement.*

The cube makes 1 mm on side. In modeling A, the cube is directed according to the Oxyz reference mark.

Modeling A

U2

Face1xy

Face1xz

Face1yz

U1
U

Faceyz
3

Ux = 0

Z

y

Uz = 0

NR
NR

1
X
2
Facexy

Facexz

1.2
Material properties

To test the establishment of thermal dilation and the withdrawal of desiccation, a field is forced of temperature and a field of drying variables so that deformations generated by the two phenomena are compensated, while considering that the dilation coefficients thermal and of withdrawal of desiccation are equal. The values related to drying do not have any physical direction, it test is from this point of view, purely data-processing.

For the usual linear mechanical characteristics:

Young modulus:
E = 32.000 MPa

Poisson's ratio:
= 0.18

Thermal dilation coefficient:
= 105/°C

Coefficient of withdrawal of desiccation:
= 10-5

Temperature of reference
Tref = 0 °C

Drying of reference
Cref = 20

For the nonlinear mechanical characteristics of model BETON_DOUBLE_DP:

Resistance in uniaxial pressing:
f' C = 40 N/mm ²

Resistance in uniaxial traction:
f' T = 4 N/mm ²

Report/ratio of resistances in compression

biaxial/uniaxial pressing:
= 1.16

Energy of rupture in compression:
Gc =10 Nmm/mm ²

Energy of rupture in traction:
WP =0.1 Nmm/mm ²

Report/ratio of the limit elastic to resistance

in uniaxial pressing:
30%

1.3
Boundary conditions and loadings mechanical

Increasing field of temperature of 0°C with 20°C.

Field of drying decreasing from 20 to 0.
Lower face of the cube (facexy):
blocked according to OZ.
Higher face of the cube (face1xy):
variable displacement imposed in mm
Left face of the cube (faceyz):
blocked according to OX.
Right face of the cube (face1yz):
variable displacement imposed in mm
Front face of the cube (facexz):
blocked according to OY.
Face postpones cube (face1xz):
variable displacement imposed in mm

The mechanical loading is applied in displacement imposed to the various faces of the cube. One apply a compression to the face face1xz, affected by a first multiplying coefficient and one traction according to faces' face1xy and face1yz, affected by a second multiplying coefficient, no one during the first part at the beginning of loading, according to the following diagram:

2 Modeling
With

2.1

Characteristics of modeling

3D (HEXA8)

1 element, stress field and uniform deformation.

U2

Face1xy

Face1xz

Face1yz

U1
U

Faceyz
3

Ux = 0

Z

y

Uz = 0

NR
NR

1
X
2
Facexy

Facexz

2.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and type: 1 HEXA8

2.3 Functionalities
tested

Orders Options

“MECHANICAL” AFFE_MODELE
“3D”

DEFI_MATERIAU “BETON_DOUBLE_DP”

DEFI_MATERIAU “ELAS_FO”
“K_DESSIC”

AFFE_CHAR_MECA “SECH_CALCULEE”

STAT_NON_LINE “BETON_DOUBLE_DP”

3
Results of modeling A

3.1 Values
tested

Were tested components xx and yy of the stress field SIEF_ELNO_ELGA, the deformation
figure cumulated in compression, plastic deformation cumulated in traction (first and
second internal variable, second component of field VARI_ELNO_ELGA) and the plastic state (
fourth variable of field VARI_ELNO_ELGA). The plastic state is worth 1 in compression, 11 afterwards
projection at the top of the cone of compression, 2 in traction, 22 after projection at the top of the
criterion
of traction, 3 in compression and traction together, and 33 after projection out of the two tops of
two cones. Displacement being imposed, field EPSI_ELNO_DEPL is not tested.
The values given here correspond to version 7.2.25.

Component field SIEF_ELNO_ELGA SIXX

Identification Reference
***Aster** %*
difference
For a displacement imposed in
- -
-
U3= 1. and U1= U2= 0.
For a displacement imposed in
- 2.5737449
-
U3= 1.725 and U1= U2= 0.010
For a displacement imposed in
- 0.6767446
-
U3= 1.8 and U1= U2= 0.02872
For a displacement imposed in
- 2.666667
10-6 -
U3= 2. and U1= U2 = 0.1

Component field SIEF_ELNO_ELGA SIYY

Identification Reference
***Aster** %*
difference
For a displacement imposed in
- -17.4575632
-
U3= 1. and U1= U2= 0.
For a displacement imposed in
- 2.5737449
-
U3= 1.725 and U1= U2= 0.010
For a displacement imposed in
- 0.6767446
-
U3= 1.8 and U1= U2= 0.02872
For a displacement imposed in
- -3.622988
10-5 -
U3= 2. and U1= U2 = 0.1

Component field VARI_ELNO_ELGA V1 (plastic deformation cumulated in compression)

Identification Reference
***Aster** %*
difference
For a displacement imposed in
- 0.1995285
-
U3= -1. and U1= U2= 0.
For a displacement imposed in
- 0.3429299
-
U3= -1.725 and U1= U2= 0.010
For a displacement imposed in
- 0.3449657
-
U3= -1.8 and U1= U2= 0.02872
For a displacement imposed in
- 0.3849539
-
U3= -2. and U1= U2 = 0.1

Component field VARI_ELNO_ELGA V2 (plastic deformation cumulated in traction)

Identification Reference
***Aster** %*
difference
For a displacement imposed in
- -
-
U3= -1. and U1= U2= 0.
For a displacement imposed in
- 1.231450e-03
-
U3= -1.725 and U1= U2= 0.010
For a displacement imposed in
- 2.638289e-02
-
U3= -1.725 and U1= U2= 0.02872
For a displacement imposed in
- 8.373868e-02 -
U3= -2. and U1= U2 = 0.1

Component field VARI_ELNO_ELGA V4 (plastic state)

Identification Reference
***Aster** %*
difference
For a displacement imposed in

- 1.
-
U3= -1. and U1= U2= 0.
For a displacement imposed in
- 22.
-
U3= -1.725 and U1= U2= 0.010
For a displacement imposed in
- 22.
-
U3= -1.725 and U1= U2= 0.02872
For a displacement imposed in
- 3.
-
U3= -2. and U1= U2 = 0.1

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal elements
Document: V6.04.152

Elastic SSNV152- Traction. Calculation of the constraints of Cauchy

Summary

The goal of this test is to validate the calculation of the constraints of Cauchy in order CALC_ELEM by the option
SIGM_ELNO_COQUE.

1

Problem of reference

1.1 Geometry

The geometry of this test is a square plate in the plan (X, y) round of 30° compared to X around of Z.

L
= 1000 .
0

No1

No4

M1

NO5
No7
Z

NO3
y
No2
X

room

X
X

total

One calls L the length of the deformed plate, one will note X, y, Z, the co-ordinates of the configuration
deformation and X, Y, Z, co-ordinates of the initial configuration

1.2

Properties of materials

One takes E = 200
.
000 MPa and = 0

1.3
Boundary conditions and loadings mechanical

One blocks the nodes No1, NO5 and No2 so that DX=DY=DZ=DRX=DRY=DRZ=0,
and one imposes a local displacement Dx=100. on nodes NO3, No4 and No7.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is analytical.

Passage of the initial state in a deformed state:

1
has
B

X =
X, y =
Y, Z =
Z
L
has
B
0
0
0

where
A is the length of the deformation of the plate following Y,
a0 is the initial length of the plate,
B is the thickness of the deformed plate,
b0 is the initial thickness of the plate.

Owing to the fact that = 0 and of the assumptions of hull, one have has = has, B = B
0
0

Green-Lagrange tensor:
1 U
U
U
U
I
J

K

K

By definition of the tensor of Green-Lagrange, there are E

ij =

+
+

2

X
X
X
X
J
I I J

L - L
1 L - L
L L
L L
1 L
L
0
- 0 (-) 2
0

2 - 2
With U = X - X
0
=
X, one thus has E

11 =

+
+
2
=
0
L

2

2 L
L
L
2
L
0

0

0

1 11002 -10002
While replacing, there are E =
= 0.105
11
2
10002

Gradient of deformation:

By definition:
dx
dx
dx L

dX
Dy
dZ

0 0

Dy
Dy
Dy
l0

F =
= 0 1 0

dX
Dy
dZ
dz
dz
dz
0
0 1

dX
Dy
dZ

L
That is to say J = det F =

l0
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Constraints of Piola-Kirchhoff of second species:

That is to say S the constraint of PK2, in our case, S = E.E = 200000 × 0.105 = 21000
11
11

Constraint of Cauchy

1
That is to say S the tensor of constraints of Cauchy, one with the relation S =
(
T
F S
. F
.
), one deduces some then
det F

1 L
L
L
1100
that S

xx =
. S.

=. S =
21000
.
= 23100
11
11
L L
L
L
1000
0
0
0

l0

2.2
Results of reference

One calculates displacements DX and DY with node NO3, the constraints of PK2 and the constraints of Cauchy on the M1 mesh.

2.3
Uncertainty on the solution

Analytical result.

2.4 References
bibliographical

Nothing.
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Code_Aster ®
Version
6.1

Titrate:

3 Modeling With

3.1 Characteristics of modeling

Elements COQUE_3D are used

3.2 Characteristics of the grid

No1

No4

No2
NO3

Co-ordinates of the principal nodes:

Coor_x node
Coor_y
Coor_z
N01 500
866.025
0.
N02

0 0 0.
N03 866.025
500
0.
N04 366.025
1366.025
0.

The meshs used are:
1 mesh QUAD9
2 meshs TRIA7

3.3
Functionalities tested

Orders
Option

CALC_ELEM
SIGM_ELNO_COQUE

4

Results of modeling A

4.1 Values tested

Identification Reference Aster Difference

DX (No4) 8.66025 E+01
8.66025 E+01
4.66 E-05%
DY (No4) 50.0
50.0
0%
PK2-SIXX (M1) 21000.
21000.
2.04 E-08%
Cauchy-SIXX (M1) 23100.
23100.
2.14 E-08%

5 Summary of the results

The found results are in agreement with the analytical solution.

Date:
19/08/02
Author (S):
P. MASSIN, *Mr. ZARROUG*

Organization (S): EDF/AMA, ECP

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.153

SSNV153 - Contact pulley - cord

Summary:

This problem corresponds to a quasi-static analysis of a problem of mechanics with contact without *friction. It is about a cord posed on a pulley, whose interior surface is embedded, and drawn from two sides with an imposed vertical displacement.*

This test, treated in 2D with elements QUAD4 is implemented to validate the smoothing of the normal of surfaces of contact.

This test is based on results 2D suggested by Papadopolous [bib1].

---

1 ***Problem of reference***

1.1 Geometry

y

With

B

C

D

Interior surface
X

embedded

Surface contact

Vertical displacements

imposed

Thickness of the cord ep = 1 Misters.

Thickness of the pulley has = 1 Misters.

Position of the points of reference on the surface of contact (mm)

X y
To 0 4 0
B 0 3 0
C 0 3 0

1.2
Material properties

Plate for the pulley and the cord:

Poisson's ratio: 0.4762

Young modulus: 147.619 105 N/m2

Finite elements of contact:

Integration: Nodes
Parameter of the method:

Coef_regu_cont =1.

1.3
Boundary conditions and loadings

The pulley is blocked:

· on its surface interns displacement is null in two directions X and Y.

No boundary conditions is imposed on the cord except that of the contact.

Loading:

· two vertical displacements are imposed on the two ends of the cord u=1

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution comes from results obtained in [bib1].

2.2
Results of reference

Tangential displacements (according to X) at points A B C of the surface of contact.
Value of yy at the point C (and thus that of the LAGS_C)

2.3 Reference
bibliographical

[1]
P. PAPADOPOULOS "Numerical formulations for contact problems with friction" Newspaper of

---

3 Modeling With

3.1 Characteristics of modeling

Modeling: 2D_PLAN for the solid elements (QUAD4)

The pulley is with a grid with a regular grid using only elements QUAD4. There is the same one a number of nodes on interior and external surface. For the cord the grid is also regular and includes/understands only elements QUAD4. There are 8 meshs in the thickness of the cord.

3.2 Characteristics of the grid

A number of nodes:
807
A number of meshs and types:
703 QUAD4 and 311 SEG2

3.3 Functionalities tested

Orders

CONTACT
METHOD
"CONTINUES"
CONTACT
INTEGRATION
"NODE"
CONTACT
SMOOTHING
"YES"
CONTACT
COEF_REGU_CONT
CONTACT
COEF_REGU_FROT
STAT_NON_LINE

4
Results of modeling A

4.1 Values
tested

Identification Reference
***Aster** %*
difference
DX at point A
0.0
-1.8289243E-08
1.83E-08
DX at the point B
0.0
-1.6557395E-08
-1.66E-08
DX at the point C
0.0
1.8398391E-09
1.84E-09
SIYY at the point C
-5.97E+05 -6.0271214E+05
0.957%

4.2 Parameters of execution

Version: 5.04.14

Machine: CLASTER

System: IRIX64
Obstruction memory:
16 megawords
Time CPU To use: 129.59 seconds
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V6.04 booklet: Nonlinear statics of the voluminal structures
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5 Summary of the results

In this case test, two surfaces of contact are not plane. The normal thus changes one net with another. This discontinuity generates problems of pairing which have large influence on calculation. Among these problems, one finds the problem of dissymetrisation, i.e to find results which do not respect the symmetry of the problem. For this case test, the problem is perfectly symmetrical (geometries, boundary conditions and loading) according to axis Y. Without regularization of the normal a dissymmetry appears on axis X. Indeed, displacements horizontal of the points A, B and C which are on the axis have there then nonnull values which do not respect the total symmetry of the problem.

With the regularization of the normal, the solution obtained by using the method continues, respects perfectly symmetry. It should however be noted that the maillor gibi, used in this case test, does not give

*not a perfectly symmetrical grid and that problems of round-offs deteriorate very slightly
the quality of the solution.*

*This problem is dealt with with the method CONTINUES, of the key word CONTACT. Integration is made with
level of the nodes of the grid. A detailed attention on the choice of the potential zones of
contact is to be taken into account in these problems of nonplane surfaces.*

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HT-66/02/001/A

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.154

SSNV154 - Triaxial compression test drained with model CJS

(level 3)

Summary

This test makes it possible to validate level 3 of model CJS. It is about a triaxial compression test in drained condition.
calculations are carried out only on the solid part of the ground without hydraulic coupling. The level of
containment is 400 KPa.
By reason of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test. Two
modelings are presented. Modeling A is axisymmetric. In modeling B, 3D, the sample
tested is turned of an angle of - /6 compared to axis X. Consequently, directions X, y, Z are not any more principal directions. That makes it possible to validate the operations of numerical integration of the model which act on
nondiagonal terms of the tensors of the strains and the stresses.
It is about a test of nonregression. Nevertheless, results obtained with Code_Aster for model CJS3
are compared with those obtained with a private version of software FLAC 2D.
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V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

Z
E
height:
H = 1 m
width:
L
= 1 m
thickness:
E = 1 m
C
H
With
B
y
X
L

Co-ordinates of the points (in meters):

With
B
C
X 0. 0.

0.5
y 0. 1.
0.5
Z 0. 0.
0.5

1.2
Material property

E = 35,6616541 103 kPa
= 0,15037594

Parameters CJS3:
= - 0,55
= 0,82 Rm = 0,05
Rc = 0,265
N = 0,6

K p
O = 25,5 103 kPa
B = 7.0 kPa
μ = 0.021
pco = -600 kPa

C = 30.0

Pa = -100 kPa

1.3
Initial conditions, boundary conditions, and loading

Phase 1:
One brings the sample in a homogeneous state: 0 = 0 = 0
xx
yy
zz, by imposing the pressure of
containment corresponding on the front, side right-hand side and higher faces. Displacements are blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0), as well as the confining pressure on the front faces and side right-hand side. One apply a displacement imposed to the higher face: U (T)
Z

, in order to obtain a deformation
zz = -20% (counted starting from the beginning of phase 2).
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V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
SSNV154 - Triaxial compression test drained with model CJS (level 3)
Date:
04/03/02
Author (S):
C. CHAVANT, pH. Key AUBERT
:
V6.04.154-A Page:
3/8

2
Reference solution

2.1
Method of calculation used for the reference solution

The results obtained with a private version of software FLAC 2D are used as reference.

2.2
Results of reference

Constraints xx, yy and zz at point A.

2.3 Bibliography

[1]
Board, "FLAC (Fast Lagrangian Analysis of Continua) Version 2.20. U.S. NRC", NUREG/CR-5430, October 1989.
[2]
"Flac Fast Lagrangian Analysis of Continua. Theory and Background. " Itasca Consulting Group.

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3 Modeling
With

3.1
Characteristic of modeling

3D:
y
Z
X

Cutting: 1 in height, 1 in width.

Loading of phase 1:
Confining pressure: 0 = 0
xx
yy = 400 kPa.
Level 3 of model CJS

3.2
Characteristic of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

3.3 Functionalities

tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
“CJS”

4
Results of modeling A

4.1 Values
tested

For 0 = 0
xx
yy = 400 kPa

Localization Number deformation

constraint
Reference
Aster %
difference
of order
axial
(kPa)
zz (%)
FLAC 2D
Not A 10
-4.0 %

xx
400.0
-400.000 <
0.05
50
-20.0
%
xx
400.0 400.000 < 0.05

10
-4.0 %
zz
-400.0
400.000 < 0.05
50
-20.0
%
zz
400.0 400.000 < 0.05

2
-0.8 %
yy
-667.209
-667.2087 <
0.05
5
-2.0
%
yy
-917.634

-917.6343 <
0.05
10
-4.0
%
yy
-1184.57
-1184.5705 <
0.05
20
-8.0
%
yy
-1337.38
-1337.3821 <
0.05
34
-12.0
%
yy
-1351.76
-1351.7551 <
0.05
40
-16.0
%
yy
-1350.80
-1350.8029 <
0.05
50
-20.0
%
yy
-1348.54
-1348.5422 <
0.05

4.2 Parameters of execution

Version: 5.07.01

Machine:
SGI-ORIGIN 2000
System:
IRIX64
Obstruction memory: 100 MO
Time CPU To use: 63 S
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

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5 Modeling
B

5.1 Geometry

Z
/6 E
F
H
height:
H = 1 m
width:
L
= 1 m
thickness:
E = 1 m
H
G

With
y
B
X
D
E
L
C

Co-ordinates of the points (in meters):

With
B
C
D
X 0. 0.
1. 1.
y 0. 0.8660254037844
0.8660254037844
0.
5
5
Z 0. 0.5
-0.5
0.

5.2
Characteristic of modeling

3D:

Cutting: 1 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 400 kPa.
Level 3 of model CJS

5.3
Characteristic of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8 and 6 QUA4

5.4 Functionalities

tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
“CJS”

6
Results of modeling B

6.1 Values
tested

For containment: 400 kPa

Localization Number deformation
constraint
Reference

Aster %
of order
axial zz (%)
(kPa)
difference
Not A
10
-2.0 %
xx
-400.0 -400.000
<
10-6
50
-10.0
%
xx
-400.0 -400.000
< 10-6
100
-20.0
%
xx
-400.0 -400.000
< 10-6

10 -2.0
% yy
-53.221
-53.22098 <
10-6
50
-10.0
%
yy
-63.7665 -63.76653
< 10-6
100
-20.0
%
yy
-63.7165 -63.71645
< 10-6

10 -2.0
% zz
-79.6629 -79.66294
< 10-6
50
-10..0
%
zz
-111.3 -111.29959 < 10-6
100
-20.0
%
zz
-111.149 -111.14935
< 10-6
10
-2.0
%
yz
-22.8994 -22.89941
< 10-6
50
-10.0
%
yz
-41.1648 -41.16483
< 10-6
100
-20.0
%
yz
-41.0781 -41.07809
< 10-6

6.2 Parameters of execution

Version: ***5.07.01***

Machine: ***SGI-ORIGIN 2000***

System:
IRIX64
Obstruction memory: 32MO
Time CPU To use: 106 S

7
Summary of the results

The results of Aster coincide with those of FLAC with a lower deviation than 0,05%.

Organization (S): EDF/AMA, CNEPE

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.155

SSNV155 - Triaxial compression test drained on a sample turned of an angle of PI/6 compared to axis X with model CJS (level 2)

Summary

This test makes it possible to supplement the validation of level 2 of model CJS already approached in the case test SSNV136.
It corresponds to the digital simulation of the same test (drained triaxial compression test) on same material but with
a different geometry. The sample tested is thus turned of an angle of /6 compared to axis X. By consequent, directions X, y, Z are not any more principal directions. That makes it possible to validate the operations
of numerical integration of the model which acts on the nondiagonal terms of the tensors of the deformations and
constraints.
As for the case test SSNV136, calculations are carried out only on the solid part of the ground, without

hydro-mechanical coupling. By reason of symmetry, one is interested only in the eighth of a sample subjected to
a triaxial compression test. The level of containment is of 400 kPa
It is about a test of nonregression. The results obtained are compared with those provided by an Aster calculation
with a grid whose axes of symmetry are the axes of co-ordinates. They correspond to them exactly with
the rotation of angle /6 near.

1
Problem of reference

1.1 Geometry

Z
/6 E
F
H
height:
H = 1 m
width:
L
= 1 m
thickness:
E = 1 m

H
G
With
y
B
X
D
E
L
C

Co-ordinates of the points (in meters):

With
B
C
D
X 0. 0.
1. 1.
y 0. 0.8660254037844
0.8660254037844
0.
5
5
Z 0. 0.5
-0.5
0.

1.2
Material property

E = 35,6616541 103 kPa
= 0,15037594
Parameters CJS2:
= - 0,55
= 0,82
Rm = 0,289
Rc = 0,265
N = 0,6

K p
O = 25,5 103 kPa
With = 0.25 kPa Pa = -100 kPa

1.3
Initial conditions, boundary conditions, and loading

Phase 1:
One brings the sample in a homogeneous state, by imposing the corresponding confining pressure on faces EFGH, CDHG and BCGF. Normal displacements are blocked on faces ABCD, ADHE and ABFE.

Phase 2:
One maintains displacements normal blocked on faces ABCD, ADHE and ABFE; as well as confining pressure on faces CDHG and BCGF. An imposed normal displacement is applied on face EFGH, in order to obtain a deformation according to the normal direction equalizes to 20% (counted starting from the beginning of phase 2).

2
Reference solution

2.1
Method of calculation used for the reference solution

By taking account of the rotation of angle of the sample, results obtained by a calculation Aster with a grid whose axes of symmetry are the axes of co-ordinates, are used as reference.

2.2
Results of reference

Constraints xx, yy, zz and yx at point A.

2.3
Uncertainty on the solution

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HT-66/02/001/A

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3 Modeling
With

3.1
Characteristics of modeling

3D:
Z
y
X

Cutting: 1 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 400 kPa.
Level 2 of model CJS

3.2
Characteristic of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8 and 6 QUA4

3.3 Functionalities
tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
“CJS”

4
Results of modeling A

4.1 Values
tested

For containment: 400 kPa

Localization Number deformation
constraint
Reference
Aster %
difference
of order
axial
(kPa)
zz (%)
Not A

-2.0 %
xx
-400.0 -400.000
<
10-6

-10.0
%
xx
-400.0 -400.000
< 10-6

-20.0
%
xx
-400.0 -400.000
< 10-6

-2.0
% *yy*
-54.0613
-54.061292 <
10-6

-10.0
%
yy
-63.5278 -63.527785 < 10-6

-20.0
%
yy
-65.0989 -65.098864 < 10-6

-2.0
% *zz*
-82.1839 -82.18387
< 10-6

-10.0
%
zz
-110.583 -110.58335

< 10-6

-20.0
%
zz
-115.297 -115.29659
< 10-6

-2.0
%
yz
-24.3549 -24.354871 < 10-6

-10.0
%
yz
-40.7513 -40.751319 < 10-6

-20.0
%
yz
-43.4725 -43.472508 < 10-6

4.2 Parameters of execution

Version:
5.03.08

Machine;
SGI-ORIGIN2000-R12000
System:
IRIX64
Obstruction memory: 128 Mo
Time CPU To use:
83s

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V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

5
Summary of the results

The results are in perfect agreement with those of the reference.

Organization (S): EDF/AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.156

SSNV156 - Column under voluminal loading.
Elastoplastic law has gradient

Summary:

In addition to the elastoplastic law with gradient which it tests only in its version with linear work hardening, this test has especially for object to validate the algorithm of integration of the laws of behavior to gradient of internal variables. In effect, the problem suggested, the setting in traction of a column under voluminal forces, led to a solution nonhomogeneous which activates the various components of algorithm (Newton, linear research, BFGS) and for which one can obtain an analytical expression. The results obtained are in agreement with this one, and it with a high degree of accuracy.

1
Problem of reference

1.1 Geometry

The structure is a cylinder, with the direction more general, height L = 2 mm and of which the form of
section does not influence the solution. So one will adopt a square section for modelings
in plane deformations and 3D (side has =
mm

1
,
0
) as well as a circular section for
axisymmetric modeling (ray R =
mm

1
,
0
).

1.2
Properties of material

The material follows an elastoplastic law of behavior to gradient whose work hardening is isotropic and
linear. Characteristics of material, respectively the Young modulus E, the coefficient of
NAKED Poisson, elastic limit SY, the slope of work hardening D_SIGM_EPSI and the length
characteristic LONG_CARA, are equal to:

E = 100
MPa

000

= ,
0 3
y =
MPa

100

T
E = 10
MPa

000

L

B =

,
0 982707 mm

1.3
Boundary conditions and loading

Vertical displacements are blocked on its higher face, horizontal displacements are blocked on the side faces and the lower face is free of any kinematic condition. By elsewhere, the structure is subjected to a voluminal force vertical and directed to the bottom of intensity
increasing F T
() = F T where
3
F =
1 N/mm and T is a parameter of loading (without unit).
0
0

2
Reference solution

2.1
Method of calculation of the reference solution

This problem admits an analytical solution. Sought sizes, namely the constraints,
deformations, plastic deformations p
and cumulated plastic deformation p,
depend that level on loading T and dimension Z of the section considered, where Z = 0
indicate the lower face (free) cylinder and Z = L its face higher (blocked).
Because of the blocking of the side faces, the sections do not become deformed horizontally, so that
the fields of displacements and deformations are written:

U (Z, T) = U (Z, T) E
(Z, T)
Z
= (Z, T) ez E
with
U (L, T)
Z
= 0 éq 2.1-1

As for the tensor of constraints, it is diagonal. Its vertical component is fixed by the equation
of balance while its horizontal components, identical in the two directions, depend
law of behavior (effect of fastening):

(Z, T) = S (Z, T) (ex ex + ey ey) + (Z, T) ez E
with
Z
(Z, T) = Z F (T) éq
2.1-2

One can notice that the evolution of the diverter of the constraints is radial:

D
1
2

= eq - (ex ex + ey ey) + ez E
and
Z
= - S

eq

éq 2.1-3
3
3

Having proposed a field of displacements kinematically acceptable and a stress field statically acceptable, it any more but does not remain to show than they are bound by the law of behavior. Well
that it is about a nonlocal model, the law of flow preserves its usual form:

D
p
3

p
1
& = p&
= p - (E
E
E
E
E
E éq
2.1-4
X
X +

y
y)

+ Z Z
2 eq
2

The same applies to the relation stress-strain, where and μ is the coefficients of Lamé which result from the Young modulus and the Poisson's ratio:

= (tr) Id + μ
2 (
p
-) éq
2.1-5
While deferring [éq 2.1-1], [éq 2.1-2] and [éq 2.1-4] in [éq 2.1-5], one deduces the expression from it from
constraints and of the deformations according to the only cumulated plastic deformation:

1 E

2 2 Z F

S =

p + Z F
= 1-
+ 1-
p

éq 2.1-6
1 - 2

1 - E

1-

The condition of coherence then makes it possible to determine p. Insofar as the evolution of the diverter
constraints is radial and monotonous, one can directly determine the current state without having with
to integrate the rate of plastic deformation. Indeed, one can distinguish two zones in the structure:
one, 0 Z B, in which the plastic deformation is null and where the threshold of plasticity is not
reached, and the other, B Z L, where the plastic deformation is nonnull and the threshold reached. The border B
between these two zones is a new unknown factor of the problem. As follows:

0 Z B p = 0

éq
2.1-7
B Z L F = 0
According to [bib1], the threshold of plasticity has as an expression:
T
2
(
E E
H L

F p)
y
4
,
B
= eq - H p - + C p

where
H =
and
C =
éq
2.1-8
T
E - E
13
Moreover, always according to [bib1], the field of cumulated plastic deformation p is 1
C and of derivative
null at the edge of the structure. That implies in particular:

p (b) = 0
p (b) = 0
p (L) = 0
éq
2.1-9

Taking into account [éq 2.1-7] and [éq 2.1-8], p checks a linear differential equation of the second order on the field B Z L:

E

1- 2
y
C p (Z) +
+
( )
éq
2.1-10
2 (1 -) H p Z

=
Z F -

1-

The data of the 3 boundary conditions [éq 2.1-9] then makes it possible to determine p completely like the position B of the free border.
To reduce the expressions, the following notations are introduced:

E
C
4 H
1- 2
H = (
H
L
L
F
2 1-) +
C =
= B
=
H
13 H
H (1 -)

éq 2.1-11
y
Z - L
Z - L
(Z) = Z -
C (Z) = cosh
S (Z) =

sinh

H
L
L
C

C

Then, after some calculations, one obtains the following expression for p:

L
S (b)
B
( )
C
-
With =
p (Z) = (Z) + AC (Z) + BS (Z)
where
C (b)

éq 2.1-12

B = - Lc
As for the free border, it is given according to the level of loading by the equation following (or conversely, the level of loading corresponding to a certain position of free border):

y

S (b)
=
éq
2.1-13
H bS (b) + L
-
C (1
C (b))

2.2
Results of reference

One examines the cumulated plastic deformation p, the total deflection, the equivalent constraint and the horizontal constraint S at the point Z = L for various levels of loading which
eq
correspond to various positions of the free border.

B L
F (
3
N/mm)
p

(
S MPa)
eq (
MPa)
0, 75
104, 811 963
1, 165.975 E-4 1, 623.833 E-3 111, 456 702
98, 167 224
0, 50
146, 159 407
6, 125.415 E-4 2, 521.534 E-3 123, 286 355
169,032 459
0, 25
250, 078 993
1, 905.213 E-3 4, 804.152 E-3 149, 717 896
350, 440 090
0, 00
875, 079 453
9, 693.407 E-3 1, 854.027 E-2 307, 704.531 1.442, 454 356

2.3

Uncertainties on the solution

It is about an analytical solution.

*2.4 References
bibliographical*

*[1]
Lorentz E., Andrieux S.: With variational formulation for nonlocal ramming models. Int. J. Plas., 15, pp. 119-138 (1999)
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A*

---

*3 Modeling
With*

*3.1
Characteristics of modeling*

*It is about a modeling 3D. The section of the cylinder is square. Linear work hardening is characterized
initially by a curve of work hardening (VMIS_ISOT_TRAC) then by its limit
of elasticity and its module (VMIS_ISOT_LINE), which makes it possible to test the two establishments.*

3.2
Characteristics of the grid

The grid is carried out by GMSH. The meshs are of smaller size in the zone where one examines the results (higher face). On the whole, 1749 TETRA10 are counted.

3.3 Functionalities
tested

Orders

DEFI_MATERIAU
NON_LOCAL
LONG_CARA
AFFE_MODELE
AFFE
MODELING = "3D_GRADIENT"
STAT_NON_LINE
LAGR_NON_LOCAL

4
Results of modeling A

4.1 Values
tested

The various values are tested with the dimension Z = L, as presented to [§2.2]. It is about cumulated plastic deformation (component "V1" of CHAM_NO "VARI_NOEU_ELGA" and component
"VANL" of CHAM_NO "DEPL"), vertical deformation (component "EPZZ" of the CHAM_NO "EPSI_NOEU_DEPL"), of the constraint of von Mises (component "VMIS" of the CHAM_NO "EQUI_NOEU_SIGM") and finally of horizontal constraint (component "SIXX" of the CHAM_NO "SIEF_NOEU_DEPL"). For recall, the analytical values are as follows.

F (
3
N/mm)
p

(

S MPa)
eq (
MPa)
104, 811 963
1, 165.975 E-4
1, 623.833 E-3
111, 456 702
98, 167 224
146, 159 407
6, 125.415 E-4
2, 521.534 E-3
123, 286 355
169,032 459
250, 078 993
1, 905.213 E-3
4, 804.152 E-3
149, 717 896
350, 440 090
875, 079 453
9, 693.407 E-3
1, 854.027 E-2
307, 704 531
1 442, 454 356

The results obtained differ extremely little from the analytical solution (lower relative difference with the precision owing to lack of 0, 1%).

---

5 Modeling B

5.1 Characteristics of modeling

It is about a modeling 3D. The section of the cylinder is square. Linear work hardening is characterized initially by a curve of work hardening (VMIS_ISOT_TRAC) then by its limit of elasticity and its module (VMIS_ISOT_LINE), which makes it possible to test the two establishments.

5.2 Characteristics of the grid

The grid is carried out by GMSH. The meshs are of smaller size in the zone where one examines the results (higher face). On the whole, 169 TRIA6 are counted.

5.3 Functionalities tested

Orders

DEFI_MATERIAU
NON_LOCAL
LONG_CARA
AFFE_MODELE
AFFE
MODELING = "D_PLAN_GRADIENT"
STAT_NON_LINE
LAGR_NON_LOCAL

6 Results of modeling B

6.1 Values tested

The various values are tested with the dimension Z = L, as presented to [§2.2]. It is about cumulated plastic deformation (component "V1" of CHAM_NO "VARI_NOEU_ELGA" and component "VANL" of CHAM_NO "DEPL"), vertical deformation (component "EPYY" of the CHAM_NO "EPSI_NOEU_DEPL"), of the constraint of von Mises (component "VMIS" of the CHAM_NO "EQUI_NOEU_SIGM") and finally of horizontal constraint (component "SIXX" of the CHAM_NO "SIEF_NOEU_DEPL"). For recall, the analytical values are as follows.

F (
3
N/mm)
p

(
S MPa)
eq (
MPa)
104, 811 963
1, 165.975 E-4
1, 623.833 E-3
111, 456 702
98, 167 224
146, 159 407
6, 125.415 E-4
2, 521.534 E-3
123, 286 355
169,032 459
250, 078 993
1, 905.213 E-3
4, 804.152 E-3
149, 717 896
350, 440 090
875, 079 453
9, 693.407 E-3
1, 854.027 E-2
307, 704 531
1 442, 454 356

The results obtained differ extremely little from the analytical solution (lower relative difference with the precision owing to lack of 0, 1%).

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---

7 Modeling C

7.1 Characteristics of modeling

It is about an axisymmetric modeling 2D. The section of the cylinder is necessarily circular. Linear work hardening is characterized initially by a curve of work hardening (VMIS_ISOT_TRAC) then by its elastic limit and its module (VMIS_ISOT_LINE), which allows to test the two establishments.

7.2 Characteristics of the grid

The grid is carried out by GMSH. With the difference in two preceding modelings, it is about one regulated grid. The meshs are smaller sizes in the zone where one examines the results (face higher). On the whole, 50 QUAD8 are counted.

7.3 Functionalities tested

Orders

DEFI_MATERIAU
NON_LOCAL
LONG_CARA
AFFE_MODELE

AFFE
MODELING = “AXIS_GRADIENT”
STAT_NON_LINE
LAGR_NON_LOCAL

8
Results of modeling C

8.1 Values
tested

The various values are tested with the dimension Z = L, as presented to [§2.2]. It is about cumulated plastic deformation (component “V1” of CHAM_NO “VARI_NOEU_ELGA” and component “VANL” of CHAM_NO “DEPL”), vertical deformation (component “EPYY” of the CHAM_NO “EPSI_NOEU_DEPL”), of the constraint of von Mises (component “VMIS” of the CHAM_NO “EQUI_NOEU_SIGM”) and finally of horizontal constraint (component “SIXX” of the CHAM_NO “SIEF_NOEU_DEPL”). For recall, the analytical values are as follows.

F (
3
N/mm)
p

(
S MPa)
eq (
MPa)
104, 811 963
1, 165.975 E-4
1, 623.833 E-3
111, 456 702
98, 167 224
146, 159 407
6, 125.415 E-4
2, 521.534 E-3
123, 286 355
169,032 459
250, 078 993
1, 905.213 E-3
4, 804.152 E-3
149, 717 896

350, 440 090
875, 079 453
9, 693.407 E-3
1, 854.027 E-2
307, 704 531
1 442, 454 356

The results obtained differ extremely little from the analytical solution (lower relative difference with the precision owing to lack of 0, 1%).

9 Summary of the results

Because of the positive character of work hardening, the problem exhibe not of instabilities, which confirms good convergence of calculations. The validation relates thus to the law of behavior itself and on the algorithm of integration of the nonlocal laws, from which the various components are activated (primal and dual iterations observed). The remarkable agreement enters the values of reference and those calculated shows the capacities of the algorithm when a fine precision is necessary (criteria of convergence severe) while the size of the dealt with problems, particularly in 3D, seems to prove its robustness.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.157

SSNV157 - Test of the method of delocalization by regularization of the deformation on a bar of variable section in traction

Summary:

One presents several tests of uniaxial traction on a variable bar of section for 3 laws of behaviors (ENDO_FRAGILE, ENDO_ISOT_BETON and MAZARS), in the case of the nonlocal model by regularization of the deformation.

1
Problem of reference

1.1
Geometry and boundary conditions

One considers a bar with variable section length 100m, thickness 1m, greater section 10m and of smaller section 1m.

Appear 1.1-a: Geometry and boundary conditions of the uniaxial tests

1.2
Properties of materials

Elastic behavior:

E = 100000 MPa; = 1
.
0

Length characteristic of the delocalization: 3m

NON_LOCAL: LONG_CARA = 0
.
3

2
Reference solution

This test is a test of nonregression.

3 Modeling With

3.1 Parameters of the model/Characteristic of material

ECRO_LINE: SY=3.0
D_SIGM_EPSI=-2000

3.2 Characteristics of modeling

Modeling 3D_GRAD_EPSI

Element MGCA_TETRA10

3.3 Characteristics of the grid

A number of nodes:
507
A number of meshs and types: 54 TRIA6
174 TETRA10

3.4
Functionalities tested

The law of behavior ENDO_FRAGILE
Type of piloting: PRED_ELAS

4
Results of modeling A

4.1
Values tested

Moment
Name of the field
Component
Place
Aster
24
DEPL
DX N2
6.66251E03
24
VARI_ELGA
V1
M169, point 2
9.89289E01

---

5 Modeling B

5.1 Parameters of the model/Characteristic of material

ECRO_LINE: SY=3.0
D_SIGM_EPSI=-2000

5.2 Characteristics of modeling

Modeling C_PLAN_GRAD_EPSI

Element MGCA_TRIA6

5.3 Characteristics of the grid

A number of nodes:
153
A number of meshs and types: 27 SEG3
50 TRIA6

5.4 Functionalities tested

The law of behavior ENDO_FRAGILE
Type of piloting: PRED_ELAS

6 Results of modeling B

6.1 Values tested

Moment
Name of the field
Component
Place
Aster
31
DEPL
DX N2
9.22566E03
31
VARI_ELGA
V1
M31, point 2
9.97526E01

---

7 Modeling
C

7.1
Parameters of the model/Characteristic of material

ECRO_LINE: SY=3.0

D_SIGM_EPSI=-2000

7.2
Characteristics of modeling

Modeling D_PLAN_GRAD_EPSI

Element MGCA_TRIA6

7.3
Characteristics of the grid

A number of nodes:
153
A number of meshs and types: 27 SEG3
50 TRIA6

7.4
Functionalities tested

The law of behavior ENDO_FRAGILE
Type of piloting: PRED_ELAS

8
Results of modeling C

8.1
Values tested

Moment
Name of the field
Component
Place
Aster
31
DEPL
DX N2
9.18672E03
31
VARI_ELGA
V1

M31, point 2
9.97544E01

---

9 Modeling D

9.1 Parameters of the model/Characteristic of material

ECRO_LINE: SY=3.0
D_SIGM_EPSI=-2000

9.2 Characteristics of modeling

Modeling 3D_GRAD_EPSI

Element MGCA_TETRA10

9.3 Characteristics of the grid

A number of nodes:
507
A number of meshs and types: 54 TRIA6
174 TETRA10

9.4
Functionalities tested

The law of behavior ENDO_ISOT_BETON
Type of piloting: PRED_ELAS

10 Results of modeling D

10.1 Values tested

Moment
Name of the field
Component
Place
Aster
37
DEPL
DX N2
6.56702E03
37
VARI_ELGA
V1
M169, point 2
9.40876E01

---

11 Modeling E

11.1 Parameters of the model/Characteristic of material

MAZARS: BETA = 1.0
EPSD0
=
9.375E-05
AC
=
1.15
AT
=
0.8
BC
=
1391.3
BT
=
10000.

11.2 Characteristics of modeling

Modeling 3D_GRAD_EPSI

Element MGCA_TETRA10

11.3 Characteristics of the grid

A number of nodes:
507

A number of meshs and types: 54 TRIA6
174 TETRA10

11.4 Functionalities tested

The law of behavior MAZARS
Type of piloting: DEFORMATION

12 Results of modeling E

12.1 Values tested

Moment	Name of the field	Component	Place	Aster
17	***DEPL***	***DX N2***		***3.13925E03***
17	***VARI_ELGA***	***V1***	***M169, point 2***	***4.29571E01***

---

13 Modeling F

13.1 Parameters of the model/Characteristic of material

MAZARS: BETA = 1.0
EPSD0
=
9.375E-05
AC
=
1.15
AT
=
0.8
BC
=
1391.3
BT
=
10000.

13.2 Characteristics of modeling

Modeling C_PLAN_GRAD_EPSI

Element MGCA_TRIA6

13.3 Characteristics of the grid

A number of nodes:
153
A number of meshs and types: 27 SEG3
50 TRIA6

13.4 Functionalities tested

The law of behavior MAZARS
Type of piloting: DEFORMATION

14 Results of modeling F

14.1 Values tested

Moment
Name of the field
Component
Place
Aster
51
DEPL
DX N2
2.67284E03
51
VARI_ELGA
V1
M31, point 2
9.34245E01

9/10

15 Modeling G

15.1 Parameters of the model/Characteristic of material

MAZARS: BETA = 1.0
EPSD0
=
9.375E-05
AC
=
1.15
AT
=
0.8
BC
=
1391.3
BT
=
10000.

15.2 Characteristics of modeling

Modeling D_PLAN_GRAD_EPSI

Element MGCA_TRIA6

15.3 Characteristics of the grid

A number of nodes:
153
A number of meshs and types: 27 SEG3
50 TRIA6

15.4 Functionalities tested

The law of behavior MAZARS

Type of piloting: DEFORMATION

16 Results of modeling G

16.1 Values tested

Moment
Name of the field
Component
Place
Aster
51
DEPL
DX N2
2.71156E03
51
VARI_ELGA
V1
M31, point 2
9.10946E01
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V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

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Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.158

SSNV158 - Triaxial compression test drained with the model of Laigle

Summary

This test makes it possible to validate the model of Laigle in rock mechanics (formalism CIH). It is about a test
triaxial in drained condition. Calculations are carried out only on the solid part of the ground without coupling
hydromechanics. Four levels of containment are applied (8 MPa 4 MPa 2 MPa 1 MPa). By reason
of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test. Modeling is
axisymmetric.

It is about a test of nonregression. Nevertheless, the results obtained with Code_Aster were post-treaties
with Excel and compared with those obtained with a private version of software FLAC-2D.

1
Problem of reference

1.1 Geometry

Z
E
height:
H = 1 m
width:
L
= 1 m

thickness:
E = 1 m
C
H
With
B
y
X
L

Co-ordinates of the points (in meters):

With
B
C
D
X 0. 0.
0.5 1.
y 0. 1.
0.5 1.
Z 0. 0.
0.5
0.

1.2
Material property

E = 1500,00 103 kPa
= 0,27

=
;
132
.
0
ult
=
;
005
.
0
E

m =
;
0
.
2
ult
m =
;
0
.
7
E
has =
;
65
.
0
E
m
=
;
0
.
15
peak
has =
;
5
.
0

peak
=
;
45
.
0
=
;
25
.
0
=

;
7
.
0
cjs
=
10

09
.
9
6
;
Pa
1
p
=
10

05
.
23
6
;
Pa
p2

1.3
Initial conditions, boundary conditions, and loading

Phase 1:
One brings the sample in a homogeneous state: 0 = 0 = 0
xx
yy
zz, by imposing the pressure of
containment corresponding on the front, side right-hand side and higher faces. Displacements are blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0), as well as the confining pressure on the front faces and side right-hand side. One apply a displacement imposed to the higher face: U (T)
Z
, in order to obtain a deformation
=
%
20
-
(counted starting from the beginning of phase 2).
zz

2
Reference solution

2.1
Results of reference

Constraints xx, yy and zz at point D.
Displacements, at point D.
xx
yy

Version
6.5

Titrate:
SSNV158 - Triaxial compression test drained with the model of Laigle

Date:
05/10/04
Author (S):
C. CHAVANT, R. FERNANDES Key
:
V6.04.158-A Page:
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References provided by software FLAC-2D:

Q-eps1 curves
25,00
20,00
FLAC 1 MPa
15,00
FLAC 2 MPa
FLAC 4 MPa
ator (MPa)
FLAC 8 MPa
10,00
dévi
HB-CJS
5,00
0,00
0,00
2,00
4,00
6,00
8,00
10,00
12,00
14,00
16,00
18,00
20,00
eps1

eps1-epsv
2,00
1,50
1,00
1Mpa
2Mpa
0,50
4Mpa
epsv
8Mpa
HB-CJS
0,00
0,00
5,00
10,00
15,00
20,00
25,00
-0,50
-1,00
eps1

---

3 Modeling
With

3.1
Characteristic of modeling

2D:
y
Z
X

Cutting: 1 in height, 1 in width.

Loading of phase 1:
Confining pressure: 0
0
= = 8 MPa.
xx
zz

3.2
Characteristic of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

3.3 Functionalities
tested

Orders

DEFI_MATERIAU LAIGLE

STAT_NON_LINE COMP_INCR
RELATION
"LAIGLE"

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V6.04 booklet: Nonlinear statics of the voluminal structures

4
Results of modeling A

4.1 Values tested

For 0
0
= = 8 MPa
xx
zz

Localization
Sequence number
Constraint (MPa)
Aster
Not D
5
xx
- 8.000

49
xx
- 8.000

5
zz

- 8.000

49
zz
- 8.000

5
yy
- 31.5966

10
yy
- 31.1055

16
yy
- 29.9622

25
yy
- 26.3670

30
yy
- 24.3922

40
yy
- 24.0000

49
yy
- 24.0000

Localization Number
of order
Deformation
Aster
**** E-02***
Not D
1
xx
0.324
10

xx
0.692805

40
xx
7.140
1
yy
- 1.200

5
yy
- 1.580
10
yy
- 2.053
25
yy
- 8.000
48
yy
- 19.04

---

5 Modeling

B

5.1
Characteristic of modeling

2D:
y
Z
X

Cutting: 1 in height, 1 in width.

Loading of phase 1:
Confining pressure: 0
0
= = 4 MPa.
xx
zz

5.2
Characteristic of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

5.3 Functionalities
tested

Orders

DEFI_MATERIAU LAIGLE

STAT_NON_LINE COMP_INCR
RELATION
“LAIGLE”

6
Results of modeling B

6.1 Values
tested

For 0
0
= = 4MPa
xx
zz

Localization
Sequence number
Constraint (MPa)
Aster
Not D
5
xx
- 4.000
49
xx
- 4.000

5
zz
- 4.000
49

zz
- 4.000

5
yy
- 19.6729
10
yy
- 17.9207
16
yy
- 16.9627
25
yy
- 14.1850
30
yy
- 12.4257
40
yy
- 12.0000
49
yy
- 12.0000

Localization Number
of order
Deformation
Aster
**** E-02***
Not D
1
xx
0.216
10
xx
0.757

40
xx
7.195
1
yy

- 0.800

5
yy
- 1.240
10
yy
- 1.789
25
yy
- 7.000
48
yy
- 16.000

---

7 Modeling
C

7.1
Characteristic of modeling

2D:
y
Z
X

Cutting: 1 in height, 1 in width.

Loading of phase 1:
Confining pressure: 0
0
= = 2 MPa.
xx
zz

7.2
Characteristic of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

7.3 Functionalities
tested

Orders

DEFI_MATERIAU LAIGLE

STAT_NON_LINE COMP_INCR
RELATION
"LAIGLE"

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/04/005/A

---

8 Results of modeling C

8.1 Values tested

For 0
0
= = 2 MPa
xx
zz

Localization	Sequence number	Constraint (MPa)	Aster
Not D	5	xx	- 2.000
	5	zz	- 2.000
	5	yy	- 10.7188
	10		

yy
- 9.7927
16
yy
- 9.1268
25
yy
- 6.2033
30
yy
- 6.0968
40
yy
- 5.9965
49
yy
- 5.9942

Localization Number
of order
Deformation
Aster
**** E-02***
Not D
1
xx
0.216
10
xx
1.151

40
xx
8.048
1
yy
- 0.800

5
yy
- 1.387
10
yy

- 2.120
25
yy
- 12.000
48
yy
- 15.500

---

9 Modeling
D

9.1
Characteristic of modeling

2D:
y
Z
X

Cutting: 1 in height, 1 in width.

Loading of phase 1:
Confining pressure: 0
0
= = 1 MPa.

xx
zz

9.2
Characteristic of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4 and 4 SEG2

9.3 Functionalities
tested

Orders

DEFI_MATERIAU LAIGLE

STAT_NON_LINE COMP_INCR
RELATION
"LAIGLE"

---

10 Results of modeling D

10.1 Values
tested

For 0
0
= = 1MPa
xx
zz

Localization
Sequence number
Constraint (MPa)
Aster
Not D
296
xx
- 1.000
596
xx
- 1.000

296
zz
- 1.000
596
zz
- 1.000

196
yy
- 4.7247
296
yy
- 4.1666
312
yy
- 4.0928
496
yy
- 3.4030
596

yy
- 3.1056

Localization Number
of order
Deformation
Aster
**** E-02***
Not D
196
xx
2.4608
396
xx
4.7711

596
xx
6.8830
196
yy
- 3.9200

296
yy
- 5.9200
396
yy
- 7.9200
496
yy
- 9.9200
596
yy
- 11.9200

6.4

Titrate:
SSNV160 - Hydrostatic test with law CAM_CLAY

Date:
02/06/03
Author (S):
***J. EL GHARIB**, G. DEBRUYNE Key*
:
V6.04.160-B Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.160

SSNV160 - Hydrostatic test with the law
CAM_CLAY

Summary:

This test makes it possible to validate the mechanical law elastoplastic Cam_Clay specific to the

grounds normally
consolidated the elastic part is non-linear and the plastic part is hardening or lenitive. It
test is a hydrostatic test of compression. These results are compared with an analytical solution for
two modelings 3D and axisymmetric. Modelings has and B which called upon linear research
are reabsorbed, this is why only modelings C and D are written.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

height: H = 1m
width: L = 1 m
thickness: E = 1 m

1.2
Properties of material

E = 4.2E7 Pa
= 0.285

= .
0
Parameters specific to CAM_CLAY:

PORO = 0.14, = 0.25, = 0.05, M = 0.9, CLOSE _ CRIT =.
3 E5 Pa, Pa = 1.E5 Pa

1.3
Boundary conditions and loadings

The hydrostatic test is carried out with a state of homogeneous stresses:
= = = P. One
xx
yy
zz
fact a first elastic design to P = Pa. One increases then P to P while carrying out
sup
a loading with Cam_Clay followed by a discharge to Pa.

1.4 Conditions
initial

In CAM_CLAY, the elastic law requires a hydrostatic constraint in an initial state (the deformation being
null).

To initialize this constraint, one chose to carry out at the beginning a purely elastic calculation in making evolve/move pressure of 0. with 1.E5 Pa. One extracts from this calculation only the field of constraints at the points of gauss. This stress field resulting from the elastic design is considered like the initial state of the hydrostatic constraint necessary to the law Cam_Clay of following calculation.

2
Reference solution

2.1
Method of calculation

tr ()
In a hydrostatic test:
= = and the hydrostatic constraint is P = -

xx
yy
zz
3
(convention of the soil mechanics).

For the calculation of the total voluminal deformation, one distinguishes the two cases:

***1st case**: Case of non-linear elasticity, the hydrostatic pressure is lower than the pressure of consolidation:*

P < P < 2P

0 = P
atm
Cr
ion
consolidat
1
P
P = P exp (
E
K) or E
=
Ln

atm
0 v
v

K
P
0
atm

in this case the total deflection is equal to the elastic strain:
E
=
v
v

***2nd case**: Case of plasticity, the hydrostatic pressure exceeded the pressure of consolidation, there is thus hardening:*

P > 2P = P
, P = 2P after plasticization.
Cr
ion
consolidat
Cr

and the critical pressure evolves/moves as follows

P = P exp (p
K)
Cr
cr0
v
P
p
1
1
P
and voluminal deformation:
Cr
= Ln
= Ln

v
K
P
K
2P
cr0

cr0

In this case, it is necessary to take into account the plastic deformation in the calculation of the total deflection
E
p
1
P
1
P
: = + =
Ln
+ Ln

v
v
v
K
P
K
2P
0
atm
cr0

2.2 Sizes and results of reference

The test is homogeneous. One tests the voluminal deformation in an unspecified node where components are equal: =
=
xx
yy
zz

2.3 Uncertainties on the solution

None. Exact analytical result.

2.4 Reference bibliographical

[1]

---

3 Modeling C

3.1 Characteristics of modeling

Modeling 3D
Z
NO7
NO5
NO8
NO6
NO1
NO3
y
NO4
NO2
X

3.2 Characteristics of the grid

A number of nodes:

8
A number of meshs:
1 of type HEXA 8

6 of type QUAD 4

The following meshs are defined:

BACK
NO1 NO3 NO7 NO5
FRONT
NO2 NO6 NO8 NO4
RIGHT-HAND SIDE
NO1 NO5 NO6 NO2
LEFT
NO3 NO4 NO8 NO7
LOW
NO1 NO2 NO4 NO3
HIGH
NO5 NO7 NO8 NO6

To represent the 1/8ème structure, the boundary conditions in displacement imposed are:

On nodes NO1, NO2, NO4 and NO3: DZ = 0
On nodes NO3, NO4, NO8 and NO7: DY = 0
On nodes NO2, NO6, NO8 and NO4: DX = 0

The loading is consisted of the same pressure divided into compression on the 3 meshs: `HIGH, "RIGHT" and "BACK" to simulate a hydrostatic test.

3.3 Functionalities tested

Orders

DEFI_MATERIAU CAM_CLAY

STAT_NON_LINE COMP_INCR
RELATION= `CAM_CLAY'
NEWTON
STAMP = TANGENT

REAC_ITER

3.4 Sizes tested and results

The component with node NO6 was tested, in this case =
=
xx
xx
yy
zz

Moment	***Reference***	***Aster***	***Difference (%)***
5000.	*-2.30686 -02*	*-2.3068616551409 -02*	*7.17-05*
6000.	*-2.56819 -02*	*-2.5681930900741 -02*	*1.20-04*

6500.
-3.14183 -02
-3.1418280283251 -02
-6.28-05
7000.
-3.67294 -02
-3.6729351192775 -02
-1.33-04
7500.
-4.16738 -02
-4.1673840301798 -02
9.67-05
8000.
-4.62991 -02
-4.6299103361551 -02
7.26-06
9000.
-4.21757 -02
-4.2175660318354 -02
-9.41-05
10000.
-1.64938 -02
-1.6493780906496 -02
-1.16-04

---

4 Modeling
D

4.1 Characteristics of modeling

Axisymmetric modeling

y
N4
N7
N3
D
C
N8
N6
With
B
N1
N5
N2
X

4.2 Characteristics of the grid

A number of nodes:
8
A number of meshs:
1 of type QUAD 8

4 of type SEG3

The following meshs are defined: AB, BC, CD and DA
To represent ¼ structure, one puts the boundary conditions following:
On AB: DY = 0
On AD: DX = 0
One imposes an equal pressure on the meshs BC and CD to simulate a hydrostatic test.

4.3 Functionalities tested

Orders

Key word

DEFI_MATERIAU CAM_CLAY

STAT_NON_LINE COMP_INCR
RELATION= `CAM_CLAY'
NEWTON
STAMP = TANGENT

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

4.4
Sizes tested and results

The component with the node a.c. tested, in this case =
=
xx
xx
yy
zz

Moment Reference
Aster
Difference
(%)

5000.
-2.30686 -02
-2.3068616551409 -02
7.17-05
6000.
-2.56819 -02
-2.5681930900741 -02
1.20-04
6500.
-3.14183 -02
-3.1418280283251 -02
-6.28-05
7000.
-3.67294 -02
-3.6729351192775 -02
-1.33-04
7500.
-4.16738 -02
-4.1673840301798 -02
9.67-05
8000.
-4.62991 -02
-4.6299103361551 -02
7.26-06
9000.
-4.21757 -02
-4.2175660318354 -02
-9.41-05
10000.
-1.64938 -02
-1.6493780906496 -02
-1.16-04

5
Summary of the results

The values obtained with Code_Aster are in agreement with the values of the analytical solution of reference.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
Document: V6.04.162

SSNV162 - Calculation of creep of dessication
intrinsic with the model of Bazant

Summary:

This test makes it possible to validate the model of intrinsic creep of dessication of Bazant. This type of creep
start under the effect of the drying accompanied by a mechanical loading. The results of this test are compared with the analytical solution for two plane forced modelings and 3D.

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

height: H = 1m
width: L = 1 m
thickness: E = 1 m

1.2
Properties of material

E = 36400E6 Pa
= 0.248

Here one informs also the curve sorption-desorption which connects the water content C to the hygroscopy h.
In this case one supposed that the numerical values of C and H are the same ones.

Parameters specific to the intrinsic creep of dessication:
= 1.875E -11
1
-
Pa

1.3
Boundary conditions and loadings

In this test, one creates a homogeneous field of drying in the structure which varies with time.
At initial time 0s, the hygroscopy is worth 1 or 100% and at the final moment 10 days = 864000s is worth 0.75 or
75%.
Concerning the mechanical loading, one charges in compression of 0 à10 MPa in 1s
according to X on the right facet (called BEFORE in the file of grid), and one it maintains

constant loading during 10 days.

1.4 Conditions
initial

The beginning of calculation is supposed moment 1. At this moment there is neither field of drying, nor forced
mechanics.
At moment 0, one applies a field of drying corresponding to 100% of hygroscopy.

2
Reference solution

2.1
Method of calculation

The equation of the model is:
fl
&
= &
dess
H

The integration of this equation between moments 0 and T gives:

fl

-
=
-

dess (T)
fldess (0) (H (T) H (0)

is a fact of the case. The loading is maintained constant, therefore is constant with all moments. (0) is null and H (0) is worth 1. One can deduce fl

at every moment of calculation.
dess (T)

The elastic component of the field of deformation remains constant during all calculation:

E
(T) =
E
and the total deflection is:

E
fl
= +
dess

2.2
Sizes and results of reference

The test is homogeneous. One tests the deformation in an unspecified node.

2.3
Uncertainties on the solution

Exact analytical result.

2.4 References
bibliographical

[1]
L. GRANGER: Behavior differed from the concrete in the enclosures of nuclear thermal power stations:
analyze and modeling. Thesis of doctorate of the ENPC (1995).
[2]
F. BENBOUDJEMA, F. MEFTAH, J.M. TORRENTI, Y. LE-PAPE: Algorithm of the model of

clean creep and of dessication. UMLV coupled to an elastic model. Note HS-DG/02/?. EDF (to be appeared)
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling forced plane.

y
N7
N6
N5
D
C
N8
N4
With
B
N1
N2
N3
X

The boundary conditions and the loading are modelled by:

FACE_IMPO and PRES_REP respectively.

One imposes a field of initial drying and a field of final drying which are homogeneous. passage of the field of drying to the hygroscopy is done with the curve sorption-desorption (given user).

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs: 1 of type QUAD 8

4 of type SEG3
The following meshs are defined: AB, BC, CD and DA
To represent ¼ structure, one puts the boundary conditions following:
On AB: DY = 0
On AD: DX = 0

3.3 Functionalities
tested

Orders
Key word

DEFI_MATERIAU ELAS_FO
FONC_DESORP

BAZANT_FD
LAM_VISC
CREA_CHAMP "AFFE"
NOM_CMP=' TEMP'

"TEMP_INF"

"TEMP_SUP"

TYPE_CHAM=' NOEU_TEMP_R'

CREA_RESU AFFE
CHAM_GD

TYPE_RESU=' EVOL_THER'
AFFE_CHAR_MECA FACE_IMPO

PRES_REP
SECH_CALCULEE
STAT_NON_LINE COMP_INCR
RELATION= `BAZANT_FD'

3.4
Sizes tested and results

The component with the N4 node was tested
xx

Moment Reference Aster %
difference
0. 0.
0.
-
1.
2.74725 E4

2.747253018 E4
1.E4
10.7999875 E+4
2.80584 E4
2.8058467007 E4
2.39 E4
53.9999375 E+4
3.04022 E4
3.0402214294 E4
4.70 E5
86400. E+4
3.12600 E4
3.2160024759 E4
7.70 E5

---

4 Modeling B

4.1 Characteristics of modeling

Modeling 3D
Z
NO7

NO5
NO8
NO6
NO1
NO3
y
NO4
NO2
X

4.2
Characteristics of the grid

A number of nodes: 8
A number of meshs: 1 of type HEXA 8

6 of type QUAD 4

The following meshs are defined:

BACK NO1 NO3 NO7 NO5
FRONT
NO2 NO6 NO8 NO4
RIGHT-HAND SIDE
NO1 NO5 NO6 NO2
LEFT NO3 NO4 NO8 NO7
LOW
NO1 NO2 NO4 NO3
HIGH
NO5 NO7 NO8 NO6

To represent the 1/8ème structure, the boundary conditions in displacement imposed are:

On nodes NO1, NO2, NO4 and NO3: DZ = 0
On nodes NO3, NO4, NO8 and NO7: DY = 0
On nodes NO1, NO3, NO5 and NO7: DX = 0

The loading is consisted of the same field of drying and the same pressure divided into compression on the "FRONT" mesh.

4.3 Functionalities
tested

Moment Reference Aster %
difference
0. 0. 0.
-
1.
2.74725 E4
2.747253018 E4
1.E4
10.7999875 E+4
2.80584 E4
2.8058467007 E4
2.39 E4
53.9999375 E+4
3.04022 E4
3.0402214294 E4
4.70 E5
86400. E+4
3.12600 E4
3.2160024759 E4
7.70 E5

4.4
Sizes tested and results

The component with node NO6 was tested.
xx

Moment Reference Aster %
difference
0. 0. 0.
-
1.
2.74725 E4
2.747253018 E4
1.E4
10.7999875 E+4
2.80584 E4
2.8058467007 E4
2.39 E4
53.9999375 E+4
3.04022 E4
3.0402214294 E4
4.70 E5
86400. E+4
3.12600 E4
3.2160024759 E4
7.70 E5

5
Summary of the results

The values obtained with Code_Aster are in agreement with the values of the analytical solution of reference. This same test was turned with Castem at laboratory LGCU with the University of the Marne
Valley the same results were obtained.

SSNV163 - Clean calculation of creep with model UMLV

Summary:

This test makes it possible to validate the clean model of creep UMLV. The results of this test are compared with analytical solution for three modelings: 3D, axisymmetric and plane constraints.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-26/03/023/A

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

height:
H = 1,00 [m]
width:
L = 1,00 [m]
thickness:
E = 1,00 [m]

1.2
Properties of material

E = 31 GPa
= ,
0 2

Here one informs also the curve sorption-desorption which connects the water content C to the hygroscopy h.
In this case one supposed that the numerical values of C and H are the same ones.

Parameters specific to clean creep:

K Sr =,
2 0E + 5 [MPa]
spherical part: rigidity connects associated with the formed skeleton
by blocks of hydrates on a mesoscopic scale

K if = 0
,
5th + 4 [MPa]
spherical part: rigidity connects intrinsically associated
with the hydrates on a microscopic scale

K Dr. =,
5 0E + 4 [MPa]
deviatoric part: rigidity associated with the capacity with water
adsorbed to transmit loads (load bearing toilets)
S

R =,
4 0E +10 [MPa.s]
spherical part: viscosity connects associated with the mechanism
of diffusion within capillary porosity
S

I = 0
,
1 E +11 [MPa.s]
spherical part: viscosity connects associated with the mechanism
of diffusion interlamellaire
D

R =,
1 0E +10 [MPa.s]
deviatoric part: viscosity associated with the water adsorbed by
layers of hydrates
D

I = 0
,

1 E +11 [MPa.s]
deviatoric part: viscosity of interstitial water.

1.3
Boundary conditions and loadings

In this test, one creates a homogeneous field of drying invariant in the structure, moisture is worth 100% (condition of a sealed test-tube). The mechanical loading corresponds to a compression one-way according to the vertical direction (Z in 3D or there of 2D); its intensity is 1 [MPa]. load is applied in 1s and is maintained constant for 100 days.

1.4 Conditions
initial

The beginning of calculation is supposed moment 1. At this moment there is neither field of drying, nor forced
mechanics.
At moment 0, one applies a field of drying corresponding to 100% of hygroscopy.

2
Reference solution

2.1
Method of calculation

This section presents the analytical resolution supplements problem of a body of test subjected to a homogeneous and one-way stress field applied instantaneously to the initial moment and maintained constant thereafter (case of a creep test in simple compression):

= E
0 Z E Z

éq 2.1-1

Whose partly spherical and deviatoric decomposition is written:

= 1
2
1
01 + E
0

Z ez -
0 (ex ex + E y E y)
éq
2.1-2

3 3
2
1
1
3
4
4
4
4
4
4
4
3 2
4
4
4
4
4
4
4
3
part
die

part
viatoric
spherical

By operating a spherical/deviatoric decomposition identical to that of the constraints, axial deformation is written in the form:
= fs
zz
(
fd
0
) 3+ (20) 3
éq
2.1-3

It is thus necessary successively to solve the response to a level of spherical constraint and one level of deviatoric constraints.

2.2
Resolution of the equations constitutive of spherical creep [bib2]

The process of deformation spherical of creep is controlled by the system of coupled equations according to (equations [éq 2.2-1] and [éq 2.2-2], cf [R7.01.06]):

fs
& = 1 H - K -
éq
2.2-1
S [
S
S
fs
R
R]
fs
I
&
R
where S
Kr indicates rigidity connect associated with the skeleton formed by blocks with hydrates on the scale mesoscopic;
and S
R viscosity connect associated with the mechanism with diffusion within capillary porosity.

fs

1
I
& =
K
K
K

H
K

éq
2.2-1
S [Sr
fs - (Sr + if) fsi] - [S - S fs
R
R] +

I

where
S
ki indicates rigidity connect intrinsically associated with the hydrates on the scale
microscopic;
and S
I viscosity connects associated with the interfoliaceous mechanism of diffusion.
+
+
1
In [éq 2.2-2], hooks
appoint the operator of Mac Cauley: X
= (X + X)
2
The resolution of the preceding system of coupled equations requires to distinguish two cases according
to
sign quantity ranging between the hooks of Mac Cauley. In the continuation, one presents
analytical resolution of the response to a level of constraint
S
. The relative humidity is supposed
invariant; the medium is saturated with water.

2.2.1 Case of short-term creep

At the initial moment, T = 0, one applies a spherical constraint S
positive. Deformations of creep

reversible and irreversible are equal to zero (initial conditions). The equation of the system [éq 2.2-2] is thus written:

fs
&

I (
+
+
T =)
1
0 =
K
K

éq
2.2.1-1

S [2 Sr 0 - S
I -
S]
1
0
=
[- S
S
] =0
I
I

The speed of irreversible deformation of creep is thus equal to zero. One deduces from it that irreversible deformation of creep is also equal to zero. The speed of deformation unrecoverable remains equalize to zero until the moment T = t0, defined by the relation [éq 2.2.1-2]:

S
S
fs

2 Kr R (t0)
S
fs
- = 0 R (t0) =

éq
2.2.1-2

S

2 Kr

Until the moment T = t0, the reversible deformation of creep is defined by the following relation:

S

S

1

T

&r =

K

T

1 exp

éq

2.2.1-3

S [S - Sr Sr]

Sr () =

-

-

S

K

S

R

R

R

S

S

R

R =

is the characteristic time associated the reversible deformation of creep. The moment T is

S

0

Kr

thus defined by the relation [éq 2.2.1-4]:

fs

T

0
R (t0)
S
S
=
=
1 - exp -
t0 = ln (2) S
S
R 0.69 R ***éq***
2.2.1-4
S
S

S
2 K

R
Kr
R

The reversible and irreversible deformations of creep are thus determined by:

S

fs (
T)

T

=

R
S
1 - exp - S

K

éq
2.2.1-5
R

R

fs
(T)

= 0
I

During the calculation of the deformations of creep for T > t0, the new initial conditions are thus:

S
fs (

t0)

=
R
S

2 Kr ***éq***
2.2.1-6

fs
(t0)

= 0

2.2.2 Case of long-term creep

By expressing speeds of reversible and irreversible deformations of creep according to deformations of creep, the relation then is obtained:

S
S
K
K

S
K

fs
R
R
fs

I
fs
1

2
& = -
- *4*
R + *2*

I
+
+
S
R

S
S

S
S
S

R
I
I
R I

éq 2.2.2-1

S
K
K

fs
R
fs
I
fs
1

&
2

I
=

R + -
I + -
S

S

S

S

I
I
I

In order to simplify calculations, the following intermediate variables are defined:

Kr
1
ki
1
Kr
urr =
:
=
, uii =
:
=
and uri =
:

éq
2.2.2-2
R R
I I
I

The system of equations [éq 2.2.2-1] can be put then in the following matric form:

-
- 4
2

fs
& fs
fs
U
U
U

1
U

+ 2u
&
R
rr
laughed
II
R
S
rr
laughed
= =

+

éq
2.2.2-3

& fs
fs
S

2 U
- U

K
- U
I
1
4
4
4
ri2
4
4
4
3
II
I

3
2
1
1r 4
4 2 4
4ri 3
With
S
B

I.e.:
fs
& = A fs
S
+ B ***éq***
2.2.2-4

Let us suppose that matrix A is diagonalisable (this property will be checked thereafter):
1
-
With = P D P where D indicates the diagonal matrix of the eigenvalues of matrix A, P
the matrix of the clean vectors of matrix A and
1
-
P the matrix reverses P. matrix In
carrying out term in the long term the product by the quantity
1
-

P, [éq 2.2.2-4] can be put under
form:

*fs, **
&
= D
*fs, **
S

*+ B**
*fs, **
with
= P-1
fs

and B = P-1 B* ***éq***
2.2.2-5

That is to say 1
and the 2 eigenvalues of matrix A. the quantities are defined:

***
***
fs

B
*,**

=
: 1
***
and B =
: 1

***
2

**2*
B
[éq 2.2.2-5] is written then:

***
S
1& (T) =

*1 **
1 (T) +
***
B

1
éq
2.2.2-6

***
S
*&2 (T) = 2 **
*2 (T) + **
b2

System whose solution is written:

S
***
***
B
1 (T) = -
1 + 1
µ exp (1
T)

1

1
0

éq
2.2.2-7
S

***

B
2 (T)
***
0
= -
2 + µ2
2
exp (2 T)

2

*One can then return to initial space, by the means of the matrix of passage; deformations of creep reversible and irreversible are linear combinations of **
*1 and **
2. Eigenvalues
matrix A, 1
and 2 are obtained while solving:

det (A - I)
1 = 0
- urr - 4 uri -
2
I
U
éq 2.2.2-8

II
= 0
2
I + (urr + 4uri + uii) I + urr uii = 0
2 uri
- uii - I

By noticing that urr, uri and uii are strictly positive, the discriminant is thus always strictly positive. The eigenvalues are thus real and distinct, matrix A is thus diagonalisable. In addition, none of the two eigenvalues is equal to zero
(= urr uii 0
1
2
). The two eigenvalues are defined by:

- (urr + 4uri + uii) -
1
=

2

éq
2.2.2-9

- (urr + 4uri + uii) +
2 =

2

One can show that the two eigenvalues are indeed negative. Let us show that second eigenvalue is negative. The spherical deformation of creep is thus asymptotic, assumption put forth in the model of clean creep spherical [bib1]. Let us determine one now base clean vectors (X 1, X 2) associated the eigenvalues 1
and 2. It is determined in
solving equation (A - I)
1 X I = 0.
A particular base of clean vectors is written:

x1
1
1
+ uii

2 uri
X 1 =
and X

2 =
with X

1 =
and x2 =
éq
2.2.2-10
1
X

2
2 uri
2 + uii

After having checked that P can be reversed indeed, one deduces the solution in space from it physics:

*b**
*b**

fs
1
2
R (T) =
S

X

-
1
+
+ x1 1
µ exp (1
T) + µ2 exp (2 T)

1

2

*b**
*b**

fs
1
2
I (T) =
S

X

-

+ 2
+ 1
µ exp (1

T) + x2 μ2 exp (2 T)

1

2

with

éq 2.2.2-11

1
*b*1 =*
[x2 (urr + 2uri) + uri]

x1 x2 -1

1
*b*2 =*
[- (urr + 2uri) - x1 uri]

x1 x2 -1

Lastly, 1
μ and μ2 are defined by the relations:

1
1
1

μ1 = -

x2 exp 2 t0 - exp 2 t0

(1x x2 -) 1exp ([1
+ 2) t0]
(
)

(
)
2 K
K
R
I

éq
2.2.2-12

1

1
1

µ2 = -
-
exp 1
t0 + 1
X exp 1
t0

(1x x2 -) 1exp ([1
+ 2) t0]
(
)
(
)

2 K
K
R
I

2.3
Resolution of the equations constitutive of creep deviatoric

The deviatoric constraints comprise a reversible part and an irreversible part
(cf [R7.01.06]):
fd
fd
fd

=

+
éq
2.3-1
{
{
R
{
I
contribution
deformation
contribution
water
ue
déviatoriq
water
absobée
total
free

The principal component jème of the total deviatoric deformation is governed by the equations [éq 2.3-2] and [éq 2.3-3]:
D D, J
D D, J
D J
R r& + K
,
R R
= H

éq
2.3-2
where D
Kr indicates rigidity associated with the capacity with water adsorbed to transmit loads (load bearing toilets);
and D
R viscosity associated with the water adsorbed by the layers with hydrates.

D D, J
D J
I i& = H
,

éq 2.3-3

where
D
I indicates the viscosity of interstitial water. The system of equations [éq 2.3-2] and [éq 2.3-3] is more simple to solve that that governing the spherical behavior owing to the fact that it is uncoupled. One always suppose that moisture remains equal to 1 during all the loading. The equation [éq 2.3-2] corresponds to the viscoelastic model of Kelvin whose response to a level of constraint is of exponential type. As for the equation [éq 2.3-3], the response in deformation is linear with time.
The total deformation of creep is thus written as the sum of the contribution of a chain of Kelvin and of the contribution of a shock absorber and series:

K D
R
-

T

D, J
T
1
D

(T) =
+
1

D,
- *E*
J
R

H (T)
éq
2.3-4
D

K D
I
R

2.4
Summary of the analytical solution

For a uniaxial loading the analytical solutions of the two components of deformation are known. The contribution of the deviatoric part is written:

D
2
T
1

K T
fd
(T)

R

= 0
+

1 - exp -

éq
2.4-1
3
D
D

K

D

I
R

R

As for the contribution of the spherical part, the solution is defined on two intervals:

S
K T
S
0

R
1 - exp -

T R
S

S
ln 2
S

fs
(T) 3k

R

R
K
=

R

éq 2.4-2

S
0 1
1
R

+
+ µ1 (1+ 1
X) exp (1
T) + µ2 (1+ x2) exp (2t) T >
ln 2
3 S
S
S

K
K

R
I

Kr
The axial deformation is a linear function of the two preceding contributions:

= fs
zz
(
fd
0
) 3+ (20) 3
éq
2.4-3

2.5
Sizes and results of reference

The test is homogeneous. One tests the deformation in an unspecified node.

2.6
Uncertainties on the solution

Exact analytical result.

2.7 References
bibliographical

[1]

BENBOUDJEMA, F.: Modeling of the deformations differed from the concrete under requests biaxial. Application to the buildings engines of nuclear thermal power stations, Memory of D.E.A. Advanced materials Engineering of the Structures and the Envelopes, 38 p. (+ appendices) (1999).
[2]
BENBOUDJEMA, F., MEFTAH, F., HEINFLING, G., the POPE, Y.: Numerical study and analytical of the spherical part of the clean model of creep UMLV for the concrete, notes technique HT-25/02/040/A, 56 p (2002).
[3]
The POPE, Y.: Relation of behavior UMLV for the clean creep of the concrete, Reference material of Code_Aster [R7.01.06], 16 p (2002).
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-26/03/023/A

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3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D
Z
NO7
NO6
NO8
NO5
NO2
NO3

y
NO4
NO1
X

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs: 1 of type HEXA 8

6 of type QUAD 4

The following meshs are defined:

S_ARR
NO3 NO7 NO8 NO4
S_AVT
NO1 NO2 NO6 NO5
S_DRT
NO1 NO5 NO8 NO4
S_GCH
NO3 NO2 NO6 NO7
S_INF
NO1 NO2 NO3 NO4
S_SUP
NO5 NO6 NO7 NO8

The boundary conditions in displacement imposed are:

On nodes NO1, NO2, NO3 and NO4: DZ = 0
On nodes NO3, NO7, NO8 and NO4: DY = 0
On nodes NO2, NO6, NO7 and NO8: DX = 0

The loading is consisted of the same field of drying and the same nodal force 1/4 applied on the four nodes of S_SUP.

3.3 Functionalities tested

Orders
Key word

DEFI_MATERIAU ELAS_FO

FONC_DESORP

UMLV_FP
K_RS
K_IS
K_RD
V_RS
V_IS
V_RD
V_ID
CREA_CHAMP "AFFE"
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
AFFE_CHAR_MECA DDL_IMPO

LIAISON_UNIF
FORCE_NODALE

SECH_CALCULEE
STAT_NON_LINE COMP_INCR
RELATION= `UMLV_FP'

3.4
Sizes tested and results

The component with node NO6 was tested.
xx

Moment Reference
***Aster** %*
difference
0. 0. 0.
-
1.0000E+00 3.225814D-05
3.225810D-05
1.37E-04
9.7041E+04 3.867143D-05
3.867140D-05
8.95E-05
1.8389E+06 6.088552D-05
6.088554D-05
3.25E-05
8.6400E+06 1.100478D-04
1.100473D-04
7.27E-06

---

4 Modeling B

4.1 Characteristics of modeling

Axisymmetric modeling 2D.

y
N3
N4
N1
N2
X

4.2 Characteristics of the grid

A number of nodes: 4
A number of meshs: 1 of type QUAD 4

4 of type SEG2

The following meshs are defined:

L_INF NO1
NO2
L_DRT NO2
NO4
L_SUP NO4
NO3
L_GCH NO3
NO1

The boundary conditions in displacement imposed are:

On L_GCH: DY = 0
On L_INF: DX = 0

The loading is consisted of the same field of drying and the same nodal force 1/2 applied on the two nodes of L_SUP.

4.3 Functionalities tested

Orders
Key word

DEFI_MATERIAU ELAS_FO

FONC_DESORP

UMLV_FP
K_RS
K_IS
K_RD
V_RS
V_IS
V_RD
V_ID
CREA_CHAMP "AFFE"
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
AFFE_CHAR_MECA DDL_IMPO

LIAISON_UNIF
FORCE_NODALE
SECH_CALCULEE
STAT_NON_LINE COMP_INCR
RELATION= `UMLV_FP'

4.4
Sizes tested and results

The component yy with node NO3 was tested

Moment Reference
***Aster** %*
difference
0. 0. 0.
-
1.0000E+00 3.225814D-05
3.225810D-05
1.37E-04
9.7041E+04 3.867143D-05
3.867140D-05
8.95E-05
1.8389E+06 6.088552D-05
6.088554D-05
3.25E-05
8.6400E+06 1.100478D-04
1.100473D-04
7.27E-06

5 Modeling
C

5.1
Characteristics of modeling

Modeling in Plane Constraints.

y
N3

N4
N1
N2
X

5.2
Characteristics of the grid

A number of nodes: 4
A number of meshs: 1 of type QUAD 4

4 of type SEG2

The following meshs are defined:

L_INF NO1
NO2
L_DRT NO2
NO4
L_SUP NO4
NO3
L_GCH NO3
NO1

The boundary conditions in displacement imposed are:

On L_GCH: DY = 0
On L_INF: DX = 0

The loading is consisted of the same field of drying and the same nodal force 1/2 applied on the two nodes of L_SUP.

5.3 Functionalities tested

Orders
Key word

DEFI_MATERIAU ELAS_FO

FONC_DESORP

UMLV_FP
K_RS
K_IS
K_RD
V_RS
V_IS
V_RD
V_ID
CREA_CHAMP “AFFE”
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
AFFE_CHAR_MECA DDL_IMPO

LIAISON_UNIF
FORCE_NODALE
SECH_CALCULEE
STAT_NON_LINE COMP_INCR
RELATION= `UMLV_FP'

ALGO_C_PLAN=' DEBORST'

5.4 Sizes tested and results

The component yy with node NO3 was tested

Moment Reference
***Aster** %*
difference
0. 0. 0.
-
1.0000E+00 3.225814D-05
3.225810D-05
1.40E-04
9.7041E+04 3.867143D-05
3.867140D-05
9.225E-05
1.8389E+06 6.088552D-05
6.088554D-05
3.08E-05
8.6400E+06 1.100478D-04
1.100478D-04
8.22E-06

6
Summary of the results

The values obtained with Code_Aster are in agreement with the values of the analytical solution of *reference. This same test was turned with Castem at the Laboratory of Mechanics with the University of The Marne the Valley, the same results were obtained.*

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.164

SSNV164 - Setting in tension of cables of prestressed in a beam 3D

Summary

One considers a concrete beam reinforced with section square, composed of two sections of 10 meters length, having respectively one and four square meters of section. The beam is vertical, weakest section in bottom. It is embedded at its base, and contains 5 rectilinear cables of prestressing.
One tests here the phasage setting in prestressing, i.e. the setting in successive tension of different cables.
The functionalities particular to test are as follows:

· operator DEFI_CABLE_BP: determination of the relations kinematics between the DDL of the nodes
of a cable and DDL of the nodes "close" to a concrete structure modelled by elements
3D and calculation of the tensions in a cable under the friction effect and of the retreat of anchoring,
· operator AFFE_CHAR_MECA associated with key word RELA_CINE_BP,
· operator CALC_PRECONT: setting in tension of the cables of prestressing.

The results obtained are validated by comparison with the computer code CASTEM 2000.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

1
Problem of reference

1.1 Geometry

One considers a concrete beam reinforced with section square, composed of two sections of 10 meters of length, having respectively one and four square meters of section. The beam is vertical, weaker section in bottom. It is embedded at its base, and contains 5 cables of prestressing rectilinear.

1
3
0.225m
5
1m
2
4
0.225m
The five cables which cross all the length of the beam are located as on plan Ci below:
Appear 1.1-a: Positioning of the cables in the beam

The section of each cable is 25 cm2.

1.2
Properties of materials

Material concrete constituting the beam:
· modulus Young:
Eb = 4. 105 MPa
· Poisson's ratio:
= 0,2
· density:
= 2500 kg/m3
Material steel constituting the cable:
· modulus Young:
Eb = 1,93 105 MPa
· Poisson's ratio:
= 0,3
· density:
= 7850 kg/m3

Characteristic concerning the setting in tension of the cables:
· retreat of anchoring = 1 mm
· linear coefficient of friction: 0,0015 M-1
· force of tension at the end of a cable: 3,75 106 NR
· age of dismantling 150 days

· age of setting in tension of the first cables 300 days

1.3
Boundary conditions and loadings

The base of the beam is blocked in direction Z. the two translatory movements per report/ratio with OX and OY are blocked as well as the rotational movement around OZ.
The sequence of loading is as follows:

· at 300 days, put in tension of 2 cables (1 and 2) by their lower end,
· at 450 days, put in tension of 2 additional cables (3 and 4) always by their end lower,
· at 600 days, put in tension of the last cable (5) by its two ends.

The beam is obviously subjected to gravity.

2
Reference solution

The reference solution was obtained by the ECA with CASTEM 2000, with a grid containing 2080 cubic elements with 20 nodes and 100 elements of cable.

3 Modeling
With

3.1
Characteristics of modeling

The concrete beam is represented by 2080 elements MECA_HEXA8, supported per as many meshs hexahedrons with 8 nodes. The 5 cables are represented using 20 elements MECA_BARRE each one supported per as many segments with 2 nodes. The figure below shows the grid of the beam.

Appear 3.1-a: Description of the grid

The material concrete is defined by behaviors ELAS and BPEL_BETON: parameters characteristics of this relation are fixed at 0 bus one does not wish to include the losses of tension had with the shrinking and the creep of the concrete.
The material steel for the cables is defined by behaviors ELAS and BPEL_ACIER.
nonnull values for BPEL_ACIER relate to friction (FROT_LINE=1,5 10-3 M-1) and the limit of elasticity since a zero value is illicit (SY = 1,94 1011 Pa). The ray of the cables is 2,8209 10-2 Mr.

The blocked DDL are as follows:
DZ for the lower face
DX and DY for the points located on the axis of symmetry of the beam
DX for the point (0.5 0. 0.) and DY for the point (0.5 0. 0.)

The F0 tension = 3,75 106 NR is applied to the lower nodes of cables 1, 2, 3 and 4 and to both ends for cable 5.

The loading is carried out in 4 steps of time:

· T =150 S, taken into account of gravity: STAT_NON_LINE with the boundary conditions, gravity and the relations kinematics for all the cables. Cables not contributing with the rigidity of the model, one affects a law of behavior to them "WITHOUT" (null constraint),
· T = 300 S, put in tension of cables 1 and 2: CALC_PRECONT with the boundary conditions, cables 1 and 2 being cables to be put in tension, cables 3, 4 and 5 being inactive,
· T = 450 S, put in tension of cables 3 and 4: CALC_PRECONT with the boundary conditions, the relations kinematics for cables 1 and 2, cables 3 and 4 being cables to be put in tension, cable 5 being inactive,
· T = 600 S, put in tension of cable 5: CALC_PRECONT with the boundary conditions, them relations kinematics for cables 1, 2, 3 and 4, cable 5 being the cable to be put in tension.

3.2 Stages of calculation and functionalities tested

The principal stages of calculation correspond to the functionalities which one wishes to validate:

· operator DEFI_MATERIAU: definition of the relations of behavior BPEL_BETON with default values and BPEL_ACIER, in the case of loss by linear friction,
· operator DEFI_CABLE_BP: determination of a profile of tension along the cable of prestressed, by taking of account losses by linear friction and losses by retreat

of anchoring; calculation of the coefficients of the relations kinematics between the DDL of the nodes of
cable and the DDL of the nodes "close" to the beam out of concrete, in the case of a beam
modelled by elements 3D,
· operator
AFFE_CHAR_MECA
: definition of a loading of the type
RELA_CINE_BP (RELA_CINE = ' OUI'),
· operator STAT_NON_LINE, option COMP_INCR: calculation of the state of balance by holding account
loading of the type RELA_CINE_BP, in the case of a beam modelled by
elements 3D,
· law of behavior WITHOUT,
· macro-order CALC_PRECONT with a nonvirgin initial state, that there is or not
inactive cables, that there are one or more cables to put in tension.

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4
Results of modeling A

One compares the value extracted field SIEF_ELNO_ELGA with reference obtained with CASTEM and this for the various characteristic moments (nonnull tension) and for nodes équirépartis along the cables.
The component to which the test relates is the tension in the cables NR.
The tolerance of relative variation compared to the reference is worth 0.1% for the phase of setting in tension then
1% for the following stages.

4.1
Tension in cable 1

T = 300 S
Node
Net
Value of reference
Computed value
Relative variation
N1 M5655 3,648.106 NR
3,6494.106 NR
0,038 %
N6 M5660 3,675.106 NR
3,6769.106 NR
0,051 %
N11 M5664 3,693.106 NR
3,6952.106 NR

0,059 %
N16 M5670 3,667.106 NR
3,6638.106 NR
-0,087 %
N101 M5674
3,640.106 NR
3,6419.106 NR
0,052 %

T = 450 S
Node
Net
Value of reference
Computed value
Relative variation
N1 M5655
3,561.106 NR
3,5634.106 NR
0,068 %
N6 M5660
3,588.106 NR
3,5903.106 NR
0,063 %
N11 M5664
3,628.106 NR
3,6132.106 NR
-0,408 %
N16 M5670
3,645.106 NR
3,6418.106 NR
-0,088 %
N101 M5674
3,629.106 NR
3,6224.106 NR
-0,183 %

T = 600 S
Node
Net
Value of reference
Computed value
Relative variation
N1 M5655

3,519.106 NR
3,5214.106 NR
0,069 %
N6 M5660
3,546.106 NR
3,5479.106 NR
0,055 %
N11 M5664
3,597.106 NR
3,5730.106 NR
-0,666 %
N16 M5670
3,635.106 NR
3,6308.106 NR
-0,115 %
N101 M5674
3,614.106 NR
3,6046.106 NR
-0,260 %

4.2
Tension in cable 3

T = 450 S
Node
Net
Value of reference
Computed value
Relative variation
N41 M5695
3,647.106 NR
3,6494.106 NR
0,066 %
N46 M5700
3,675.106 NR
3,6769.106 NR
0,051 %
N51 M5705
3,695.106 NR
3,6914.106 NR
-0,097 %
N56 M5710
3,667.106 NR

3,6638.106 NR
-0,087 %
N103 M5714
3,640.106 NR
3,6419.106 NR
0,052 %

T = 600 S
Node
Net
Value of reference
Computed value
Relative variation
N41 M5695
3,605.106 NR
3,6075.106 NR
0,070 %
N46 M5700
3,632.106 NR
3,6346.106 NR
0,070 %
N51 M5705
3,662.106 NR
3,6720.106 NR
0,272 %
N56 M5710
3,655.106 NR
3,6529.106 NR
-0,058 %
N103 M5714
3,625.106 NR
3,6241.106 NR
-0,024 %

4.3
Tension in cable 5

T = 600 S

Node	**Net**	**Value of reference**	**Computed value**	**Relative variation**
N81	M5735	3,647.106 NR	3,6494.106 NR	0,066 %
N86	M5740	3,674.106 NR	3,6768.106 NR	0,078 %
N91	M5745	3,695.106 NR	3,6952.106 NR	0,005 %
N96	M5750	3,674.106 NR	3,6714.106 NR	-0,072 %
N105	M5754	3,647.106 NR	3,6494.106 NR	0,066 %

5
Summary of the results

It is noted that the macro-order makes it possible to obtain the tension given by the BPEL (guaranteed by
procedure implemented by CASTEM) with a very good precision since the variation is lower than 0.1%. In addition, the effect of the setting in tension of the cables on the remainder of the structure and in particular
on the already tended cables, is completely satisfactory since the variation enters the reference solution and it
aster calculation is lower than 1%, whereas the grid of reference was quadratic and calculation carried out
here used linear meshs.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.165

SSNV165 - Triaxial compression test not drained with the law CAM_CLAY

Summary:

This test makes it possible to validate the mechanical law elastoplastic Cam_Clay specific to the grounds normally
consolidated. This law integrates an elastoplastic hydrostatic mechanism (of which the elastic part is non-linear and the threshold of flow corresponds to the pressure of consolidation) coupled to a mechanism
deviatoric elastoplastic the elastic part is linear. The behavior is hardening or
softening according to the combination of the two mechanisms.
This test carried out in hydro-mechanical coupling includes/understands two ways of loading:
1) a hydrostatic way of compression in condition drained until the pressure of consolidation,
2) a way not-drained by maintaining the pressures lateral confining on the sample and by imposing one

vertical displacement of compression which induces a triaxial state of stresses.
Modeling is carried out in 3D.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/03/008/A

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

height: H = 1m
width: L = 1 m
thickness: E = 1 m

1.2
Properties of material

E = 22.4E6 Pa
= 0.3
= 1.E - 5
Parameters specific to CAM_CLAY:

PORO = 0.14, = 0.25, = 0.05, M = 0.9, CLOSE _ CRIT =.
3 E5 Pa, Pa = 1.E5 Pa

1.3
Boundary conditions and loadings

The first way of loading is carried out with a state of hydrostatic stresses:
= = = P. One makes a first elastic design to P = Pa (to establish an initial state).
xx
yy
zz
One increases then P to P
= P
= .
6 E5Pa = 2P by using Cam_Clay,
sup
ion
consolidat
Cr
pressure of water is null
1
PRE = 0 (drained condition). For the second way, one maintains
pressure P on the side faces and one imposes then a vertical displacement imposed in
compression to model a triaxial compression test, calculation is now not drained, which corresponds to
a hydrostatic flow no one on all the faces.

1.4 Conditions
initial

In CAM_CLAY, the elastic law requires a hydrostatic constraint strictly higher than zero with the initial state (deformation being null).

To initialize this constraint, one chose to carry out at the beginning a purely elastic calculation in making evolve/move pressure of 0. with 1.E5 Pa. One extracts from this calculation only the field of constraints at the points of gauss. This stress field resulting from the elastic design is considered like the initial state of the hydrostatic constraint necessary to the law Cam_Clay of following calculation.

2
Reference solution

An exact solution exists as much as the loading is hydrostatic (cf SSNV160). For the second triaxial way, an analytical solution is not obvious to find. In the same way, one does not have data and of triaxial experimental test results allowing to compare with calculations.
This test is a test of not-regression.

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D
Z
NO3
NO5
NO8
NO2
NO7
y
NO1
NO4
NO6
NO12
NO10
NO9
NO11
X
NO15
NO17
NO20
NO14
NO19
NO13
NO18
NO16

3.2
Characteristics of the grid

A number of nodes:
20
A number of meshs:
1 of type HEXA 20

6 of type QUAD 8

The following meshs are defined:

RIGHT-HAND SIDE
NO3 NO5 NO8 NO10 NO12 NO15 NO17 NO20

LEFT
NO1 NO4 NO6 NO9 NO11 NO13 NO16 NO18
IN FRONT OF
NO6 NO7 NO8 NO11 NO12 NO18 NO19 NO20
BEHIND
NO1 NO2 NO3 NO9 NO10 NO13 NO14 NO15
LOW
NO13 NO14 NO15 NO16 NO17 NO18 NO19 NO20
HIGH
NO1 NO2 NO3 NO4 NO5 NO6 NO7 NO8

To represent the 1/8ème structure, the boundary conditions in displacement imposed are:

On the LOW face: DZ = 0
On the LEFT face: DY = 0
On the face BEHIND: DX = 0

The loading is consisted of the same pressure divided into compression on the 3 meshs: `HIGH, "RIGHT" and "IN FRONT" to simulate a hydrostatic test with
1
PRE = 0 in drained. Then,
pressure distributed is maintained constant on the side faces "RIGHT-HAND SIDE" and "IN FRONT", one
displacement DZ is imposed on the variable face "HIGH" with time in not drained.

3.3 Functionalities tested

Orders

DEFI_MATERIAU CAM_CLAY

STAT_NON_LINE COMP_INCR
RELATION= `KIT_HM'

`RELATION_KIT'=

"CAM_CLAY"

"LIQU_SATU"

"HYDR_UTIL"
NEWTON
STAMP = TANGENT

3.4
Sizes tested and results

The components, and of the constraint are tested at moments 3. , 6. , 15. and 20. and
xx
yy
zz
value of the pressure of water PRE1 at moment 20 with nodes NO8. The values of reference are values of not-regression.

Values of and:
xx
yy

Moment
Reference
Aster
1st loading 3.
-3.000000+05 -3.000000+05
1st loading 6.
-6.000000+05 -6.000000+05

2nd loading 15.
-2.590356+05 -2.590355371917+05
2nd loading 20.
-2.495777+05 -2.495776491115+05

Values of:
zz

Moment
Reference
Aster
1st loading 3.
-3.000000+05 -3.000000+05
1st loading 6.
-6.000000+05 -6.000000+05
2nd loading 15.
-5.560431+05 -5.650429335188+05
2nd loading 20.
-5.578873+05 -5.578813428168+05

Values of PRE1:

Moment
Reference
Aster
2emechargement 20.
3.50422+05 3.50422350888+05
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4
Summary of the results

tr ()
By interpreting the diagram, (P, Q), P = -
and Q = - (-) in the case of this case test, one
3
3
1
note well that the loading remains hydrostatic up to a value of 6.E5Pa. Once it vertical displacement is imposed and varies with time, the pressures on the side faces being maintained constant, a diverter of constraints is induced and increases with time with one positive work hardening. When one approaches the point Q = MP, one tends towards perfect plasticity with plastic flow without work hardening and variation of constraints (see [§6] Doc. [R7.01.14]).

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V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.166

SSNV166 Rolls fissured under loadings multiples

Summary

The purpose of this test is calculation of the stress intensity factors along the bottom of crack for a cylinder comprising an axisymmetric crack.

The influence of the degree of the elements and the type of the method is studied through various modelings.

· Modeling A tests K1 and K3 with a linear grid 3D and a method with the finite elements traditional (FEM).
· Modeling B tests K1 and K3 with a quadratic grid 3D (elements of Barsoum) around melts of crack and a FEM.
· Modeling C tests K1 and K3 with a linear grid 3D with a traditional resolution but one extraction of the factors of intensity based on an energy calculation.

Moreover, for each modeling, various cases of loadings are studied:
- traction (request in mode I);
- torsion (request in mode III);
- inflection (opening of dimensioned, closing of the other) with and without taking into account of the contact.

The cases of traction and torsion do not put concerned the contact.

Although symmetries exist in certain cases (axisymetry for case 1, symmetry planes for 2nd) representation is made in 3D to make the test generalizable under multiple loading.
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1 Problem of reference

1.1 Geometry

The crack is a circular ring in an orthogonal plan with the axis of the cylinder [Figure 1.1-a]. parameters has and B determine the ray of the cylinder and the depth of the crack. [Figure 1.1-b] is a cut of the cylinder in the plan of crack (plane Oyz). So that the medium is regarded as infinite, the height of the cylinder is H = 10 B.

Appear 1.1-a: Geometry of the fissured cylinder

2b
2a
PFON_FIN
.
NODE A
y
Z
.
Z one
fissured

Appear 1.1-b: Plan of cracking

1.2
Material properties

Young modulus: E= 205000 MPa

Poisson's ratio: = 0.3

1.3
Boundary conditions and loadings

Three loadings will be applied in order to calculate the stress intensity factors K1 and K3 in 3D by using operator POST_K1_K2_K3.

Loading 1 tests K1, and K3.
Loading 2 tests K2 without taking into account of the contact.
Loading 3 tests K2 with taking into account of the contact.

One expects that K1 and K3 are constant along the bottom of crack and so that K2 varies.

Note: the cases of traction and torsion can be treated indifferently with or without contact (here, without contact) because it y forever of closing of the crack.

Case 1: traction and
Case 2: inflection without
Case 3: inflection with
torsion

contact
contact
Higher face
Nx = 6 MN
My = 1.5 MN
My = 1.5 MN
Tx = 3 MN
Table 1.3-1: Case of loadings

The preceding efforts are applied to the structure via discrete elements 3D located at center higher face. It is noted that the point of maximum opening due to the imposed inflection (moment following OY) will be node A (see [Figure 1.1-b].

The rigid movements of body are blocked by the same process with embedding of the center of the lower face.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

For an axisymmetric crack in a cylinder infinite length, method of the Equations

Singular integrals and of the Asymptotic Developments [bib1] makes it possible to calculate the values of
stress intensity factors.

· Cas 1: Traction and Torsion

Traction induces an opening in mode 1. K1 is given by the following formula:
P
K =
F has

I
2
1 (has b)
has
where P is the effort applied to the higher and lower face and F1 a given function [Figure 2.1-a].

Torsion induces an opening in mode 3. K3 is given by the following formula:
T
2
K =
has
F

III
3
3 (has b)
has

where T is the moment applied to the higher and lower face and F3 a given function
[Figure 2.1-a].

· Cas 2: Inflection without contact

The inflection induces an opening in mode 1. The value of K1 at the point of maximum opening A is given
by the following formula:
4M
K =
has
F

I
3
2 (has b)

With
has

where M is the moment applied to the higher and lower face and F2 a given function [Figure 2.1-a].

· Cas 3: Inflection with contact

There is not analytical solution with this problem. One expects on the one hand that K1 is close to case without contact on the part of the crack in opening, and in addition that K1 is null on the part of the crack in closing.

Appear 2.1-a: Functions F1, F2 and F3

These three functions come from [bib1].

2.2
Results of reference

Numerical application:

Except contrary mention, in the continuation of this document, the parameters retained for A and B are:

= 0.4 m has
B = 0.5 m

Case 1: Traction and torsion
Case 2: Inflection
K1 = 5.35 MPa.m1/2
K1
K3 = 11.22 MPa.m1/2
To = 11.71 MPa.m1/2
Table 2.2-1: Values of reference

3
Linear modeling a: Grid, traditional formulation

3.1
Characteristics of modeling

Appear 3.1-a: Cut grid in the plan of the crack

The elements are all of order 1.

The interest of this modeling is to be used as a basis for more evolved/moved formulations, and thus,

of
to be able to note the contribution and the improvements of the other methods.

3.2
Characteristics of the grid

A number of nodes: 11310
A number of meshs: 14453

Type of meshs	A number of meshs
POI1	4
SEG2	39
TRIA3	360
QUAD4	930
PENTA6	5440
HEXA8	7680

Table 3.2-1: Characteristics of the meshs

3.3 Functionalities
tested

Orders

DEFI_FOND_FISS

POST_K1_K2_K3

CALC_G_LOCAL_T

3.4 Notice

The calculation of the stress intensity factors is done using POST_K1_K2_K3 (method of extrapolation of displacements on the lips of the crack) [bib2].

4
Results of modeling A

4.1 Values
tested

Procedure POST_K1_K2_K3 makes it possible to identify the values of the stress intensity factors with a coefficient close, by two methods. We will limit the test to the results resulting from the method 1, which
seem more stable. One recalls that this method calculates, for each couple of nodes in opposite around the point of the bottom of crack considered, the jump of the field of displacement squared and divides it
by R [bib2]. One limits oneself to 3 or 4 couples of nodes, and one will take the maximum value like value
result (the most constraining value).

4.1.1 Results in the case of a loading in traction (K1) and torsion (K3)

Identification Reference
Aster
% difference
K1 with node PFON_FIN
5.35 106 4.98
106
6.92
K3 with node PFON_FIN
-11.22 106 -10.12
106 9.80

The values of K1 and K3 must be identical [Figure 4.2-a] for all the nodes of the bottom of crack because there is an axisymmetric configuration. Here, we test only the values with node PFON_FIN.

4.1.2 Results in the case of a loading in inflection (K1) without contact

Identification Reference
Aster
% difference
K1 with node A
11.71 106 10.17
106
13.15

One compares the value of K1 with the reference solution only to the point of maximum opening (node A) because it is the only analytical value available in the literature.

4.1.3 Results in the case of a loading in inflection (K1) with contact

Identification Reference
Aster
% difference
K1 with node A
10.17 106 9.29
106
8.66

One not compares the result obtained with that obtained by Code_Aster without taking into account of the contact (
regression). This taking into account is carried out by the method of the active constraints.

4.2
Evolutions of K1, K2, K3 along the bottom of crack

Appear 4.2-a: K1, K2 and K3 along the bottom of crack (in MPa.m1/2)

Appear 4.2-b: K1 along the bottom of crack (in MPa.m1/2)

Comments on the results:

[Figure 4.2-a] the evolution of the factors of intensity of the constraints along the bottom of crack shows
axisymmetric crack of depth 100 mm subjected to traction and torsion. One observes
many axisymmetric results (with the miscalculations near). Moreover, one notes that the crack is not not solicited in mode II.
On [Figure 4.2-b], one highlights the taking into account of the contact. On half of crack in opening, K1 has lower values with taking into account of the contact, because the contact rigidifies structure. On half in closing, K1 is null.
In fact, the contact does not take place on all the higher half of the crack [Figure 4.2-c] but on one surface a little smaller. On [Figure 4.2-c] the zone in red the zone of contact represents and
zone in blue that of noncontact.

Appear 4.2-c: Contact

5 quadratic Modeling b: Grid, formulation traditional

5.1 Characteristics of modeling

Appear 5.1-a: Grid and torus

A torus is created around the crack. The elements of the torus are quadratic elements. elements apart from the torus are linear. Moreover, one uses elements of BARSOUM (nodes mediums moved with the quarter) for the meshs having an edge pertaining to the bottom of crack [bib3].

The interest of the use of a grid of the type BARSOUM is obtaining more precise results.

5.2 Characteristics of the grid

A number of nodes: 20030
A number of meshs: 16449

Type of meshs	*A number of meshs*
POI1	*2000*
SEG3	*39*
TRIA3	*360*
QUAD4	*610*
QUAD8	*320*
PENTA6	*4800*
PENTA15	*640*
HEXA8	*5760*
HEXA20	*1920*

Table 5.2-1: Characteristics of the meshs
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The nodes mediums of the edges of the elements touching the bottom of crack are moved with the quarter of these edges, to obtain a better precision.

5.3 Functionalities tested

Orders

DEFI_FOND_FISS

CALC_G_LOCAL_T

POST_K1_K2_K3

Code_Aster ®
Version
7.4

Titrate:
SSNV166 Rolls fissured under multiple loadings
Date

:

15/02/06
Author (S):
***P. MASSIN**, Key S. GENIAUT*
:
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6
Results of modeling B

6.1 Values tested

6.1.1 Results in the case of a loading in traction (K1) and torsion (K3)

Identification	***Reference***	***Aster***	***% difference***
K1 with node PFON_FIN	*5.35 106*	*5.19 106*	*2.93*
K3 with node PFON_FIN	*-11.22 106*	*-11.08 106*	*1.25*

The values of K1 and K3 must be identical [Figure 6.2-a] for all the nodes of the bottom of crack because there is an axisymmetric configuration. Here, we test only the values with the last node of crack (PFON_FIN).

6.1.2 Results in the case of a loading in inflection (K1) without contact

Identification	***Reference***	***Aster***	***% difference***
K1 with node A	*11.71 106*	*10.59 106*	*9.54*

One compares the value of K1 with the reference solution only to the point of maximum opening (Node A) because it is the only analytical value available in the literature.

6.1.3 Results in the case of a loading in inflection (K1) with contact

Identification Reference
Aster
% difference
K1 with node A
10.59 106 9.82
106
7.30

One compares the result obtained with that obtained by Aster calculation without taking into account of the contact
(not-regression). The method of resolution of the contact is that of the active constraints.

6.2
Evolutions of K1, K2, K3 along the bottom of crack

Appear 6.2-a: K1, K2 and K3 along the bottom of crack (in MPa.m1/2)

Appear 6.2-b: K1 along the bottom of crack (in MPa.m1/2)

Note:

When one calculates the jumps of displacements along the bottom of crack (POST_K1_K2_K3), it first point met on the basis of the node on the bottom is the node moved with the quarter of the element of adjacent Barsoum. However for this node with the quarter, the management of the traditional contact is not valid.
Indeed, the method of the active constraints with linearization with the nodes mediums implies that it displacement of the nodes mediums is worth the average of displacements of the adjacent nodes. However here,
the node medium being moved with the quarter, this approximation is not licit.
As the contact is not taken into account correctly for these nodes with the quarter, it appears judicious not to estimate K1 at it, especially when there is contact. On the following nodes, the jump of displacement is quite correct and K1 is worth zero (see [Figure 6.2-b]).

.
.

Melts of crack
.

.
.
Nodes with the quarter
.
.
.
Node of the bottom of
. .
fissure considered
.
.
.
False K1 if contact
Correct K1

Appear 6.2-c: Configuration of calculation close to the bottom of crack

This is not quite serious in practice bus when there is contact, one knows that K1 must be null.

Moreover, a solution consists in tracing K1_MAX when the crack opens, and K1_MIN when it firm (it is what is made on [Figure 6.2-b]. In the case of closing, K1_MIN is quite null since it is based on the values of K1 given by the jumps of displacements of the following traditional nodes the nodes with the quarter, which are correctly treated with regard to the contact.

7
Modeling C: Linear grid, traditional formulation and energy method

7.1
Characteristics of modeling

The modeling of the problem is the same one as that used in A. All the elements are of order 1.

7.2
Characteristics of the grid

The grid is similar to that used in A.

A number of nodes: 13630
A number of meshs: 17013

Type of meshs	*A number of meshs*
POI1	*4*
SEG2	*39*
TRIA3	*360*
QUAD4	*1090*
PENTA6	*5760*
HEXA8	*9760*

Table 7.2-1: Characteristics of the meshs

7.3 Functionalities tested

Orders

DEFI_FISS_XFEM

CALC_G_LOCAL_T
OPTION CALC_K_G

Option CALC_K_G was introduced into order CALC_G_LOCAL_T. This option allows *to calculate the stress intensity factors by an energy method. This method is more general that the method of extrapolation of displacements (POST_K1_K2_K3) because it can be used in the case of an unspecified crack (not-plane crack, at bottom not-right). This method is freed thus orders DEFI_FOND_FISS [U4.82.01] and POST_K1_K2_K3 [U4.82.05] but requires order DEFI_FISS_XFEM [U4.82.08] which defines two functions of levels (level sets) for to characterize the crack.*

---

8 *Results of modeling C*

8.1 Values tested

L `option CALC_K_G of order CALC_G_LOCAL_T makes it possible to extract the values from the factors of intensity of constraints by the G-théta method by using the bilinear form of G (generalization with 3D of the case already existing 2D in Code_Aster). As for the traditional G-théta method, it is necessary to give a value for Rinf and Rsup (rays lower and higher of the torus being used as support than field théta).

8.1.1 Results in the case of a loading in traction (K1) and torsion (K3)

Identification Reference
Aster
% difference
Max (K1)
5.35 106 5.11
106 4.47
Max (K3)
11.22 106 10.52
106 6.24

The values of K1 and K3 must be identical [Figure 8.2-a] for all the nodes of the bottom of crack because there is an axisymmetric configuration. Here, we test the maximum of K1 and K3 for all them points of the bottom of crack.

8.1.2 Results in the case of a loading in inflection (K1) without contact

Identification Reference
Aster
% difference
K1 with node A
11.71 106 10.32
106 11.88

One compares the value of K1 with the reference solution only to the point of maximum opening bus it is the only analytical value available in the literature. This point is not any more one "node" but one "not" of the bottom of crack, it should then be located by its number in the list of the points of the bottom of
fissure. It is the point located by NUM_PT=11.

8.1.3 Results in the case of a loading in inflection (K1) with contact

Identification Reference
Aster
% difference
K1 with node A
10.32 106 9.43
106 8.57

One compares the result obtained with that obtained by Code_Aster without taking into account of the contact
(not-regression). This taking into account is carried out by the method of the active constraints.

[Figure 8.2-b] compares the values of K1 along the bottom of crack in the case of inflection with and without contact.

8.2
Evolutions of K1 and K3 along the bottom of crack

Appear 8.2-a: K1 and K3 along the bottom of crack (in MPa.m1/2)

Inflection
1,50E+07
without contact
with contact
1,00E+07
5,00E+06
0,00E+00
0,00
0,10
0,20
0,30
0,40
0,50
0,60
0,70

0,80
0,90
1,00
-5,00E+06
-1,00E+07
-1,50E+07
Curvilinear X-coordinate norm ée

Appear 8.2-b: K1 along the crack (in MPa.m1/2)
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Note:

It is noted that if the contact is taken into account (see [Figure 8.2-b]), K1 is not really no one on the segments of the bottom of crack where there is closing. That comes owing to the fact that energy method of calculation of K projects the field of solution displacement on the fields singular auxiliaries of displacement of an infinitely long crack in opening. However these fields auxiliaries are not compatible with the mode of closing present.

9 Summaries of the results

The objectives of this test are achieved:

.

It is a question of validating the taking into account of the contact on the lips of the crack with elements quadratic (and of the elements of Barsoum). The results better, are compared with those obtained with a linear grid.

.

This test shows the interest of the method "G-theta" for calculation of the factors of intensity of constraint. This energy method has the advantage of being more general than that using the jump of displacements (POST_K1_K2_K3) because it can apply to cracks of unspecified geometry, whereas POST_K1_K2_K3 is restricts with the plane cracks. Of more, the method "G-theta" gives better results (compared with the analytical solution) that POST_K1_K2_K3 for the same linear grid.

.

In addition, this test constitutes a reference and will allow the validation of the introduction of method X-FEM in Code_Aster applied to calculations of the factors of intensity of constraints.

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10 Bibliography

[1]
TADA, PARIS, IRWIN: The Stress Analysis Of Cracks Handbook, Del Research Corporation,

Hellertoxn, Pennsylvania (1973).
[2]
PROIX: Calculation of the factors of intensity of the constraints by extrapolation of the field of displacements, Handbook of reference of Code_Aster, R7.02.08
[3]
CORNELIU: Quarter-point elements for curved ace faces, Computers & Structures vol. 17, No 2, pp. 227-231, 1983

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J. EL GHARIB, T. KANIT, J.M. PROIX Key

Organization (S): EDF-R & D /AMA

SSNV171 - Comparison POLY_CFC and MONOCRYSTAL

Summary:

***One presents here a test having for reference another model of behavior already validated in Code_Aster,
who is POLY_CFC. The treated geometry is a cube. The goal is to test the concept MONOCRYSTAL while using
a law of behavior equivalent to POLY_CFC.***

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1
Problem of reference

1.1 Geometry

P1
P2
P5
P6
P3
P4
Y
P7
P8
X
Z

One defines an element MA1, containing the P1 nodes, P2, P3, P4, P5, P6, P7 and P8.

1.2
Material properties

Young modulus: E = 145200MPa

Poisson's ratio: = 0.3

Modeling a:

A monocrystal of the type POLY_CFC, directed according to
)
0
,
0
,
30
(
with:
D = 0
L
D = 0
With
NR = 10
K = 40
=
5
.
75
0
B = 19.34
1
H = 0
L
Q = 9.77
1
Q = -33.27
2
B = 5.345
2
C = 0.00001
1
D =
.
36 68
1
C = 0
2

Modeling b:

ECOU_VISC2 with:
TYPE_PARA=' ECOU_VISC'
NR = 10
K = 40
C = 0
D =
68
,
36

To = 10

ECRO_ISOT2 with:
TYPE_PARA=' ECRO_ISOT'
R =
5
.
75
0

B = 19.34
1

B = 5.345
2

Q = 9.77

1

Q = -33.27
2

H = 0

ECRO_CINE1 with:
TYPE_PARA=' ECRO_CINE'
D = 36.68
The selected orientation is the same one as that of modeling A,
)
0
,
0
,
30
(
.

1.3
Boundary conditions and loadings

.
P4 node
: DX = DY = 0
.
P8 node
: DX = DY = DZ = 0
.
Nodes P2 and P6
: DX = 0
.
Nodes P1, P3, P5 and P7: FX = 35

The loading is increasing FX = 0 with FX = 35, divided into 100 increments.

2
Reference solution

2.1
Method of calculation

One compares the functionality of new concepts with a concept already implemented in Code_Aster, which is POLY_CFC.

3 Modeling With

3.1 Characteristics of the grid

A number of nodes: 8.
Modeling 3D: 1 element of quadratic volume: HEXA8.
Clean texture has POLY_CFC, with a family of systems of slip corresponding to the structure cubic with centered faces, in fact the OCTAHEDRAL system. The structure contains only one grain, therefore a voluminal fraction equal to 1 and the selected orientation is
)
0
,
0
,
30
(
.

4
Results of modeling A

4.1 Functionalities tested

Orders Options

DEFI_TEXTURE SYST_GLISSEMENT NR, L
PLAN
ANGL_NAUT,
PROPORTION
DEFI_MATERIAU POLY_CFC
TEXTURE,

DL, DA, NR, K, TAU_0, B1, HL, Q1, Q2, B2, C1, D1, C2
STAT_NON_LINE COMP_INCR
RELATION=' POLY_CFC'

4.2 Values tested

Identification Reference
***Aster** %*
difference
of
xx
SIEF_ELGA
-210 -210
-7.38E-05
of
xx
EPSI_ELGA_DEPL
-0.0018955 -0.0018955

-4.30E-04
of
yy
EPSI_ELGA_DEPL
0.000503377

0.000503377 9.11E-05
of
xx
EPSP_ELGA
-0.000449212
-0.000449212 5.43E-05
of
yy
EPSP_ELGA
0.0000694943
0.00006949337 -3.46E-05

5 Modeling B

5.1 Characteristics of the grid

A number of nodes: 8.
Modeling 3D: 1 element of quadratic volume: HEXA8.
The structure contains only one grain (voluminal fraction equal to 1) and the selected orientation is
)
0
,

0
,
30
(
.

6
Results of modeling B

6.1 Functionalities
tested

Orders Options

DEFI_MATERIAU ELAS
E, NAKED
ECOU_VISC2
TYPE_PARA=' ECOU_VISC',

NR, K, C, D, A
ECRO_ISOT2
TYPE_PARA=' ECRO_ISOT',

R_0, B1, B2, Q1, Q2, H
ECRO_CINE1
TYPE_PARA=' ECRO_CINE',
D
DEFI_COMPOR MATER MONOCRYSTAL,

ECOULEMENT=' ECOU_VISC2',

ECRO_ISOT=' ECRO_ISOT2',
ECRO_CINE=' ECRO_CINE1',
ELAS=' ELAS',
FAMI_SYST_GLIS=' OCTAEDRIQUE'
MODEL AFFE_CARA_ELEM

SOLID MASS
GROUP_MA=' TOUT',
ANGL_REP
STAT_NON_LINE CARA_ELEM

COMP_INCR
RELATION=' MONOCRISTAL',
COMPOR

6.2 Values
tested

Identification Reference
***Aster** %*
difference
of
xx
SIEF_ELGA
-210 -210
-7.38E-05
of
xx
EPSI_ELGA_DEPL
-0.00189 -0.00189

-4.30E-04
of
yy
EPSI_ELGA_DEPL
0.0005033 0.0005033
9.15E-05
of
xx
EPSP_ELGA
-0.000449 -0.000449
5.66E-05
of
yy
EPSP_ELGA
0.0000695 0.0000695
-3.23E-05

---

7 Modeling C

7.1 Characteristics of the grid

A number of nodes: 8.
Modeling 3D: 1 element of quadratic volume: HEXA8.
The structure contains only one grain (voluminal fraction equal to 1) and the selected orientation is
)
0
,
0
,
30
(
.
The goal of this modeling is the comparison between the values of the stress fields and of deformations obtained with the monocrystal into implicit and explicit as well as the comparison for two modelings of the values of the variable interns V43 which is the cumulated plastic deformation total of the monocrystal.

8 Results of modeling C

8.1 Functionalities tested

Orders Options

DEFI_MATERIAU ELAS
E, NAKED
ECOU_VISC1
TYPE_PARA=' ECOU_VISC',

NR, K, C
ECRO_ISOT1
TYPE_PARA=' ECRO_ISOT',

R_0, B1, B2, Q1, Q2, H
ECRO_CINE1
TYPE_PARA=' ECRO_CINE',
D
DEFI_COMPOR MATER MONOCRYSTAL,

ECOULEMENT=' ECOU_VISC1',

ECRO_ISOT=' ECRO_ISOT1',
ECRO_CINE=' ECRO_CINE1',
ELAS=' ELAS',
FAMI_SYST_GLIS=' OCTAEDRIQUE'
MODEL AFFE_CARA_ELEM

SOLID MASS
GROUP_MA=' TOUT',
ANGL_REP
STAT_NON_LINE CARA_ELEM

COMP_INCR
RELATION=' MONOCRISTAL',

COMPOR
CONVERGENCE
RESO_INTE=' IMPLICITE'
STAT_NON_LINE CARA_ELEM

COMP_INCR
RELATION=' MONOCRISTAL',

COMPOR
CONVERGENCE
RESO_INTE=' RUNGE_KUTTA_2'

Handbook of Validation

8.2 Values
tested

Into implicit

Identification Reference Aster %
difference
of
xx
SIEF_ELGA
-210 -210
-5.97E-05
of
xx
EPSI_ELGA_DEPL
-0.00189
-0.00189
1E-2
of
yy
EPSI_ELGA_DEPL
0.0005056
0.0005059 6th-3
of
yy

EPSP_ELGA
0.0000686
0.0000687 4.7E-3
V43 of VARI_ELGA
0.0004846
0.0004846 5.8E-8

Into explicit

Identification Reference Aster % difference
of
xx
SIEF_ELGA
-210 -210
-8.24E-05
of
xx
EPSI_ELGA_DEPL
-0.00188
-0.00188 2.25E-4
of
yy
EPSI_ELGA_DEPL
0.0005021
0.0005021 1.83E-6
of
yy
EPSP_ELGA
0.0000682
0.0000682 2.22E-4
V43 of VARI_ELGA
0.0004813
0.0004813 5.21E-4

9
Summary of the results

The results obtained are in perfect agreement with the reference solution.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.172

Viscoplastic SSNV172 Behaviors
single-crystal

Summary:

This test makes it possible to validate the single-crystal behaviors in a uniaxial situation. Geometry treated is a cube, the stress and strain state is homogeneous. In order to test the laws as well as possible of
behavior, independently of the definition of the systems of slip, one uses a system here of particular slip, nonphysical, which represents a slip in only one direction. This allows
to compare two of the single-crystal viscoplastic behaviors, (with kinematic work hardening defined by
a variable of recall) to the macroscopic viscoplastic behaviors of Chaboche. For the others behaviors one checks only nonthe regression of the results.

All these tests are carried out in only one modeling.

---

1 Problem of reference

1.1 Geometry

P1
P2
P5
P6
P3
P4
Y
P7
P8
X
Z

One defines an element MA1, containing the P1 nodes, P2, P3, P4, P5, P6, P7 and P8.

1.2 Material properties

Elastic behavior with:
Young modulus: E = 145200MPa

Poisson's ratio: = 0.3

The first calculation (reference)

Behavior VISC_CIN1_CHAB
CIN1_CHAB=_F (R_0=75.5 MPa
R_I=85.27 MPa
B=19.34,
C_I=10.0 MPa
K=1.0,
W=0.0,
G_0=36.68,
A_I=1.0,),

LEMAITRE=_F (N=10.0,
UN_SUR_K=0.025 Mpa-1
UN_SUR_M=0.0,),

The second calculation: single-crystal, with system of UNIAXIAL slip

The behavior of the monocrystal is defined by:

Type of flow: ***ECOU_PLAS1*** *whose parameters are:*
C = 10MPa, N =
,
10 K = 40MPa

Isotropic type of work hardening: ***ECRO_ISOT1*** *whose parameters are:*
R
5
.
75 MPa
0 =

B = 19.34
Q = 77
.
9
MPa
H = 0

*Kinematic type of work hardening: **ECRO_CINE1** whose parameters are:*
D = 36.68

*The family of the systems of slip is: **UNIAXIAL***

The parameters used here, into uniaxial, correspond to those used for VISC_CIN1_CHAB, in noticing simply that Q = IH - 0
R.

The third calculation:

The behavior of the monocrystal is defined by:

*Type of flow: **ECOU_VISC2** whose parameters are:*
N = 10
K = 40 MPa
C = 10 MPa
D = 1010
= 0 have

*Isotropic type of work hardening: **ECRO_ISOT2** whose parameters are:*
R =
5
.
75
0
1
B = 19.34
b2 = 0
1
Q = 77
.
9

Q2 = 0
H = 0

*Kinematic type of work hardening: **ECRO_CINE2** whose parameters are:*
D = 36.68
10
M = 10
m = 0
C = 0

The family of the systems of slip is: ***UNIAXIAL***

There still, the parameters used here, into uniaxial, correspond to those used for VISC_CIN1_CHAB, by noticing simply that Q=R_I-R_0.

The fourth calculation:

The behavior of the monocrystal is identical to that of the second calculation (the difference comes from resolution: implicit in this case, and clarifies in the second calculation).

The fifth calculation:

The behavior of the monocrystal is this multiple time. Moreover its orientation compared to total reference mark of definition of the co-ordinates is defined by an angle of 30 degrees around Z.

For the family of systems of BASAL slip, the laws are:
Type of flow: ***ECOU_PLAS1*** *whose parameters are:*
C = 10MPa, N =
,
10 K = 40 MPa

Isotropic type of work hardening: ***ECRO_ISOT1*** *whose parameters are:*
R
5
.
75 MPa
0 =

B = 19.34
Q = 77
.
9
MPa
H = 0

Kinematic type of work hardening: ***ECRO_CINE1*** *whose parameters are:*
D = 36.68

For the family of systems of PRISMATIC slip, the behavior of the monocrystal is defined by:

Type of flow: ***ECOU_VISC2*** *whose parameters are:*
N = 10
K = 40 MPa

C = 10 MPa
D = 1010
= 0 have

Isotropic type of work hardening: ***ECRO_ISOT2*** *whose parameters are:*
R =
5
.
75
0
1
B = 19.34
b2 = 0
1
Q = 77
.
9

Q2 = 0
H = 0

Kinematic type of work hardening: ***ECRO_CINE2*** *whose parameters are:*
D = 36.68
10
M = 10
m = 0
C = 0

For the family of systems of slip CUBIQUE1, the behavior of the monocrystal is defined by:

Type of flow: ***ECOU_VISC3*** *whose parameters are:*
K = 40
= 10 MPa
μ

= 10
0
V = 1

Isotropic type of work hardening: ***ECRO_ISOT1*** *whose parameters are:*
R =
5
.
75
0
B = 19.34
Q = 77
.
9

H = 0

Kinematic type of work hardening: ***ECRO_CINE2*** *whose parameters are:*
D = 36.68
M = 10
m = 1.5
C = 1

For the family of systems of slip STIRRING, the behavior of the monocrystal is defined by:
Type of flow: ***ECOU_VISC3*** *whose parameters are:*
K = 40
= 10 MPa
µ

= 10
0
V = 1
Isotropic type of work hardening: ***ECRO_ISOT2*** *whose parameters are:*

R =
5
.
75
0
1
B = 19.34
b2 = 0
1
Q = 77
.
9

Q2 = 0
H = 0
Kinematic type of work hardening: ***ECRO_CINE1*** *whose parameters are:*
D = 36.68

1.3
Boundary conditions and loadings

.
P4 node
: DX = DY = 0
.
P8 node
: DX = DY = DZ = 0
.
Nodes P2 and P6
: DX = 0
.
Nodes P1, P3, P5 and P7
: FX = 25

*The loading is increasing FX = 0 with FX = 25 * 0.755 NR, in an increment, which leads to one uniaxial state of stresses of 75.5 MPa (limit of linearity)*
*The loading believes then until FX = 25 * 0.955 NR in 100 increments.*

---

2 *Reference solution*

2.1 *Method of calculation*

The first calculation (behavior VISC_CIN1_CHAB) is used as reference. Values obtained with last increment are (in any point of the mesh):

Constraint SIXX	*-9.55E+01*
Total deflection EPXX	*-6.7594E-04*
Plastic deformation EPXX	*-1.823E-05*

The second, third and the fourth calculations will be validated by comparison with this result. On the other hand,
the fifth calculation does not have a value of reference. The tests are thus of not-regression.

3 Modeling *With*

3.1 *Characteristics of the grid*

A number of nodes: 8.
*Modeling 3D: 1 element of quadratic volume: **HEXA8**.*
The structure contains only one grain, the stress and strain state is homogeneous.

The second, third and the fourth calculations will be validated by comparison with this result.
The second and the third calculations use an explicit integration (RUNGE_KUTTA).

The fourth calculation uses an implicit integration.

The fifth calculation uses an implicit integration, the selected orientation is
)
0
,
0
,
30
(
.

4
Results of modeling A

4.1 Functionalities
tested

Orders Options

DEFI_MATERIAU ECOU_VISC1

ECOU_VISC2
ECOU_VISC3
ECRO_ISOT1
ECRO_ISOT2
ECRO_CINE1
ECRO_CINE2
DEFI_COMPOR MONOCRYSTAL FAMI_SYST_GLIS
STAT_NON_LINE COMP_INCR
RELATION=' MONOCRISTAL'
COMPOR
RESO_INTE

4.2 Values
tested

The second calculation (clarifies, ECOU_VISC1, ECRO_ISOT1, ECRO_CINE1)

Identification Reference
***Aster** %*
difference
SIEF_ELGA
-95.5 -95.5
0
xx
of
-6.7594E-04
-6.7575E-04 0.03
xx
EPSI_ELGA_DEPL
EPSP_ELGA
-1.823E-05 -1.804E-05
1.04
xx

The third calculation (clarifies, ECOU_VISC2, ECRO_ISOT2, ECRO_CINE2)

Identification Reference
***Aster** %*
difference

of
xx
SIEF_ELGA
-95.5 -95.5
0
of
xx
EPSI_ELGA_DEPL
-6.7594E-04 -6.7575E-04
0.03
of
xx
EPSP_ELGA
-1.823E-05 -1.804E-05
1.04

The fourth calculation (implicit, ECOU_VISC1, ECRO_ISOT1, ECRO_CINE21)

Identification Reference
***Aster** %*
difference
of
xx
SIEF_ELGA
-95.5 -95.5
0
of
xx
EPSI_ELGA_DEPL
-6.7594E-04
-6.7624E-04 0.04
of
xx
EPSP_ELGA
-1.823E-05 -1.8528E-05
1.6

The fifth calculation (implicit, all behaviors, 4 families of systems of slip)
Test of nonregression

Identification Reference
Aster *%*
difference
of
xx
SIEF_ELGA
-95.5 -95.5
0
xx of EPSI_ELGA_DEPL
-6.7571E-04 -6.7571E-04
0

---

5 ***Summary of the results***

The results obtained are in concord with the reference solution. The noted difference (1.6% to the maximum) comes from the different numerical diagrams, sensitive to the discretization temporal.

8.2

Titrate:
SSNV173 Bar fissured with X-FEM

Date:
25/11/05
Author (S):
***S. GENIAUT**, Key P. MASSIN*
:
V6.04.173-B Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Linear statics of the voluminal structures
Document: V6.04.173

SSNV173 Bar fissured with X-FEM

Summary

The purpose of this test is to validate two aspects of elementary calculation within the framework of X-FEM [R7.02.12]:

· the integration of a discontinuous size thanks to a under-cutting of the element,
· the enrichment of the functions of form by the Heaviside function.

This test brings into play a parallelepipedic bar fissured on all its section, subjected to a displacement imposed, which has as a consequence the total opening of the crack and the separation of the two parts of structure.

The influence of the grid and the boundary conditions is also studied.

---

1 Problem of reference

1.1 Geometry

The structure is a right with low square and healthy parallelepiped. Dimensions of the bar (see [Figure 1.1-a]) are: LX = 5, LY = 5 and LZ = 25. It does not comprise any crack.

The crack will be introduced by functions of levels (level sets) directly into the file order using operator DEFI_FISS_XFEM [U4.82.08]. The crack is present in the middle of the structure by the means of its representation by 2 level sets LSN and LST (see [Figure 1.1-b]) of which them equations are as follows:

LSN (for the plan of crack): Z - LZ/2
éq
1.1-1
:

fissure)

of

melts

(for

LST
X -10
éq
1.1-2

Thus, the bottom of crack is located to Z = LZ/2 and at X = 10. It is thus located apart from the structure, it
who allows to have the structure completely cut into two.

Appear 1.1-a
Appear 1.1-b
Geometry of the bar and positioning of the crack

1.2
Properties of material

Young modulus: E= 205000 MPa

Poisson's ratio: = 0.3

1.3
Boundary conditions and loadings

The nodes of the lower face of the bar are embedded and a displacement is imposed on those of the higher face. One wishes to show here the possibility of separating a finite element into two with X-FEM.

Version
8.2

Titrate:
SSNV173 Bar fissured with X-FEM

Date:
25/11/05
Author (S):
S. GENIAUT, Key P. MASSIN
:
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2
Modeling a: only one finite element

2.1
Characteristics of the grid

The structure is modelled by only one finite element of type HEXA8. The crack is thus present at centre of this element by the means of the level sets.

2.2
Boundary conditions

Considering that the nodes close to the crack, i.e. here the 8 nodes of the grid are enriched by ddls additional, the boundary conditions are written a little differently. That relates to the enrichment of the traditional functions of forms [R7.02.12] by the function Heaviside H (X).

To impose a null displacement on the nodes of the lower face amounts writing a linear relation between the ddls. For each node, one imposes DCX H1X = 0 (idem according to y and Z) where DCX is the ddl traditional and H1X the enriched ddl.

For the nodes of the higher face, one imposes a displacement according to Z being worth 10-6 and no one following two other directions, i.e. DCX + H1X = 0, DCY + H1Y = 0 and DCZ + H1Z = 10-6.

2.3 Resolution
analytical

The solution of such a problem is of course obvious. It is seen well that mechanically speaking, both *left the structure will be detached: the lower part will have a null displacement and the part higher an overall movement equal to imposed displacement will have (see [Figure 2.3-b]).*

In our case, it does not occur anything according to X and y, and according to symmetries of the problem, one can
to study only on one vertical edge (for example that joining the noted nodes N1 and N2).
There are four conditions to satisfy:

· displacement of null the N1 node
· displacement of the point lower medium Has no one
· displacement of the node N2 equal to imposed displacement, noted uz
· displacement of the point medium higher A+ equal to uz

According to the formulation, these four conditions are written respectively:

dcz1 - H z1
1 = 0

1
dcz 0
0
1
1.-10 uz 2
1 (dcz1 - H z1
1 + dcz2 - H z2
1) = 0

1

2
1
H Z
1 2
1 2
1 2
1 2
0 uz 2

=
=

dcz2 + H z2
1 = uz
2
dcz
1 2 -1 2 1 2 -1 2

uz uz 2

2
1
-1
0
0
uz uz 2
1 (
1
H Z

dcz1 + H z1
1 + dcz2 + H z2
1) = uz

2

The analytical solution is then the following one: all the ddls according to X and are null there and all the ddls
according to Z are worth uz/2.

Titrate:

Appear 2.3-a
Appear 2.3-b

States initial and final of the structure

2.4 Functionalities
tested

Orders

DEFI_FISS_XFEM

MODI_MODELE_XFEM

3
Results of modeling A

3.1 Values
tested

One tests the values of displacement after convergence of the iterations of the operator STAT_NON_LINE. It is checked that one finds the values well determined with [§2.3].

Identification Reference
Aster %
difference
DCX for all the nodes
0.00
0.00
0.00
DCY for all the nodes
0.00
0.00
0.00
DCZ for all the nodes
0.5E-6
0.5E-6
0.00
H1X for all the nodes
0.00
0.00
0.00
H1Y for all the nodes
0.00
0.00
0.00
H1Z for all the nodes
0.5E-6

0.5E-6
0.00

To test all the nodes in only once, one test the MIN and the MAX of the column.

3.2 Comments

It is noticed that the values of the ddls Heaviside in Z are not null because there is discontinuity of field of displacement following this direction to the interface.
Handbook of Validation
V6.04 booklet: Linear statics of the voluminal structures
HT-66/05/005/A

4
Modeling b: Several finite elements

4.1
Characteristics of the grid

One discretizes the structure in 5 finite elements HEXA8

The nodes on both sides of the crack are nodes nouveau riches, therefore them three central meshs having such nodes are they also enriched.
Only the two extreme meshs are traditional meshs having only traditional nodes.

One will be able to thus impose boundary conditions on the extreme meshs in the usual manner.

4.2
Boundary conditions

The boundary conditions applied represents the same phenomenon physics that for modeling A. One embeds the nodes of the face lower and one imposes a displacement of the nodes of the face higher:
Appear 4.1-a: Grid

Lower face (Nodes N1, N6, N11, N16): DX = 0, DY = 0 and DZ = 0
Higher face (Nodes N21, N22, N23, N24): DX = 0, DY = 0 and DZ = uz.

This constitutes the 1st case of loading.

In fact, one takes freedom to move the higher part of the structure according to the three directions, one will thus choose like 2nd case of loading:
Lower face (Nodes N1, N6, N11, N16): DX = 0, DY = 0 and DZ = 0
Higher face: DX = ux, DY = uy and DZ = uz

ux = 10-6
uy = 2. 10-6
uz = 3. 10-6

4.3 Resolution analytical

The solution of such a problem is of course still obvious. In a way similar to [§2.3], one can to show that the solution is as follows:

Nodes of the lower face (stage n°0):
DX = 0, DY = 0 and DZ = 0.
Nodes of the stage n°1:
DX = 0, DY = 0 and DZ = 0.
Nodes of the stages n°2 and 3:
DCX = ux/2, DCY = uy/2, DCZ = uz/2,

H1X = ux/2, H1Y = uy/2 and H1Z = uz/2.
Nodes of the stage n°4:
DX = ux, DY = uy and DZ = uz.
Nodes of the higher face (stage n°5):
DX = ux, DY = uy and DZ = uz.

4.4 Functionalities tested

Orders

DEFI_FISS_XFEM

MODI_MODELE_XFEM

AFFE_CHAR_MECA LIAISON_XFEM

5
Results of modeling B

5.1 Values
tested

One tests the values of displacement after convergence of the iterations of the operator STAT_NON_LINE. It is checked that one finds the values well determined with [§4.3] for the 2 cases of loadings. One obtains the following table for the 2nd case of loading.

Identification Reference
***Aster** %*
difference
DX in N1 (stage n°0)
0.00
0.00
0.00
DY in N1 (stage n°0)
0.00
0.00

0.00
DZ in N1 (stage n°0)
0.00
0.00
0.00
N2 DX (stage n°1)
0.00
0.00
0.00
N2 DY (stage n°1)
0.00
0.00
0.00
N2 DZ (stage n°1)
0.00
0.00
0.00
DCX in N3 (stage n°2)
0.5E-6
0.5E-6
0.00
DCY in N3 (stage n°2)
1.0E-6
1.0E-6
0.00
DCZ in N3 (stage n°2)
1.5E-6
1.5E-6
0.00
H1X in N3 (stage n°2)
0.5E-6
0.5E-6
0.00
H1Y in N3 (stage n°2)
1.0E-6
1.0E-6
0.00
H1Z in N3 (stage n°2)
1.5E-6
1.5E-6
0.00
DCX in N4 (stage n°3)
0.5E-6

0.5E-6
0.00
DCY in N4 (stage n°3)
1.0E-6
1.0E-6
0.00
DCZ in N4 (stage n°3)
1.5E-6
1.5E-6
0.00
H1X in N4 (stage n°3)
0.5E-6
0.5E-6
0.00
H1Y in N4 (stage n°3)
1.0E-6
1.0E-6
0.00
H1Z in N4 (stage n°3)
1.5E-6
1.5E-6
0.00
DX in N5 (stage n°4)
1.0E-6
1.0E-6
0.00
DY in N5 (stage n°4)
2.0E-6
2.0E-6
0.00
DZ in N5 (stage n°4)
3.0E-6
3.0E-6
0.00
DX in N21 (stage n°5)
1.0E-6
1.0E-6
0.00
DY in N21 (stage n°5)
2.0E-6
2.0E-6
0.00
DZ in N21 (stage n°5)

3.0E-6
3.0E-6
0.00

One does not test with each time only one node of each stage.

5.2 Comments

It is noticed that the values of the ddls Heaviside in X, y and Z are not null because there is discontinuity field of displacement following these three directions to the interface.

6
Modeling C: Several elements and interfaces leaning

6.1
Characteristics of the grid and the interface

One considers a structure of dimensions LX = 5 m, LY = 5 m and LZ = 25 Mr. This structure are discretized with 5 finite elements HEXA8. One is interested in a plane interface of normal

1
-

N = 1

1

passing by point A of co-ordinates (5, 5, 5). [Figure 6.1-a] a zoom of the 2nd element shows where the trace of the interface is represented in red.

N9

Appear 6.1-a: Grid C and zoom

The interface is characterized by the level set normal having for Cartesian equation:

lsn = - X + y + Z -
5

Note:

The parameter has a strong influence on the problem. If 0 or 1 are worth, then point A coincides with a node, and the interface passes by this node. If is nonnull, but small in front of 1, the interface will separate the element into 2 part, very different volumes. In this situation, enrichment N9 node by the Heaviside function becomes almost useless, and led to very small pivots during the factorization of the matrix of rigidity. That results in a significant loss of a number of decimals and with a false result. For = a 0.1 (either point A accounting for 10% of the edge), one loses already 8 decimals (default value causing a fatal error) and for = 0.05, one lose 10 decimals. The idea thus consists in not enriching the N9 node by the function Heaviside when such cases arise. An algorithm of detection was set up, based on the volumetric ratio for an element crossed into two. This problem makes it possible to test the good operation of the algorithm, when the parameter becomes small.
In the continuation, one will take = 0.02. This value leads to the loss of 13 decimals at the time of factorization (before the installation of a special treatment).

The algorithm will be validated if calculation proceeds normally, without loss of decimals in factorization. One will check also solution displacement in a selected node.

6.2 Boundary conditions

The boundary conditions are the same one as those of modeling B. One embeds the nodes of the lower face and one impose a displacement of traction on the nodes of the higher face:

Lower face (Nodes N21, N22, N23, N24): DX = 0, DY = 0 and DZ = 0
Higher face (Nodes N13, N14, N15, N16): DX = 0, DY = 0 and DZ = 10-6.

6.3 Functionalities tested

The determination of the nodes where Heaviside enrichment is superabundant is carried out in order MODI_MODELE_XFEM [U4.44.11] and the cancellation of these ddls is carried out by the order AFFE_CHAR_MECA [U4.44.01] with key word LIAISON_XFEM=' OUI'.

Orders	
MODI_MODELE_XFEM	
AFFE_CHAR_MECA	*LIAISON_XFEM*

7
Results of modeling C

7.1 Values
tested

The good course of calculation makes it possible a priori to validate the case. Moreover, one tests the values of displacement with the N1 node of co-ordinates (0, 5, 0) as well as contact pressures (LAGS_C). One make sure that the displacement of the N1 node is correct and that contact pressures all are null (loading of traction).

Identification	***Reference***	***Aster***	*%* ***difference***
MIN (LAGS_C)	*0.00*	*0.00*	*0.00*
MAX (LAGS_C)	*0.00*	*0.00*	*0.00*
DCZ in N1	*5.E-7*	*5.E-7*	*0.00*
H1Z in N1	*5.E-7*	*5.E-7*	*0.00*

Recall:
DCZ is the component according to Z of the traditional ddl

H1Z is the component according to Z of the enriched ddl

8
Summaries of the results

The objectives of this test are achieved:

.
It is a question of validating the taking into account of enrichment by the Heaviside function of traditional functions of form.
.
Moreover, modeling B allowed the validation of the operand LIAISON_XFEM which allows to remove the ddls nouveau riches in excess.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.176

SSNV176 Identification of the law
ENDO_ORTH_BETON

Summary:

One presents here the tests of law ENDO_ORTH_BETON on a single element allowing to identify them
parameters of the model. Insofar as there is not empirical formula making it possible to gauge them
parameters, the user will be able to use some of the cases tests presented here to adjust his parameters. The study
parameters of the model is in documentation [R7.01.09]. The 5 tests suggested are as follows:

1) traction
simple
2) simple traction with piloting
3) compression
simple
4) simple compression with piloting
5) simple traction, simple compression and a biaxial test

1
Problem of reference

1.1
Geometry and boundary conditions

The element used is a tetrahedron at a point of gauss. There is thus no problem of homogeneity fields in the element.

The conditions of blockings and the relations linear between the nodes which should be applied are summarized
on [Figure 1.1-a]. Edges N0N1, N0N2 and N0N3 are length 1.

Taking into account the geometry of the element, conditions of blockings and relations linear, deformation is directly connected to displacements of the nodes:

= DX (N1)
xx
= DY (N2)
yy
= DX (N3)
zz
= DX (N2) =DY (N1)
xy
= DX (N3) =DZ (N1)
xz
= DY (N3) =DZ (N2)

yz

If one works with imposed deformation, it is thus enough to impose displacement on the adequate nodes.

If one wishes to work with imposed force, as it is the case for modeling E, it is necessary to impose them
following loadings (see it [Figure 1.1-a] for the definition of the faces F1, F2, F3 and F4):

> 0: FX on F1 and - 3/3FX on F4, FX<0 (traction according to X)
xx
< 0: FX on F1 and - 3/3FX on F4, FX<0 (compression according to X)
xx
> 0: FY on F2 and - 3/3FY on F4, FY<0 (traction according to y)
yy
< 0: FY on F2 and - 3/3FY on F4, FY<0 (compression according to y)
yy
> 0: FZ on F3 and - 3/3FZ on F4, FZ<0 (traction according to Z)
zz
< 0: FZ on F3 and - 3/3FZ on F4, FZ<0 (compression according to Z)
zz

N2
Blockings
:

N0: DX=DY=DZ=0

N0
Linear relations:
Traction/compression in imposed displacement:
N1
DY (N1) =DX (N2)
According to X DX imposed on N1
DZ (N1) =DX (N3)
According to y DY imposed on N2
DZ (N2) =DY (N2)
According to X DZ imposed on N3

N3

Definition of the faces:
Traction/compression in imposed force:

y
F1=N0 N2 N3
According to X: FX on F1 and - 3/3 FX on F4

F2=N0 N1 N3
According to y: FY on F2 and - 3/3 FY on F4

X
F3=N0 N1 N2
According to X: FZ on F3 and - 3/3 FZ on F4

Z
F4=N1 N2 N3

Appear 1.1-a: Geometry and boundary conditions of the uniaxial tests

---

1.2

Material properties

The characteristics materials are identical for the 5 tests which are presented.

The elastic characteristics of materials are as follows:

E = 32000 MPa; = 0.2

The breaking stresses in traction and compression are:

traction

= 3, 2 MPa;
compression

= 3
- 1,8 MPa
rupture
rupture

One uses the play of parameter following for the law of behavior:

ALPHA
K0 (Mpa) ECROB (MJ/m3)
ECROD (MJ/m3) K1 (Mpa)
K2
0.87 3.10-4 1.10-3 6.10-2 10.5
6.10-4

Note:

There are several sets of parameters which provide the same breaking stresses.
parameters were identified so that the envelope of rupture of the biaxial tests does not present
of swelling (cf Doc. [R7.01.09]).

The answers of the model for the uniaxial tests are represented below.

Appear 1.2-a: Response of law ENDO_ORTH_BETON in simple traction

Appear 1.2-b: Response of law ENDO_ORTH_BETON in simple compression

The internal variables, which are numbered in Aster, have the following significance:

V1=Dxx; V2=Dyy; V3=Dzz; V4=Dxy; V5=Dxz; V6=Dyz; V7=d;

Where D is the tensor representing the orthotropic damage of traction, and D is the damage isotropic of compression (cf Doc. [R7.01.09]).

2
Reference solution

This test is a test of nonregression.

Version
7.4

Titrate:
SSNV176 Identification of law ENDO_ORTH_BETON

3 Modeling With

3.1 Characteristics of modeling

Modeling 3D

Element MECA_TETRA4.

3.2 Characteristics of the grid

A number of nodes: 4

A number of meshs and types: 1 TETRA4

3.3 Functionalities tested

The law of behavior ENDO_ORTH_BETON in simple traction (without piloting).

3.4 Way of loading

The element is subjected to a uniaxial traction in direction X. displacement DX is imposed on N1 node.

3.5 Values tested

Moment
Name of the field
Component
Place
Aster
50
DEPL
DX N1 3.E-04
50
EPSI_ELGA_DEPL
EPXX
VOLUME, point 1
3.E-04
50
SIEF_ELGA
SIXX
VOLUME, point 1
1.11388E+00
50
VARI_ELGA
V1 (Dxx)
VOLUME, point 1
6.59365E-01
50
VARI_ELGA
V7 (D)
VOLUME, point 1
2.42260E-04

4 Modeling B

4.1 Characteristics of modeling

Modeling 3D

Element MECA_TETRA4.

4.2 Characteristics of the grid

A number of nodes: 4

A number of meshs and types: 1 TETRA4

4.3 Functionalities tested

The law of behavior ENDO_ORTH_BETON in simple compression (without piloting of the loading).

4.4 Way of loading

The element is subjected to a uniaxial traction in direction X. displacement DX is imposed on N1 node.

4.5 Values tested

Moment
Name of the field
Component
Place
Aster
50
DEPL
DX N1 -3.E-03
50
EPSI_ELGA_DEPL
EPXX
VOLUME, point 1
-3.E-03
50
SIEF_ELGA
SIXX
VOLUME, point 1
-2.74465E+01
50
VARI_ELGA
V2 (Dyy)
VOLUME, point 1
1.30416E-01
50
VARI_ELGA
V7 (D)
VOLUME, point 1
4.80080E-01

5 Modeling
C

5.1
Characteristics of modeling

Modeling 3D

Element MECA_TETRA4.

5.2
Characteristics of the grid

A number of nodes: 4

A number of meshs and types: 1 TETRA4

5.3 Functionalities
tested

The law of behavior ENDO_ORTH_BETON in simple traction (with piloting of the loading).

5.4
Way of loading

The element is subjected to a uniaxial traction in direction X. displacement DX is imposed on

N1 node. The difference with modeling A is that one uses the method of piloting of the loading PRED_ELAS (cf Doc. [R5.03.80]).

5.5 Values tested

Moment
Name of the field
Component
Place
Aster
51
DEPL
DX N1 1.44744E-04
51
EPSI_ELGA_DEPL
EPXX
VOLUME, point 1
1.44744E-04
51
SIEF_ELGA
SIXX
VOLUME, point 1
2.89945E+00
51
VARI_ELGA
V1 (Dxx)
VOLUME, point 1
2.08793E-01
51
VARI_ELGA
V7 (D)
VOLUME, point 1
2.30235E-04

6 Modeling D

6.1 Characteristics of modeling

Modeling 3D

Element MECA_TETRA4.

6.2 Characteristics of the grid

A number of nodes: 4

A number of meshs and types: 1 TETRA4

6.3 Functionalities tested

The law of behavior ENDO_ORTH_BETON in simple compression (with piloting of the loading).

6.4 Way of loading

The element is subjected to a uniaxial traction in direction X. displacement DX is imposed on

N1 node. The difference with modeling B is that one uses the method of piloting of the loading PRED_ELAS (cf Doc. [R5.03.80]).

6.5 Values tested

Moment	**Name of the field**	**Component**	**Place**	***Aster***
51	DEPL	DX	N1	-1.17993E-03
51	EPSI_ELGA_DEPL	EPXX	VOLUME, point 1	-1.17993E-03
51	SIEF_ELGA	SIXX	VOLUME, point 1	-2.86498E+01
51	VARI_ELGA	V2 (Dyy)	VOLUME, point 1	4.73153E-02
51	VARI_ELGA	V7 (D)	VOLUME, point 1	1.34312E-01

7 Modeling
E

7.1
Characteristics of modeling

Modeling 3D

Element MECA_TETRA4.

7.2
Characteristics of the grid

A number of nodes: 4

A number of meshs and types: 1 TETRA4

7.3 Functionalities
tested

One tests here the law of behavior ENDO_ORTH_BETON in 3 cases of loading:

1) U1: Simple traction
2) U2: Compression
3) U3: Biaxial loading (traction in the direction y, compression in direction X, with one
report/ratio fixes constraints:

= - 0.2
yy
xx

This case test makes it possible to check that the set of parameters chosen by the user respects the data following:

· breaking stresses in traction,
· breaking stresses in compression,
· not of swelling of the envelope of rupture for biaxial tests. That consists in checking that the maximum constraint in traction of the biaxial test is lower than the constraint of
yy
rupture in simple traction.

7.4
Way of loading

With the difference in modelings A, B, C and D, it is the force, and not the displacement, which is here imposed. One uses the method of piloting of loading PRED_ELAS, because the behavior is polishing substance. The following loadings are applied:

1) U
-
1: FX on F1,
3/3FX on F4, FX<0 (Traction)
2) U
-
2: FX on F1,
3/3FX on F4, FX>0 (Compression)
3) U
-
3: FX on F1,
3/3FX on F4, FX>0 (Compression according to axis X);
FY on F2, - 3/3FY on F4, with FY= -0,2 FX (Traction according to the axis y).

7.5 Values
tested

Moment	**Result**	**Name of the field**	**Component**	**Place**	***Aster***
42	U1	SIEF_ELGA	SIXX	VOLUME, point 1	3.20684E+00
76	U2	SIEF_ELGA	SIXX	VOLUME, point 1	-3.18000E+01
74	U3	SIEF_ELGA	SIXX	VOLUME, point 1	-1.42038E+01

One tests for each calculation, the maximum value (in absolute value) of the constraint. One obtains
xx
then the breaking stress in traction (U1), in compression (U2), and one checks that the constraint of traction in the biaxial test (U3) is lower than the breaking stress in simple traction (U1):

· U1: *traction*

= 3.20684 MPa
rupture

· U2: *compression*

= 31.8

-

MPa

rupture

· U3: *traction*

= - 0.2 *compression*

= 0.2*14.2038 MPa

traction

traction

<

U 3

U 3

U 3

rupture

Warning 1: It may be that the number of steps of time is insufficient to reach the phase lenitive. The user will thus check that for calculations U1 and U2, U3 calculation being subjected to one warning additional (cf **warning 2**), it is well in the lenitive phase (reduction in the parameter of piloting). The maximum constraint in absolute value should not be attack for the last step of time. In the contrary case, it is necessary to continue calculation until the phase lenitive.

Warning 2: It is possible, for certain set of parameters, to observe difficulties of convergence for U3 calculation at the time of the lenitive phase. Indeed, the law of behavior ensures the existence and the unicity of the solution in imposed deformation, but not in imposed force. These problems of convergence appearing only in the lenitive phase, the user will be able to consider the greatest value of the parameter of piloting reached, equal to the greatest constraint of compression reached in absolute value, like reference to gauge K2. This is true only

xx

if there are problems of convergence. If there is no problem of convergence for U3 calculation, and that the maximum constraint in absolute value is reached for the last step of time, calculation should be continued.

8
Summary of the results

The objective of the modelings presented in this document is to identify the parameters of the law ENDO_ORTH_BETON. Insofar as there is not empirical formula for the values of parameters to be used, the user will have to gauge his parameters step by step on the various tests proposed. The method to gauge the parameters, which is in the document [R7.01.09], can to be summarized as follows:

· choice of ALPHA: (0,85 to 0,9),
· calibration of K0, ECROB on modelings A, C or E (U1 calculation). Once these parameters gauged, it should not be modified in the phase of calibration of the other parameters,
· calibration of K1, K2 and ECROD on modelings B (or D) and E. In fact, modeling E (calculations U2 and U3) is enough. It makes it possible to check the value of the breaking stress in simple compression, and to ensure that the envelope of rupture for biaxial tests do not inflate. It is not necessary to gauge the K2 parameter in a very fine way bus it rise from a qualitative argument, and no experimental data is never available for to identify.

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7.4

Titrate:
SSNV179 - Cubic under creep via law LEMA_SEUIL

Date:
22/07/05
Author (S):
***S. LECLERCQ**, L. SALMONA Key*
:
V6.04.179-A Page:
1/6

Organization (S): EDF-R & D /MMC, CS IF

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.179

SSNV179 - Cubic under creep via law LEMA_SEUIL

Summary:

The purpose of this test is to validate law LEMA_SEUIL derived from the law of traditional LEMAITRE. In particular, us

we will delay on the activation of the specific threshold to this law. One thus carries out a creep test on one
geometry simple to know a cube here.

A modeling 3D with elements HEXA8 is currently available.

1
Problem of reference

1.1 Geometry

D C

Z

B
With
y

X

H

G

F

E

Co-ordinates of the points:

WITH B C D E F G H
0. 1.
1. 0. 0.
1. 1. 0.
0. 0.
1. 1. 0.
0. 1. 1.
0. 0. 0. 0. -1.
-1.
-1. -1.

1.2
Material properties

Elastic properties:

E = 165000 MPa

= 0.3

Viscous properties:

Law of LEMA_SEUIL

To = 14.143 10-13 MPa-1.neutron-1
S = 0.0788 1010 MPa-1.s-1

1.3
Boundary conditions and loadings

Surface force:

F = 220 MPa

Irradiation:
Flow of irradiation: 1.85 1015 neutrons.cm 2.s-1.

Imposed displacements:

Node a: DX=DY=DZ=0.
Node E: DX=DY=0.
Node D and node H: DX=0.
On the first increment of time the force passes from 0 to its maximum value 220 MPa linearly by report/ratio at time for then being maintained constant over all the duration of the experiment.

2
Reference solution

2.1
Method of calculation used for the reference solution

The goal of the reference solution is analytically to calculate the value of the threshold from which creep appears.
Some results of nonregression on displacements with the last step of time are added
to check the total rigidity of the system.

For the analytical calculation of the threshold one a:

As long as the structure remains elastic and because of the boundary conditions, the tensor of the constraints is written:

· For the first step of time ranging between 0 and 106 S
(T
4
-
xx) =
2
.
2 10 T, T in second and xx in MPa. The other components of the tensor are null.
· For the others not of time, = 220 MPa
xx

However one a:
T
1
D = U of
eq ()
S 0

Maybe as in this case
=, one obtains in an immediate way by solving D=1 the value of
eq
xx
time from which creep is declared: T1 = 4.08181818 106 S

Thus for a time equal to T1, the viscous deformations are null and D is worth 1.

2.2
Results of reference

Variable interns V1 and V2 at the point A, B, C and E as well as the displacement of the points B to the last step of time

2.3 References bibliographical

[1]
P. BONNIERES: Integration of the viscoelastic relations in STAT_NON_LINE
[R5.03.08] February 2001
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/05/005/A

---

3 Modeling With

3.1 Characteristics of modeling

Elements 3D (HEXA8)

Only one element was modelled to represent the cube

D C

Z
y

B
With

X

H

G

E
F

Along axis Z:
1 layer of elements
Total thickness:
1

Limiting conditions:

Node A
DX=DY=DZ=0.
Node E
DX=DY=0.
Node D
DX=0.
Node H
DX=0.

pressure on face BCFG
F = 220. MPa

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8 and 1 QUAD4 (faces external skin).

3.3 Functionalities
tested

Orders

AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

FORCE_FACE
GROUP_MA

"MECHANICAL" AFFE_MODELE "3D"
ALL

DEFI_MATERIAU LEMA_SEUIL_FO

CALC_ELEM "VARI_ELNO_ELGA"

"SIEF_ELNO_ELGA"

---

4 ***Results of modeling A***

4.1 Values tested

Localization Size
Reference
***Aster** %*
difference

In V1
0.00000000
0.00000000 0%
V2
1.00000000
9.9999999949239
10-01 -5.08
10-8%
B V1
0.00000000
0.00000000 0%
V2
1.00000000
9.9999999949239
10-01 -5.08
10-8%
DX
/
7.8380536694423
10-2 /
DY
/
1.2984914071992
10-16
/
DZ
/
1.2984914071992
10-16 /
C V1 0.00000000
0.00000000 0%
V2
1.00000000
9.9999999949239
10-01 -5.08
10-8%
E V1
0.00000000
0.00000000 0%
V2
1.00000000
9.9999999949239
10-01 -5.08

10-8%

5
Summary of the results

The objective of this case test is completely filled since activation of creep via the detection of threshold is very precise (about 10-8% of error). Of course, since it is about viscous phenomenon, the discretization in time plays a very important part in particular in the surrounding of the activation of the threshold.
In this case test a very particular care was taken to surround time when the threshold is reached in way specify to obtain satisfactory results.

Organization (S): EDF-R & D /MMC

Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
Document: V6.04.180

SSNV180 - Taking into account of dilation thermics and of the creep of desiccation in model BETON_UMLV_FP

Summary:

This test makes it possible to validate the taking into account of thermal dilation and the creep of desiccation in the law of behavior BETON_UMLV_FP. The results of this test are compared with a numerical solution *obtained with Scilab 2.7.2 in the case of a modeling 3D.*

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

Height:
H = 1,00 [m]
Width:
L = 1,00 [m]
Thickness: E = 1,00 [m]

1.2
Properties of material

E = 31 [GPa]
modulus of elasticity
= ,
0 2
Poisson's ratio
kre = 60 [µm/m]
endogenous coefficient of withdrawal
krd = 10 [µm/m.m3/l]
coefficient of withdrawal of desiccation
=10 [µm/m/°C]

thermal dilation coefficient

Here one informs also the curve sorption-desorption which connects the water content C to the hygroscopy h.
In this case one supposed that the two quantities were connected by the following linear relation:
C [l/m3] = H [%].

Parameters specific to clean creep:

K Sr =,
1 20th + 5 [MPa]
spherical part: rigidity connects associated with the skeleton formed by
blocks of hydrates on a mesoscopic scale

K if =,
6 22E + 4 [MPa]
spherical part: rigidity connects intrinsically associated with
hydrates on a microscopic scale

K Dr. = 86
,
3
E + 4 [MPa]
deviatoric part: rigidity associated with the capacity with water adsorbed with
to transmit loads (load bearing toilets)
S

R =,
2 21E +10 [MPa.s]
spherical part: viscosity connects associated with the mechanism with
diffusion within capillary porosity
S

I =
16
,
4
E +10 [MPa.s]
spherical part: viscosity connects associated with the mechanism with
diffusion interlamellaire
D

R =
19
,
6
E +10 [MPa.s]
deviatoric part: viscosity associated with the water adsorbed by layers of hydrates
D

I = 64
,
1
E +12 [MPa.s]
deviatoric part: viscosity of interstitial water.

Parameters specific to the creep of desiccation:

= 30
.
5
E + 4
fd
[MPa.s]

1.3

Boundary conditions and loadings

In this test, one creates a homogeneous field of drying in the structure varying linearly on one 750 days duration, initial moisture is worth 100% (condition of a sealed test-tube) and decrease gradually up to 50% with the 750ème day.
The degree of hydration varies linearly from 0 to 1 between the initial moment and the 28th day.
The temperature of reference is worth 20°C. The thermal loading corresponds to a rise in temperature varying of 20 °C and 40°C between the initial moment and the final moment.
The mechanical loading corresponds to an one-way compression according to the direction vertical (Z in 3D); its intensity is 12 [MPa]. The load is applied in 1s and is maintained constant during 100 days.

1.4 Conditions initial

The beginning of calculation is supposed moment 1. At this moment there is neither field of drying, nor forced mechanics.
At moment 0, one applies a field of drying corresponding to 100% of hygroscopy, a field of hydration corresponding to a null advance and a thermal field to the temperature of reference.

---

2 Reference solution

2.1
Method of calculation

One did not develop the analytical solution for this hydro-mechanical loading. Also, the solution from reference is obtained numerically by using the software Scilab 2.7.2. Each component of deformation is calculated separately:

· the deformations of endogenous withdrawal are given starting from the relation:
-
Re = K
.
Re
where the degree of hydration of material indicates
· the deformations of withdrawal of desiccation are given starting from the relation:
-
& = K C
. &
rd
rd
where C indicates the water content of material
· the deformations of thermal dilation are given starting from the relation:
-
HT = (T - ref.
T
) where T and ref.
T
indicate the temperature at the moment respectively
running and the temperature of reference of material
· the deformations of clean creep are calculated numerically by using one
discretization identical to that established in Code_Aster.
· the deformations of creep of desiccation are calculated analytically from
relation:
1
-
& =
h&
fd
where H = F (C) indicates the moisture of material
fd
The results of calculation with Scilab are presented in the figure below.

2.2
Sizes and results of reference

The test is homogeneous. One tests the deformation in an unspecified node.

2.3
Uncertainties on the solution

Numerical result obtained with Scilab 2.7.2.

2.4 References bibliographical

[1]
POPE Y.: Relation of behavior UMLV for the clean creep of the concrete,
Reference material of Code_Aster, [R7.01.06] 16 p (2002).

3 Modeling With

3.1 Characteristics of modeling

Modeling 3D
Z
NO7
NO6
NO8
NO5
NO2
NO3
y
NO4
NO1
X

3.2 Characteristics of the grid

A number of nodes: 8
A number of meshs: 1 of type HEXA 8

6 of type QUAD 4

The following meshs are defined:

S_ARR
NO3 NO7 NO8 NO4
S_AVT
NO1 NO2 NO6 NO5
S_DRT

NO1 NO5 NO8 NO4
S_GCH
NO3 NO2 NO6 NO7
S_INF
NO1 NO2 NO3 NO4
S_SUP
NO5 NO6 NO7 NO8

The boundary conditions in displacement imposed are:

On nodes NO1, NO2, NO3 and NO4: DZ = 0
On nodes NO3, NO7, NO8 and NO4: DY = 0
On nodes NO2, NO6, NO7 and NO8: DX = 0

The loading is consisted of the same field of drying and the same nodal force 1/4 applied on the four nodes of S_SUP.

3.3 Functionalities tested

Orders
Key word

DEFI_MATERIAU ELAS_FO

K_DESSIC

BETON_UMLV_FP
B_ENDOGE
FONC_DESORP
K_RS
K_IS
K_RD
V_RS
V_IS
V_RD
V_ID
CREA_CHAMP "AFFE"
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
CREA_RESU "AFFE"
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
AFFE_CHAR_MECA DDL_IMPO

LIAISON_UNIF
FORCE_NODALE
SECH_CALCULEE
HYDR_CALCULEE
STAT_NON_LINE COMP_INCR
RELATION= `BETON_UMLV_FP'

3.4
Sizes tested and results

Component xx with node NO6 was tested.

Moment Reference
***Aster** %*
difference
64800
-4.081E-04
-4.0854E-04
0.108
648000
-5.250E-04

-5.2533E-04
0.063
6480000
-9.065E-04
-9.0689E-04
0.043
64800000
-22.990E-04
-23.0189E-04
0.126

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HT-66/05/005/A

4
Summary of the results

The values obtained with Code_Aster are in agreement with the values of the numerical solution of reference.

Organization (S): EDF-R & D /MMC

Handbook of Validation
V6.04 booklet: Non-linear statics of the voluminal structures
Document: V6.04.181

SSNV181 - Checking of the good taking into account
shearing in model BETON_UMLV_FP

Summary:

This test makes it possible to validate the good taking into account of shearing in the law of behavior BETON_UMLV_FP. The results of this test are compared with an analytical solution.

Author (S):
Y. The Key POPE

1
Problem of reference

1.1 Geometry
Z
E
H
y
X
L

Height:
H = 1,00 [m]
Width:
L = 1,00 [m]
Thickness:
E = 1,00 [m]

1.2
Properties of material

E = 31 [GPa] modulus of elasticity
= ,
0 2
Poisson's ratio

Parameters specific to clean creep:

K Sr =,
1 20th + 5 [MPa]
spherical part: rigidity connects associated with the skeleton formed by blocks of hydrates on a mesoscopic scale

K if =,
6 22E + 4 [MPa]
spherical part: rigidity connects intrinsically associated with hydrates on a microscopic scale

K Dr. = 86
,

3
E + 4 [MPa]
deviatoric part: rigidity associated with the capacity with water adsorbed with
to transmit loads (load bearing toilets)

Sr =,
2 21E +10 [MPa.s]
spherical part: viscosity connects associated with the mechanism with
diffusion within capillary porosity

if = 16
,
4
E +10 [MPa.s]
spherical part: viscosity connects associated with the mechanism with
diffusion interlamellaire

Dr. = 19
,
6
E +10 [MPa.s]
deviatoric part: viscosity associated with the water adsorbed by the layers
hydrates

di =, 164E +12 [MPa.s]
deviatoric part: viscosity of interstitial water.

1.3 Boundary conditions and loadings

In this test, one creates a field of homogeneous and constant drying in the structure.
The mechanical loading corresponds to a shearing in the xz plan; its intensity is of
10 [MPa]. The load is applied in 1s and is maintained constant for 750 days.

1.4 Conditions initial

The beginning of calculation is supposed moment 1. At this moment there is neither field of drying, nor forced
mechanics.
At moment 0, one applies a field of drying corresponding to 100% of hygroscopy.

---

2 Reference solution

2.1 Method of calculation

The analytical solution rests on the resolution of the two differential equations which control deviatoric part of the behavior (cf [R7.01.06]).

The deviatoric constraints are at the origin of a mechanism of slip (or mechanism of quasi dislocation) of the layers of HSC in nano-porosity. Under deviatoric constraint, creep be carried out with constant volume. In addition, the law of creep UMLV supposes the isotropy of creep deviatoric. Phénoménologiquement, the mechanism of slip comprises a contribution reversible viscoelastic of the water strongly adsorbed with the layers of HSC and a contribution irreversible viscous of interstitial water:

fd
fd
fd

=

+
éq
2.1-1
{
{
R
{
I
contribution
deformation
contribution
water
ue
déviatoriq
water
absobée
total
free

The principal component jème of the total deviatoric deformation is governed by the equations [éq 2.1-2] and [éq 2.1-3]:

D D, J
D D, J
D J
R &r + K
,
R R
= H

éq
2.1-2

where D
Kr indicates rigidity associated with the capacity with water adsorbed to transmit loads (load bearing toilets);
and D
R viscosity associated with the water adsorbed by the layers with hydrates.

D D, J
D J
I &
=
I
H
,

éq 2.1-3

where D
I indicates the viscosity of interstitial water.
In the case of a level of constraint xz, the corresponding deformation of creep deviatoric is immediately deduced:

D
ki T

- D
T

F

xz = xz
+ 1-
I
E
éq

2.1-4
D
I

When the elastic part is added, it follows that the total deflection of shearing is worth:

D
K

- I T
D

F
1
T
xz =
+

I
xz
+
+ 1 - E
éq
2.1-5

D
E

I

2.2
Sizes and results of reference

The test is homogeneous. One tests the deformation in an unspecified node.

2.3
Uncertainties on the solution

Analytical solution.

2.4 References
bibliographical

[1]
POPE Y.: Relation of behavior UMLV for the clean creep of the concrete,
Reference material of Code_Aster [R7.01.06] 16 p (2002).

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D
Z
NO7
NO6
NO8
NO5
NO2
NO3
y
NO4
NO1
X

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs: 1 of type HEXA 8

6 of type QUAD 4

The following meshs are defined:

S_ARR
NO3 NO7 NO8 NO4
S_AVT
NO1 NO2 NO6 NO5
S_DRT
NO1 NO5 NO8 NO4
S_GCH
NO3 NO2 NO6 NO7
S_INF
NO1 NO2 NO3 NO4
S_SUP
NO5 NO6 NO7 NO8

The boundary conditions in displacement imposed are:

On nodes NO1, NO2, NO3 and NO4: DZ = 0
On nodes NO3, NO7, NO8 and NO4: DY = 0
On nodes NO2, NO6, NO7 and NO8: DX = 0

The loading is consisted of the same field of drying and the same nodal force 1/4 applied on the four nodes of S_SUP.

3.3 Functionalities

tested

Orders
Key word

DEFI_MATERIAU ELAS_FO

FONC_DESORP

BETON_UMLV_FP
K_RS
K_IS
K_RD
V_RS
V_IS
V_RD
V_ID
CREA_CHAMP "AFFE"
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
CREA_RESU "AFFE"
NOM_CMP=' TEMP'

TYPE_CHAM=' NOEU_TEMP_R'
AFFE_CHAR_MECA DDL_IMPO

LIAISON_UNIF
FORCE_NODALE
STAT_NON_LINE COMP_INCR
RELATION= `BETON_UMLV_FP'

3.4
Sizes tested and results

Component xx with node NO6 was tested.

Moment Reference
Aster %
difference
64800
+3.975E-04

+3.997E-04
0.063
648000
+4.770E-04
4.771E-04
0.035
6480000
+6.811E-04
+6.811E-04
0.003
64800000
+10.413E-04
+10.413E-04
-0.001

4
Summary of the results

The values obtained with Code_Aster are in agreement with the values of the analytical solution of reference.

Code_Aster ®
Version
8.2

Titrate:
SSNV182 Block in contact with X-FEM

Date:
25/11/05
Author (S):
S. GENIAUT, Key P. MASSIN
:
V6.04.182-B Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.182

SSNV182 Block with interface in rubbing contact with X-FEM

Summary

The purpose of this test is to validate the taking into account of the contact on the lips of the crack, while being limited if
the crack crosses the structure completely. The contact is taken into account by the method continues [bib1]
adapted to the framework of method X-FEM [bib2].

This test brings into play a parallelepipedic block in compression. The interface the beam is represented by one
levet set within the framework of X-FEM. One takes into account several angular positions of the interface: = 0°
(the interface follows the faces of the elements) and = 22.5° (the interface cuts the elements). By taking a coefficient
of friction of sufficiently high Coulomb so that there is adherence, one finds the solution of same problem without interface.

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1
Problem of reference

1.1 Geometry

The structure is a right at square base and healthy parallelepiped. Dimensions of the block (see [Figure 1.1-a]) are: LX = 5 m, LY = 20 m and LZ = 20 Mr. It does not comprise any crack.

The interface is introduced by functions of levels (level sets) directly into the file order using operator DEFI_FISS_XFEM [U4.82.08]. The interface is present in the middle of the structure by the means of its representation by the level sets. The level set normal (LSN) allows to define a plane interface forming an angle with the Oxy plan by the following equation:

LSN= Z - (aY + b)

éq 1.1-1

LZ
LY
where A is the slope of the interface, that is to say has = - tan ()
and B =
- has
.

2
2

Appear 1.1-a: Geometry of the bar and positioning of the interface

1.2 Properties of material

Young modulus: E= 100 MPa
Poisson's ratio: = 0.

1.3 Boundary conditions and loadings

The nodes of the lower face of the bar are embedded and a displacement UZ = -10-6 m is imposed on those of the higher face which corresponds to a loading in pressure along axis Z. Displacements along axes X and are blocked there for the nodes of the upper surface.

1.4 Characteristics of the grid

The structure is modelled by a regular grid composed of 5x20x20 HEXA8 [Figure 1.4-a].

Appear 1.4-a: Grid

This grid is composed of linear finite elements. However, within the framework of the continuous method [bib1] with X-FEM [bib2], it is necessary to pass to a little special linear elements. These elements have linear functions of form and a quadratic mesh support. On these elements, them nodes top carry the unknown factors of displacement, and the nodes medium carry the dependent unknown factors with the contact. Moreover, when the interface follows the edge of an element, its nodes top carry too unknown factors of contact.

---

2 Modeling a: interfaces right

In this modeling, one represents a right interface, the angle is worth 0 then. The interface coincides with the faces of certain finite elements.

2.1 Resolution analytical

The interface being right, and the state of uniaxial pressing and normal to the interface, it does not have there possible slip. The solution of the problem is that of the same problem without interface.
The constraint in the structure is:

UZ
= E

éq 2.1-1
zz
LZ

and the value of the contact pressure on the interface is:

=

éq 2.1-2
zz

With the numerical values previously introduced, = -5.0 Pa.

2.2 Functionalities tested

Orders

DEFI_FISS_XFEM CONTACT

This case does not require the activation of friction. Under the key word CONTACT of the operator DEFI_FISS_XFEM, one stipulates FROTTEMENT=' SANS' then.

Moreover, as of the first iteration of the active constraints, one makes the assumption that the points of contact
have a contacting statute. This is possible by specifying CONTACT_INIT=' OUI'.
If not, at the end of the first iteration, the contact not being activated, the higher block returns in
lower block but the two blocks did not become deformed. Their state of stresses is thus null, and it
is then necessary to choose a total criterion (RESI_GLOB_MAXI) for the convergence of the algorithm of
Newton-Raphson [bib3], criterion which is likely to be unsuited in the continuation of calculations when the contact
will be activated.
To avoid that, and to have a relative criterion, one needs a state of stresses not no one as of the first
iteration, and thus to activate the contact as of the beginning.

The algorithm of the active constraints thus converges in an iteration.

---

3 Results of modeling A

3.1 Values tested

One tests the values of the normal pressure of contact after convergence of the iterations of
operator STAT_NON_LINE and of the loop on the active constraints. One tests all the points of
contact, which corresponds to the nodes of the grid on the interface. It is checked that one finds them

well
values determined with [§2.1].

Identification Reference
***Aster** %*
difference
LAGS_C for all the nodes of
-5.00
-5.00
0.00
the interface

To test all the nodes in only once, the MIN and the MAX of the column are tested.

3.2 Comments

This modeling shows the possibilities of the continuous method of contact applied to the framework X-FEM. The advantage is that the procedure of pairing is intrinsic with method X-FEM since here, there are not really surface Master and slave considering whom one has only one surface.

4
Modeling b: interfaces leaning

In this modeling, one represents a leaning interface. The angle is worth 22.5°, that is to say a slope has

being worth -1/2. The interface does not coincide any more with the faces of the finite elements, and cuts them now
elements. The normal with the interface is noted ***N*** *and the tangent vector is noted:*

0
0

N *= 1 5, = 2 5*

éq 4-1

2 5
-1 5

4.1 Resolution analytical

The interface being leaning, it is likely y to have slip. To avoid that, one forces adherence in choosing a coefficient of friction of sufficiently high Coulomb. Theoretically, it is enough to to take:
μ > tan ()

éq 4.1-1

Thus, the solution of the problem remains identical to that of the same problem without interface. The constraint in the structure is always that of [éq 2.1-1], and the value of the contact pressure on the interface is a function of normal ***N*** *to the interface:*

*= **N N** = N N*
éq
4.1-2
Z
zz Z
*where nz is the component according to Z of **N**.*

The semi-multiplier of friction is defined by:

***R** =*

μ

éq 4.1-3

With the density of tangential stress being written as follows:

***R** =*

éq 4.1-4

(N)

From where:
*1 **N***
1
=
=
Z

éq
4.1-5
*µ **N N***

µ nz
M = 1 is taken.
With the numerical values previously introduced, = - 0
.
4 Pa and = - 5
.
0 .

4.2 Functionalities
tested

Orders

DEFI_FISS_XFEM CONTACT

This case requires the activation of friction. Under the key word CONTACT of the operator DEFI_FISS_XFEM, one stipulates FROTTEMENT=' COULOMB' then.
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Code_Aster ®
Version
8.2

Titrate:
SSNV182 Block in contact with X-FEM

Date:

5
Results of modeling B

5.1 Values
tested

One tests the values of the normal pressure of contact and the semi-multiplier of friction afterwards convergence of the iterations of operator STAT_NON_LINE, the loop on the active constraints and loop on the thresholds of friction. All the points of contact are tested. It is pointed out that these points of contact can be of two kinds: either of the nodes top, or of the nodes medium, according to whether the interface cuts or not the elements.
It is checked that one finds well the values determined with [§4.1]. LAGS_F1 corresponds to semi-multiplier of friction in direction OX (it is thus null), whereas LAGS_F2 corresponds with the semi-multiplier of following friction.

Identification	***Reference***	***Aster***	*%* ***difference***
LAGS_C for all the points of contact	*-4.00*	*-4.00*	*0.00*
LAGS_F1 for all the points of contact	*0.00*	*2.10-14*	*0.00*
LAGS_F2 for all the points of contact	*-0.50*	*-0.50*	*0.00*

To test all the points of contact in only once, the MIN and the MAX of the column are tested.

5.2 Comments

Let us specify that in this study, the key word CONTACT_INIT = "YES" makes it possible to begin the loop on the active constraints with an assumption of statute contacting for all the points of contact. That authorizes to take a relative criterion ("RESI_RELA_MAX") for the convergence of the iterations of Newton. Indeed, if one selected CONTACT_INIT = "NOT", at the time of the phase of prediction of Newton, it contact not being activated, the higher structure moves without becoming deformed, and that lower remain motionless. The constraints are then null and a relative criterion is not usable, only a criterion total is, whose value is left with the choice of the user. The problem is that this value can to reveal calculation (active contact thereafter….) inadequate with the loadings and the constraints then in play. Thus, it is to better provide to take a single relative criterion as of the beginning.

Moreover, the initial value of the threshold of friction was taken to -1011 in order to be sure that one has adherence as of the 1st iteration on the thresholds of friction.

6
Modeling C: interface right and under-integration

This modeling is exactly the same one as modeling A, except that the diagram of integration numerical the terms of contact changed.
In modeling A, one uses a diagram of Gauss at 12 points by triangular facets of

contact. In modeling C, one only uses a diagram reduced to 4 points.
Indeed, the diagram must allow the exact integration of a constant field of pressure. The intégrande on the facet is then a students'rag procession in
xi yi
with I + J 3.

According to [bib4], a diagram at 4 points of Gauss is enough.

6.1 Functionalities tested

Orders

DEFI_FISS_XFEM CONTACT
INTEGRATION=' FPG4'

7 Results of modeling C

7.1 Values tested

One tests the same values as for modeling A.

Identification Reference
***Aster** %*
difference
LAGS_C for all the points of contact
-5.00
-5.00
0.00
LAGS_F1 for all the points of contact
0.00
0.00
0.00
LAGS_F2 for all the points of contact
0.00
0.00
0.00

To test all the nodes of the interface in only once, one tests the values min and max.

7.2 Comments

This modeling shows that a diagram of integration reduced to 4 points makes it possible to pass the patch test
where the solution in pressure is constant.

8
Summaries of the results

The objectives of this test are achieved:

.
It is a question of showing the feasibility of the taking into account of the contact rubbing on the lips of fissure with the method continues adapted to framework X-FEM. Only the case of a crack crossing the structure completely was considered (interface).
.
The cases where the interface follows the border of the elements (= 0°) and where the interface cut them elements (= 22.5°) were validated.

9 Bibliography

[1]
MASSIN P., BEN DHIA H., ZARROUG Mr.: Elements of contacts derived from a formulation continuous hybrid, Manual of reference of Code_Aster, [R5.03.52]
[2]
MASSIN P., GENIAUT S.: Method X-FEM, Handbook of reference of Code_Aster, [R7.02.12]
[3]
TARDIEU NR., VAUTIER I., LORENTZ E.: Quasi-static nonlinear algorithm, Handbook of Reference of Code_Aster, [R5.03.01]
[4]
DHATT G., TOUZOT G.: A presentation of the finite element method, Maloine ED., PARIS

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Code_Aster ®
Version
8.1

Titrate:
SSNV183 Creep test with model VENDOCHAB

Date:
01/09/05
Author (S):
O. DIARD Key
:
V6.04.183-A Page:
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Organization (S): EDF-R & D /MMC

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.183

SSNV183 - Creep test with the model
VENDOCHAB

Summary:

Model VENDOCHAB, takes again a formulation suggested by Chaboche. It is about a coupled formulation
who covers a élasto-viscoplastic law with multiplicative isotropic work hardening and kinetics
of isotropic damage. This law was initially developed to predict the lifespan and cracking
paddles of the turbojets and more generally to envisage the time of ruin of the structures requested with
high temperatures.

This test of nonlinear quasi-static mechanics makes it possible to validate model VENDOCHAB in 3D in the case
of a test-tube subjected to an isothermal uniaxial creep test. Stress and strain states
are homogeneous in the test-tube. This test validates the explicit integration of this model. Equations of this
coupled formulation are described in the booklet of reference [R5.03.15].

The modeling of the test-tube is carried out with an element 3D with 8 nodes (HEXA8).

1
Problem of reference

1.1 Geometry

The geometry is selected voluntarily simple, to translate a stress and strain state homogeneous, as it is the case in uniaxial creep. It is here about an element of volume represented by a cube on side 3 Misters modeling is voluminal and creep is done with imposed constraint.

1.2
Properties of material

The characteristics are as follows:

Key word ELAS:

YOUNG = 150000.0 MPa
NAKED = 0.30

Key word VENDOCHAB:

S_VP = 0. ,
SEDVP1 = 0. ,
SEDVP2 = 0. ,
N_VP = 12. ,
M_VP = 9. ,
K_VP = 2110. ,
A_D = 3191. ,

R_D = 6.3,
K_D = 14.

1.3
Boundary conditions and loadings

DZ = 0 on the lower side (Z==0)
DY = 0 on the left side (Y==0)
DX = 0 on the side postpones (X==0)

Pressure of 200 MPa imposed on the upper surface, such as:
P = 0 with T = 0s
P = 200 MPa with T = 0.1s
P = 200 MPa until T = 2.5.106s

This corresponds to a uniaxial creep test under a constant loading of 200 MPa.

1.4 Conditions
initial

Null constraints and deformations.

2
Reference solution

2.1
Method of calculation

Analytical solution for the variable of damage D:

1
R
+

0
1
D (T)

= 1 - 1 - (1+ K)
K

T

With

0,3
0,25
0,2
0,15
0,1
Damage D
0,05
0
0,00E+00 5,00E+05 1,00E+06 1,50E+06 2,00E+06 2,50E+06 3,00E+06
Time (S)

Analytical solution for the variable of isotropic work hardening viscoplastic, R, in the case of a threshold
Y null:
M
+
1 K - NR

M + NR

- R
NR
R

+

1

+

0
0
0

R (T)
(MR. NR)
K
=

1 - 1 - 1
(+
)

M (1+ K - NR)
K
T
WITH K

With

0,008
0,007
(
R
)
0,006
0,005
0,004
0,003
C
isotropic steeping
0,002
0,001
Varaible of é
0
0,00E+00 5,00E+05 1,00E+06 1,50E+06 2,00E+06 2,50E+06 3,00E+06
Time (S)

In the preceding expressions, D is the variable of damage corresponding to the variable *intern VARI_9 and R are the variable of multiplicative viscoplastic work hardening corresponding to internal variable VARI_8.*

There is also the correspondence following, by reports/ratios with the parameters of key word VENDOCHAB:

NR = N_VP
M = M_VP
K = K_VP
WITH = A_D
R= R_D
K = K_D

2.2
Sizes and results of reference

Evolution of the variable of damage, D, according to time. One tests this value with different moments:

Moment	Reference	Aster	% difference
520000	1.52596E-02	1.52081E-02	-0.34
1000000	3.30676E-02	3.29962E-02	-0.22
2000000	9.9465369E-02	9.92747E-02	-0.19
2250000	1.37520763E-01	1.37173E-01	-0.25
2500000	2.66018229E-01	2.62867E-01	-1.18

Evolution of the variable of isotropic work hardening viscoplastic, R, according to time. One tests this value at various moments:

Moment	Reference	Aster	% difference
520000	2.300147E-03	2.29431E-03	-0.25
1000000	3.179469E-03	3.17481E-03	-0.15
2000000	4.95103E-03		

4.94641E-03 -0.09
2250000 5.592847E-03
5.58683E-03 -0.11
2500000 6.99749E-03
6.97181E-03 -0.37

The variation observed on D for T = 2.5.106s is due to the very strong not linearity of the evolution of the variable of damage.

2.3
Uncertainties on the solution

Precision of the codes

---

3 Modeling
With

3.1
Characteristics of modeling

The discretization in time is rather fine:

(JUSQU_A = 2, A NUMBER = 10),

(JUSQU_A = 2. , A NUMBER = 10),
(JUSQU_A = 20. , A NUMBER = 10),
(JUSQU_A = 200. , A NUMBER = 10),
(JUSQU_A = 2000. , A NUMBER = 10),
(JUSQU_A = 20000. , A NUMBER = 10),
(JUSQU_A = 200000. , A NUMBER = 10),
(JUSQU_A = 1000000. , A NUMBER = 30),
(JUSQU_A = 1600000. , A NUMBER = 30),
(JUSQU_A = 1700000. , A NUMBER = 40),
(JUSQU_A = 1800000. , A NUMBER = 40),
(JUSQU_A = 1900000. , A NUMBER = 40),
(JUSQU_A = 2000000. , A NUMBER = 40),
(JUSQU_A = 2100000. , A NUMBER = 40),
(JUSQU_A = 2200000. , A NUMBER = 40),
(JUSQU_A = 2300000. , A NUMBER = 40),
(JUSQU_A = 2400000. , A NUMBER = 40),
(JUSQU_A = 2500000. , A NUMBER = 40),

3.2 Characteristics of the grid

A number of nodes: 8
A number of meshs: 1 (HEXA8)

3.3 Functionalities tested

Orders

DEFI_MATERIAU VENDOCHAB

STAT_NON_LINE COMP_INCR RELATION VENDOCHAB

DEFORMATION SMALL

NEWTON STAMP = "ELASTIC"

CONVERGENCE
RESO_INTE
=
“RUNGE_KUTTA_2”

3.4
Sizes tested and results

Evolution of the variable of damage, D, according to time. One tests this value with different moments:

Moment	***Reference***	***Aster***	***% difference***
520000	*1.52596E-02*	*1.52081E-02*	*-0.34*
1000000	*3.30676E-02*	*3.29962E-02*	*-0.22*
2000000	*9.9465369E-02*	*9.92747E-02*	*-0.19*
2250000	*1.37520763E-01*	*1.37173E-01*	*-0.25*
2500000	*2.66018229E-01*	*2.62867E-01*	*-1.18*

Evolution of the variable of isotropic work hardening viscoplastic, R, according to time. One tests this value at various moments:

Moment	Reference	Aster	% difference
520000	2.300147E-03	2.29431E-03	-0.25
1000000	3.179469E-03	3.17481E-03	-0.15
2000000	4.95103E-03	4.94641E-03	-0.09
2250000	5.592847E-03	5.58683E-03	-0.11
2500000	6.99749E-03	6.97181E-03	-0.37

3.5 Remarks

The variation observed on D for T = 2.5.106s is due to the very strong not linearity of the evolution of the variable of damage.

4 Summary of the results

The results obtained with Code_Aster are close to the analytical solution of reference since the variation with the reference solution is lower than 1.2% and generally lower than 0.4% before strong non-linearity leading to the final rupture.

15/02/06
Author (S):
***C. CHAVANT**, V. GERVAIS Key*
:
V6.04.184-A Page:
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Organization (S): EDF-R & D /AM, CS-SI

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.184

SSNV184 - Triaxial compression test with the model of Hoek-Brown modified

Summary

This test makes it possible to validate the elastoplastic law of behavior of Hoek-Brown modified in mechanics of rocks. It is about a triaxial compression test for which calculations are carried out in pure mechanics. Three levels of containment are applied: 5 MPa, 12 MPa and 25 MPa. For reasons of symmetry, one is interested only in eighth of a sample subjected to a triaxial compression test.
It is about a test of not-regression.

Contents

1
Problem of reference

1.1 Geometry

One considers here a cube of dimension 1m × 1m × 1m.

Z

1 m

· D

· C

1 m

With
B

.
.

y

X
1 m

Co-ordinates of the points (in m):

WITH B C D
X 0 0.0.5 1
y 0 1.0.5 1
Z 0 0.0.5 1

1.2
Properties of material

Parameters of the elastic law of behavior:
E = 4500 MPa
= 0.3

Parameters of the law of Hoek-Brown modified:
rup
= 0.005
LMBO
= 0.017
2 end
(S) = 225 MPa2
C
2 rup
(S) = 482.5675 MPa2
C
end

(m) = 13.5 MPa
C
rup
(m) = 83.75 MPa
C
= 3 MPa
rup
= 15°
LMBO
= 30°
= 3.3
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1.3 Conditions
initial,
with the limits and loading

The test breaks up into two phases:

1) Initially, one brings the sample in a homogeneous state 0
0
0
= =. For
xx
yy

zz
that, the corresponding confining pressure is imposed on the front faces (X = 1),
side right-hand side (y = 1) and higher (Z = 1), while displacements are taken null on
the faces postpones (U
= 0), side left (U
= 0) and the lower (U
= 0).
X x=0
y y=0
Z z=0
2) Once the homogeneous state obtained, displacements are maintained blocked on the faces
back, side left and lower and the confining pressure are always imposed on
front faces and side right-hand side. A displacement is imposed on the higher face (U (T))
Z
in order to obtain a deformation equalizes to 25% starting from the beginning of the second phase
zz
(with t=2). The increment of deformation is taken constant:
= 2
- .5E - 4 for
zz
modelings A and B, and = 3
- .33E - 4 for modeling C.
zz

2
Reference solution

2.1
Calculation of solution

The value of the major principal constraint can be calculated at the frangible joint (rup
) and with
residual resistance (LMBO
) starting from the form of the diverter of constraint:

rup
2 rup
rup
-
= (S) - (m)
1
3

C
3
C
LMBO

2 LMBO
LMBO
LMBO
-
= (S) - (m) - B
1
3
-

1
3
C
3
C

data base

3

rup
rup 2
2
2 rup
- (m) - ((m)) + 4 1
(-) (S)
data base
C
C
C
LMBO
2 rup

with
=
B

and

= - (S)
3
2
C
2 1
(-)

2.2
Results of reference

Constraints (), () and () at point D.
xx
3
yy
1
zz
3
Displacements () and () at point D.
xx
3
zz
1

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D
Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = - MPa

5
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0

3.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

3.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR
RELATION

"HOEK_BROWN"

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4
Results of modeling A

4.1 Values
tested

Rupture:
rup
Value
:
reference

of

-
= 30.0219
1
3 ref.
rup
Value

Code_Aster: -
= 29.7520 (
of

number
43

:

order
)
1
3

relative

Variation
réf

-
Code_Aster
%

0.90
:

Residual resistance:
rup
Value

reference

of

:
-
= 15.7215
1
3 ref.

rup
Value

Code_Aster
: -
= 15.7215 (
of

number
65
:

order
)
1
3

Localization Number
of order Forced
(MPa) Code_Aster
Not D
12

-5.00
xx
40

-5.00
xx
12

-5.00
yy
40

-5.00
yy
12

-18.5
zz
16

-22.4982
zz
30

-29.0442
zz
43

-34.7520
zz

45

-31.3756
zz
50

-24.4274
zz
55

-21.6325
zz
65

-20.7215
zz

Localization Number
of order Code_Aster Deformation
Not D
12

0.9 E-3
xx
16

1.22296 E-3
xx
30

2.82301 E-3
xx
43

4.59944 E-3
xx
45

5.39287 E-3
xx
50

7.41788 E-3
xx

55

9.07385 E-3
xx
65

11.9257 E-3
xx
12

-3 E-3
zz
65

-16.25 E-3
zz

---

5 Modeling B

5.1 Characteristics of modeling

Modeling 3D
Cutting: 1m in height, 1m in width
Loading of phase 1: 0

0
0
= = = - MPa

12
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0

5.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

5.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR
RELATION
"HOEK_BROWN"

6
Results of modeling B

6.1 Values tested

Rupture:
rup
Value
:
reference

of

-
= 38.5690
1
3 ref.
rup
Value

Code_Aster: -

=
of

(number

38.4447
51)
:

order
1
3

réf

Variation

-
Code_Aster
%

0.32
:

Residual resistance:
rup
Value
:
reference

of

-
= 30.8023
1
3 ref.

rup
Value

Code_Aster: -
=
of

(number

30.8023
80)
:

order

1
3

Localization Number
of order Forced
(MPa) Code_Aster
Not D
16

-12.00
xx
50

-12.00
xx
16

-12.00
yy
50

-12.00
yy
16

-30
zz
20

-33.2264
zz
40

-44.5889
zz
51

-50.4447
zz
55

-48.0512
zz
60

-45.5579
zz
70

-43.0472
zz
80

-42.8023
zz

Localization Number
of order Code_Aster Deformation
Not D
16

1.2 E-3
xx
20

1.56091 E-3
xx
40

3.78317 E-3
xx
51

5.22869 E-3
xx
55

6.32002 E-3
xx
60

7.74068 E-3
xx
70

10.5716 E-3
xx
80

13.3372 E-3
xx
16

-4 E-3
zz
80

2nd-2
zz

---

7 Modeling
C

7.1
Characteristics of modeling

Modeling 3D
Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = -
MPa

25

(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0

7.2 Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

7.3 Functionalities tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR
RELATION
“HOEK_BROWN”

8
Results of modeling C

8.1 Values tested

Rupture:
rup
Value

reference

of

:
-
= 50.7574
1
3 ref.
rup
Value

Code_Aster: -
=
of

(number

50.3064
46)
:

order
1
3

réf

Variation

-
Code_Aster
%

0.89
:

Residual resistance:
rup
Value
:
reference

of

-
= 55.1249
1
3 ref.

rup
Value

Code_Aster: -
=
of

(number

55.1249
81)
:

order
1
3

Localization Number

of order Forced
(MPa) Code_Aster
Not D
18

- 25.00
xx
81

- 25.00
xx
18

- 25.00
yy
81

- 25.00
yy
18

-50.8398
zz
24

-56.4340
zz
36

-66.9436
zz
46

-75.3064
zz
54

-77.6467
zz
66

-79.7633
zz
81

-80.1249
zz

Localization Number
of order Code_Aster Deformation
Not D
18

1.85408 E-3
xx
24

2.63445 E-3
xx
36

4.35497 E-3
xx
46

5.98034 E-3
xx
54

7.90516 E-3
xx
66

11.3535 E-3
xx
81

16.7102 E-3
xx
18

-6 E-3
zz
36

-12 E-3
zz
81

-27 E-3
zz

9
Summary of the results

The results obtained show an agreement of stress the rupture and to residual resistance
1
between the computed values and those obtained with Code_Aster.
This case test is a test of not-regression developed to validate the modified model of Hoek-Brown.

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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.185

SSNV185 Fissures emerging in a plate 3D of width finished with X-FEM

Summary

The purpose of this test is to validate method X-FEM [bib1] on an academic case 3D, within the framework of linear elastic breaking process.

This test brings into play a plate 3D comprising an emerging crack plane at right bottom. Complete calculation as well as the extraction of the stress intensity factors is realized within the framework of method X-FEM. grid is healthy, the crack being represented virtually with level sets.

Several configurations of grid are tested and compared with the analytical solution. The same problem treated in a traditional way (with a fissured grid) is used as reference in order to compare the precise details of

two methods.

1
Problem of reference

1.1 Geometry

The structure is a plate 3D of dimensions LX = 1 m, LY = 10 m and LZ = 30 m, comprising one emerging plane crack length has = 5 m, being located at middle height (see [Figure 1.1-a]).

If the problem is dealt with by traditional method, the crack is with a grid. On the other hand, if method X-FEM is employed, the crack is not with a grid, and the geometry is in fact a healthy plate without crack. The crack will then be introduced by functions of levels (level sets) directly in the file orders using operator DEFI_FISS_XFEM [U4.82.08]. Level set normal (LSN = distance to the plan of cracking) makes it possible to define the plan of crack and the level set tangent (LST = distance to the bottom of crack) makes it possible to define the position of the bottom of crack.

Appear 1.1-a: Geometry of the fissured plate

One defines the points A (1, 0, 15), B (0, 0, 15) and C (1, 3, 15) which will be used to block the rigid modes.

1.2

Properties of material

Young modulus: E= 205.000 MPa (except contrary mention)
Poisson's ratio: = 0.

2
Modeling a: fissures with a grid (traditional case)

In this modeling, it crack is with a grid, and one uses the standard method of the finite elements to carry out calculation. This modeling will be used as reference and will allow the comparison with method X-FEM.

2.1
Characteristics of the grid

The structure is modelled by a regular grid composed of 5x30x50 HEXA8, respectively according to axes X, y, Z (see [Figure 2.1-a]). Two superimposed surfaces are the lips of fissure.
higher face
fissure
lower face
Appear 2.1-a: Fissured grid

2.2
Boundary conditions and loadings

Two types of loading will be studied: a loading of traction on the faces lower and higher of the structure, then a loading which consists in imposing a field of displacement in any node, identical to the asymptotic field of displacement in mode I (solution of Westergaard for an infinite medium [bib2]).

2.2.1 Loading of traction

A pressure distributed is forced on the faces lower and higher of the structure (see [Figure 2.1-a]). The pressure is
6
p = 10
-
Pa (
= p
zz
-), which makes it possible to request the crack in mode of opening I pure.
The rigid modes are blocked in the following way:

N4265
DX
= 0

N4265
· Point A is blocked according to the 3 directions:
DY
= 0

N4265
DZ
= 0

· The point B is blocked along axis OZ:

N3751
DZ
= 0

N4256

DX
= 0

· ***The point C is blocked along axes OX and OZ:***

N4256

DZ
= 0

2.2.2 Loading with the asymptotic field in mode I

The asymptotic field in pure mode I, solution of a problem of elastic rupture linear is known in an analytical way [bib2]. In the defined reference mark, this field takes the following form:
U = 0

éq 2.2.2-1
X
1+
R

U = -
cos
éq
2.2.2-2
y
(3 - 4 - cos)
E
2
2

1+

U =
R sin

éq
2.2.2-3
Z
(3 - 4 - cos)
E
2
2

This field is imposed on all the nodes of the structure by the means of formulas in the operator AFFE_CHAR_MECA_F [U4.44.01]. These formulas utilize the polar co-ordinates (R,) in base local at the bottom of crack:
15
R = (5 - y)
Z -
² + (Z -) ²
15, = arctan

éq 2.2.2-4
5 - y

However, it is advisable to treat separately the nodes belonging to the lips of the crack. Indeed, for the nodes of the lower lip, the formula being used to calculate the angle is not valid (it would give whereas theoretically, is worth). For the nodes of the lower lip, the value of the angle is thus not calculated by the equation [éq 2.2.2-4] but is directly put at. For nodes of the upper lip, the formula is nevertheless valid.

2.3
Solutions of the problem

2.3.1 Loading of traction

The stress intensity factor in mode I is given [bib3] by:
has
K =
has

F
I
zz

éq 2.3.1-1

LY
where

has 3

has
1 2
752
.
0
+ 37
.
0
1 - sin
+ 02
.
2
B has
2
has

B
2
B
F =
tan

éq 2.3.1-2

B has

B
2
has

cos B
2

has
The precision of this formula reaches 0.5% whatever the report/ratio
.
B

2.3.2 Loading with the asymptotic field in mode I

In the presence of such a loading, the theoretical value is

K = 1

éq 2.3.2-1
I

2.4 Functionalities tested

Option CALC_K_G of operator CALC_G_LOCAL_T [U4.82.04] allows the calculation of the factors of intensity of constraints by the energy method "G-theta". This functionality is tested with the loading n°1. This case of loading is used as a basis of comparison for method X-FEM. When one of the loads is a function or a formula (coming from AFFE_CHAR_MECA_F [U4.44.01]), the option becomes CALC_K_G_F. This functionality is tested with the loading n°2.

Orders

CALC_G_LOCAL_T CALC_K_G

CALC_K_G_F

3
Results of modeling A

3.1 Values tested

One tests the values of KI along the bottom of crack, for various crowns of fields theta. The values of the rays inf and sup of the torus are as follows:

Crown 1 Crown 2 Couronne 3 Crown 4 Couronne 5
Crown 6
Rinf 2 0.666 1 1 1 2.1
Rsup 4 1.666 2 3 4 3.9
Table 3.1-1

To test all the nodes of the bottom of crack in only once, one tests the min and max values of KI on all the nodes of the bottom of crack.

3.1.1 Loading of traction

Identification
Aster
Reference %
difference
Crown 1: MAX (KI)
1.051 107 1.120
107 -6.1
Crown 1: MIN (KI)
1.051 107 1.120
107 -6.1
Crown 2: MAX (KI)
1.049 107 1.120
107 -6.3
Crown 2: MIN (KI)
1.048 107 1.120
107 -6.3
Crown 3: MAX (KI)
1.051 107 1.120
107 -6.2
Crown 3: MIN (KI) 1.051
107 1.120
107 -6.2

Crown 4: MAX (KI)
1.051 107 1.120
107 -6.2
Crown 4: MIN (KI)
1.051 107 1.120
107 -6.2
Crown 5: MAX (KI)
1.051 107 1.120
107 -6.2
Crown 5: MIN (KI)
1.051 107 1.120
107 -6.2
Crown 6: MAX (KI)
1.051 107 1.120
107 -6.1
Crown 6: MIN (KI) 1.051
107 1.120
107 -6.1

3.1.2 Loading with the asymptotic field in mode I

Identification
Aster *Reference*
%
difference
Crown 1: MAX (KI)
0.999987 1.0
-0.001
Crown 1: MIN (KI)
0.999987 1.0
-0.001
Crown 2: MAX (KI)
0.998279 1.0
-0.172
Crown 2: MIN (KI)
0.998279 1.0
-0.172
Crown 3: MAX (KI)
1.000162 1.0
0.016
Crown 3: MIN (KI) 1.000162
1.0
0.016

Crown 4: MAX (KI)
1.000058 1.0
0.006
Crown 4: MIN (KI)
1.000058 1.0
0.006
Crown 5: MAX (KI)
1.000045 1.0
0.005
Crown 5: MIN (KI)
1.000045 1.0
0.005
Crown 6: MAX (KI)
0.999981 1.0
-0.002
Crown 6: MIN (KI) 0.999981
1.0
-0.002

3.2 Comments

The 1st loading of this modeling is used as a basis of comparison for method X-FEM.
2nd case of loading makes it possible to validate option CALC_K_G_F for the elements 3D.

4

Modeling b: fissures nonwith a grid (case X-FEM)

In this modeling, the crack is not with a grid any more, but it is represented by level sets:

LSN = Z -15

éq 4-1
LST = LY - has - y

éq 4-2

4.1
Characteristics of the grid

The structure is modelled by a healthy, regular grid composed of 5x30x50 HEXA8, respectively according to axes X, y, Z in order to have the same number of elements as for the grid of modeling A (see [Figure 4.1-a]). Thus, the plan of crack is in correspondence with faces HEXA8 and bottom of crack with edges of HEXA8.

Appear 4.1-a: Healthy grid

4.2
Boundary conditions and loadings

Only one type of loading is studied here: it is about a pressure distributed imposed on the faces lower and higher of the structure (identical to the 1st case of loading of modeling A).
The rigid modes are blocked in the following way:

N3751
DX
= 0

N3751
· Point A is blocked according to the 3 directions:
DY
= 0

N3751
DZ
= 0

· The point B is blocked along axis OZ:

N9276
DZ
= 0

N3760

DX
= 0
· The point C is blocked along axes OX and OZ:

N3760

DZ
= 0

4.3 Functionalities
tested

Orders

DEFI_FISS_XFEM

CALC_G_LOCAL_T CALC_K_G

5
Results of modeling B

5.1 Values
tested

One tests the values of KI along the bottom of crack, for various crowns of fields theta.
The values of the rays inf and sup of the torus are as follows:

Crown 1 Crown 2 Couronne 3 Crown 4 Couronne 5 Crown 6
Rinf 2 0.666 1 1 1 2.1
Rsup 4 1.666 2
3
4 3.9
Table 5.1-1

To test all the nodes of the bottom of crack in only once, one tests the min and max values of KI on all the nodes of the bottom of crack.

Identification
Aster
Reference %
difference
Crown 1: MAX (KI)
1.111 107 1.120
107 -0.8

Crown 1: MIN (KI)
1.110 107 1.120
107 -0.9
Crown 2: MAX (KI)
1.112 107 1.120
107 -0.8
Crown 2: MIN (KI)
1.111 107 1.120
107 -0.9
Crown 3: MAX (KI)
1.111 107 1.120
107 -0.8
Crown 3: MIN (KI) 1.110
107 1.120
107 -0.9
Crown 4: MAX (KI)
1.111 107 1.120
107 -0.8
Crown 4: MIN (KI)
1.110 107 1.120
107 -0.9
Crown 5: MAX (KI)
1.111 107 1.120
107 -0.8
Crown 5: MIN (KI)
1.110 107 1.120
107 -0.9
Crown 6: MAX (KI)
1.111 107 1.120
107 -0.8
Crown 6: MIN (KI) 1.110
107 1.120
107 -0.9

5.2 Comments

The results are stable for any selected crown.
With same number of elements, the precision of the results obtained with X-FEM is much better than that obtained in the traditional case (less than 1% for X-FEM against 6% for a method traditional).
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6
Modeling C: crack nonwith a grid (case X-FEM)

In this modeling, the crack is not with a grid, but it is represented by level sets:

LSN = Z -15

éq 6-1

LST = LY - has - y

éq 6-2

6.1
Characteristics of the grid

The structure is modelled by a healthy, regular grid composed of 5x31x51 HEXA8, respectively *according to axes X, y, Z. In this manner, the bottom of crack is in the center of elements and the plan of crack does not correspond any more to faces of elements. [Figure 6.1-a] represents out of Oyz cut enrichment in a zone near bottom of crack.*

Appear 6.1-a: Various enrichments in bottom of crack

6.2
Boundary conditions and loadings

Just as previously, a pressure distributed is imposed on the faces lower and higher structure (identical to the 1st case of loading of modeling A).

In order to reproduce the preceding cases, it is necessary to block the same points A, B and C. however here, there are no nodes in the median plane. To block the rigid modes, it is necessary then to impose relations between the ddls nodes just above and below the median plane [Figure 6.2-a]:

NR 4031
DX
+
NR 3876
DX
= 0

NR 4031
NR 3876
· point A is blocked according to the 3 directions:
DY
+ DY
= 0

NR 4031
NR 3876
DZ
+ DZ
= 0
·

· the point B is blocked along axis OZ:

NR 3886
4041
DZ
+
NR
DZ
= 0

NR 9768
DX
+
NR 9767
DX
= 0
· the point C is blocked along axes OX and OZ:

NR 9768
DZ
+
NR 9767
DZ
= 0

Appear 6.2-a: Conditions of Dirichlet around the median plane

[Figure 6.2-a] is a diagrammatic sight of the Oyz plan, on which the number of finite elements is not not respected. It is simply used to include/understand the linear relations forced in order to block them
displacements of points A and C. For the point B, one acts in the same way.

6.3 Functionalities
tested

Orders

DEFI_FISS_XFEM

CALC_G_LOCAL_T CALC_K_G

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7
Results of modeling C

7.1 Values
tested

One tests the values of KI along the bottom of crack, for various crowns of fields theta.
The values of the rays inf and sup of the torus are as follows:

Crown 1 Crown 2 Couronne 3 Crown 4 Couronne 5 Crown 6
Rinf 2 0.666 1 1 1 2.1
Rsup 4 1.666 2
3
4 3.9
Table 7.1-1

To test all the nodes of the bottom of crack in only once, one tests the min and max values of KI on all the nodes of the bottom of crack.

Identification
Aster
Reference %
difference
Crown 1: MAX (KI)
1.084 107 1.120
107 -3.2
Crown 1: MIN (KI)
1.079 107 1.120
107 -3.7
Crown 2: MAX (KI)
1.087 107 1.120
107 -3.0
Crown 2: MIN (KI)
1.083 107 1.120
107 -3.4
Crown 3: MAX (KI)
1.083 107 1.120
107 -3.3
Crown 3: MIN (KI) 1.079
107 1.120

107 -3.7
Crown 4: MAX (KI)
1.084 107 1.120
107 -3.3
Crown 4: MIN (KI)
1.079 107 1.120
107 -3.7
Crown 5: MAX (KI)
1.083 107 1.120
107 -3.3
Crown 5: MIN (KI)
1.079 107 1.120
107 -3.7
Crown 6: MAX (KI)
1.084 107 1.120
107 -3.2
Crown 6: MIN (KI) 1.079
107 1.120
107 -3.7

7.2 Comments

The results are stable for any selected crown.
The precision of the results obtained is worse than for modeling B. That can be explained by the fact that the zone of enrichment is less wide here.

However, the results remain better than in the traditional case.

8
Modeling D: crack nonwith a grid (case X-FEM)

This modeling is exactly the same one as modeling B, except that the length of the crack is: has = 4.8333, so that the bottom of crack does not coincide with edges of elements.

Appear 8-a: Enrichment in a zone close to the bottom of crack

9
Results of modeling D

9.1 Values tested

One tests the values of KI along the bottom of crack, for various crowns of fields theta.
The values of the rays inf and sup of the torus are as follows:

Crown 1 Crown 2 Couronne 3 Crown 4 Couronne 5 Crown 6
Rinf 2 0.666 1 1 1 2.1
Rsup 4 1.666 2
3
4 3.9

To test all the nodes of the bottom of crack in only once, one tests the min and max values of KI on all the nodes of the bottom of crack.

Identification
Aster
Reference %
difference
Crown 1: MAX (KI)
1.020 107 1.045
107 -2.4
Crown 1: MIN (KI)
1.033 107 1.045
107 -1.1
Crown 2: MAX (KI)
1.021 107 1.045

107 -2.3
Crown 2: MIN (KI)
1.034 107 1.045
107 -1.1
Crown 3: MAX (KI)
1.021 107 1.045
107 -2.3
Crown 3: MIN (KI) 1.033
107 1.045
107 -1.1
Crown 4: MAX (KI)
1.021 107 1.045
107 -2.3
Crown 4: MIN (KI)
1.033 107 1.045
107 -1.1
Crown 5: MAX (KI)
1.021 107 1.045
107 -2.3
Crown 5: MIN (KI)
1.033 107 1.045
107 -1.1
Crown 6: MAX (KI)
1.020 107 1.045
107 -2.3
Crown 6: MIN (KI) 1.033
107 1.045
107 -1.1

9.2 Comments

These results confirm that the size of the zone of enrichment influences the precision of the results. Here, the zone of enrichment is intermediate between the of the same case B and case C, and precision.

---

10 Modeling E: crack nonwith a grid (case X-FEM)

In this modeling, the crack is not with a grid, but it is represented by level sets:

LSN = Z -15

éq 10-1
LST = LY - has - y

éq 10-2

In this modeling, the Young modulus is equal to 100 MPa.

10.1 Characteristics of the grid

The structure is modelled by a healthy, regular grid composed of 3x11x31 HEXA8, respectively according to axes X, y, Z (see [Figure 10.1-a]). Such a discretization leads to a configuration of enrichment similar to that of modeling C.

Appear 10.1-a: Grid

10.2 Boundary conditions and loadings

One wishes to apply the same loading as the loading n°2 of modeling A, i.e.

to impose on all the nodes of the grid the asymptotic field of displacement in mode I pure.

For all the traditional nodes (not nouveau riches), one then imposes the fields previously definite.
For the nodes nouveau riches in bottom of crack, one seeks to impose each ddl enriched.
With this intention, one rewrites the analytical expressions of the fields of displacements to be imposed on
nodes in the base of the functions of enrichment:
U = 0

éq 10.2-1
X

1+
1

U = -
R cos

éq
10.2-2
y
(2-
4)

+ R sin sin
E
2
2
2

1+
1

U =
R sin
éq
10.2-3
Z
(4- 4)

- R cos sin
E
2
2
2

It is pointed out that the base of the functions of enrichment is as follows:

R sin, R cos, R sin sin, R cos sin ***éq***
10.2-4

2
2

2
2

For the nodes nouveau riches by the Heaviside function, it is also necessary to carry out a calculation as a preliminary.
Let us consider a couple of nodes A and B, and note C+ and C the points located on the upper lips and lower of the crack, this one cutting a symmetrical element of way. One is in following configuration:

Appear 10.2-a: Heaviside enrichment

The nodes represented by rounds [Figure 10.2-a] carry traditional ddls has and of the ddls Heaviside h.
According to approximation X-FEM, the crack passing in the middle of the elements, displacements are written:
U ()
WITH = A
+ A has
H

U (B) = B
has - B
H

With
With
B
B

+
+ H has
+ H has
U (C) =
+

éq
10.2-5

2
2

With
With
B
B

-
- H has
- H has
U (C) =
+

2
2

By reversing this linear system, one obtains the expressions of the nodal unknown factors according to analytically known displacements:
With U (A) - U (B)
has =
+ U (-
C)

2
With U (A) + U (B)
H =
- U (-
C)

2

éq
10.2-6
B
U (B) - U (A)
has =
+ U (+
C)

2
B - U (B) - U (A)
H =
+ U (-
C)

2

10.3 Functionalities tested

Orders

CALC_G_LOCAL_T CALC_K_G_F

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Code_Aster ®
Version
8.2

Titrate:
SSNV185 Fissures emerging in 3D with X-FEM

Date:
25/11/05
Author (S):
***P. MASSIN**, Key S. GENIAUT*
:
V6.04.185-A Page:
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11 Results of modeling E

11.1 Values tested

One tests the values of KI along the bottom of crack, for various crowns of fields theta.
The values of the rays inf and sup of the torus are as follows:

	Crown 1	Crown 2	Couronne 3	Crown 4	Couronne 5	Crown 6
Rinf	2	0.666	1	1	1	2.1
Rsup	4	1.666	2	3	4	3.9

Table 11.1-1

To test all the nodes of the bottom of crack in only once, one tests the min and max values of KI on all the nodes of the bottom of crack.

Identification
Aster
Reference %
difference
Crown 1: MAX (KI)
0.9996 1.0
-0.04
Crown 1: MIN (KI)
0.9996 1.0
-0.04
Crown 2: MAX (KI)
1.0272 1.0
2.7
Crown 2: MIN (KI)
1.0272 1.0
2.7
Crown 3: MAX (KI)
1.0053 1.0
0.53
Crown 3: MIN (KI) 1.0053
1.0
0.53
Crown 4: MAX (KI)
1.0023 1.0
0.23
Crown 4: MIN (KI)
1.0023 1.0
0.23
Crown 5: MAX (KI)
1.0015 1.0
0.15
Crown 5: MIN (KI)
1.0015 1.0
0.15
Crown 6: MAX (KI)
9.9969 1.0
-0.03
Crown 6: MIN (KI) 9.9969
1.0
-0.03

11.2 Comments

The results are stable for any selected crown.
They make it possible to validate option CALC_K_G_F for the elements 3D X-FEM.

12 Modeling F: crack nonwith a grid (case X-FEM)

This modeling is exactly the same one as modeling C. the only difference is as the zone of enrichment in bottom of crack has now a size fixed by the user, it is not thus more limited to only one elements layer in bottom of crack.

12.1 Enrichment in bottom of crack

The nodes being at a distance from the bottom of crack equal or lower than a certain criterion are nouveau riches by the singular functions. This criterion is selected as in [bib4], equal to a tenth of cut structure. Here, it is worth 1 m since LY are worth 10 Mr.

12.2 Functionalities tested

Orders

DEFI_FISS_XFEM RAYON_ENRI

CALC_G_LOCAL_T CALC_K_G

---

13 Results of modeling F

13.1 Values tested

One tests the values of KI along the bottom of crack, for various crowns of fields theta.
The values of the rays inf and sup of the torus are as follows:

Crown 1 Crown 2 Couronne 3 Crown 4 Couronne 5 Crown 6
Rinf 2 0.666 1 1 1 2.1
Rsup 4 1.666 2
3
4 3.9
Table 13.1-1

To test all the nodes of the bottom of crack in only once, one tests the min and max values of KI on all the nodes of the bottom of crack.

Identification
Aster
Reference %
difference
Crown 1: MAX (KI)
1.109 107 1.120
107 -1.0
Crown 1: MIN (KI)
1.104 107 1.120
107 -1.5
Crown 2: MAX (KI)
1.111 107 1.120
107 -0.8
Crown 2: MIN (KI)
1.106 107 1.120
107 -1.2
Crown 3: MAX (KI)
1.110 107 1.120
107 -0.9
Crown 3: MIN (KI) 1.105
107 1.120
107 -1.4
Crown 4: MAX (KI)
1.110 107 1.120
107 -1.0
Crown 4: MIN (KI)
1.105 107 1.120
107 -1.4
Crown 5: MAX (KI)
1.110 107 1.120
107 -1.0
Crown 5: MIN (KI)
1.104 107 1.120
107 -1.4
Crown 6: MAX (KI)
1.109 107 1.120
107 -1.0
Crown 6: MIN (KI) 1.104
107 1.120
107 -1.5

13.2 Comments

The results are stable for any selected crown.
The precision of the results obtained is better than for modeling C. That proves the influence beneficial of the increase size of the zone of enrichment, with identical grid.
However, if it one compares with the precision of modeling B (lower than 1%) one could to be astonished not to find better results with the fixed zone. The explanation is in [bib4].
Indeed, on modeling B, the approximation of displacement is exactly in R on one lay down element around the bottom. On the other hand, in modeling F, the approximation is R
elt nouveau riches
on the zone of enrichment. In this case (relatively coarse grid), the approximation by one summon square roots on a wide zone is worse than the approximation by only one square root on a more restricted zone.

However, when one refines sufficiently the grid, precision obtained with an enrichment on a fixed zone becomes better than that obtained with an enrichment on only one layer elements.

---

14 Summaries of the results

The objectives of this test are achieved:

.
To validate on a simple case the taking into account of singular enrichment in bottom of crack with method X-FEM.

.

To validate the calculation of the stress intensity factors (here only mode I) for elements X-FEM, whatever the load (fixed or function).

It will be retained that the use of method X-FEM makes it possible to appreciably improve the precision of calculation of KI, and that this one increases when the zone of enrichment is not restricted with one only layer of elements in bottom of crack.

15 Bibliography

[1]
MASSIN P., GENIAUT S.: Method X-FEM, Handbook of reference of Code_Aster, [R7.02.12]
[2]
SCREW E.: Calculation of the coefficients of intensity of constraints, Handbook of reference of Code_Aster, [R7.02.05]
[3]
BARTHELEMY B.: Concepts practise breaking process, Eyrolles, 1980.
[4]
LABORDE P., APPLE TREE J., FOX Y., SALÜN Mr.: "High-order extended finite element method for cracked domains ", International Newspaper for Numerical Methods in Engineering, 64 *(3), 354-381, 2005.*

Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.186

SSNV186 LBB condition and contact rubbing with X-FEM

Summary

The purpose of this test is to validate the taking into account of the contact (by the method continues [bib1]) on the lips of fissure within the framework of method X-FEM [bib2], when the LBB condition [bib3] [bib4] is not respected.

This test brings into play a parallelepipedic block in compression. The interface the beam is represented by one level set. The interface right, is nonpenchée and crosses completely the elements.

1
Problem of reference

Oscillations of contact pressures can appear in certain cases, in particular for structures where the interface cuts pentahedrons, under a non-uniform loading.

That is due to the non-observance of the LBB condition [bib3] [bib4]. This phenomenon of oscillations is comparable with that met of incompressibility [bib5]. Physically, in the case of the contact, that amounts wanting to impose the contact in too many points of the interface (overstrained), returning the system hyperstatic. To slacken it, it is necessary to restrict the space of the multipliers of Lagrange, like that is done in [bib6] for the conditions of Dirichlet with X-FEM. The algorithm proposed by Moës [bib6] to reduce the oscillations is adapted to the case 3D (algorithm version 1). This algorithm made the object of an improvement to make it more physical and more effective (algorithm version 2). One comparison of the two versions is carried out.

Let us note that with a grid of hexahedrons, there are no oscillations.

1.1 Geometry

The structure is a right at square base and healthy parallelepiped. Dimensions of the block are: LX = 5 m, LY = 20 m and LZ = 20 Mr. It does not comprise any crack [Figure 1.1-a].

The interface is introduced by functions of levels (level sets) directly into the file of orders using operator DEFI_FISS_XFEM [U4.82.08]. The interface is present within the structure by the means of its representation by the level sets. The level set normal (LSN) allows to define an interface planes not-leaning which crosses the elements completely, by the equation following:
LSN = Z-17.5
éq

1.1-1

Appear 1.1-a: Geometry and positioning of the interface

1.2
Properties of material

Young modulus: E= 1000 Pa.
Poisson's ratio: = 0.

A higher Young modulus involves a very bad conditioning of the matrix of rigidity, which results in a null pivot during factorization. For stage this problem, a scaling of contact pressures is in the course of implementation.

1.3
Boundary conditions and loadings

The lower face is embedded.
The higher face is subjected to a parabolic pressure having for expression:

(Y-10) ² E
pressure = 100-
Pa

éq
1.3-1
6

2
10

Displacements along axes X and are blocked there for the nodes of the upper surface.

2
Modeling a: hexahedrons

In this modeling, the grid considered comprises only hexahedrons. This modeling is used as reference for the others, because this case does not have oscillations of contact pressures. Indeed, in the case of hexahedrons cut by an interface parallel to the faces, the number of contact pressures (one by cut edge) is compatible with the discretization of the field of displacement [bib1] [bib2]. The LBB condition is then respected and there are no oscillations of contact pressures.

2.1
Characteristics of the grid

The problem is invariant following axis OX. In order to limit the computing time, the grid considered here *comprise one element along this axis. The structure is then modelled by a grid regular composed of 1x20x20 HEXA8 to see [Figure 2.1-a].*

Appear 2.1-a: Grid of hexahedrons

This grid is composed of linear finite elements. However, within the framework of the continuous method [bib1] with X-FEM [bib2], it is necessary to pass to a little special linear elements. These elements have linear functions of form and a quadratic mesh support. On these elements, them nodes top carry the unknown factors of displacement, and the nodes medium carry the dependent unknown factors with the contact. Moreover, when the interface follows the edge of an element, its nodes top carry too unknown factors of contact.

2.2 Functionalities tested

One uses the diagram of integration reduced to 4 points of Gauss per facet of contact.
Friction is taken into account and the contact is active as of the 1st iteration of active constraints.
The algorithm aiming at restricting the space of the multipliers of Lagrange is decontaminated.

Orders

DEFI_FISS_XFEM CONTACT
INTEGRATION=' FPG4'

CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' NON'

8.3

Titrate:
SSNV186 LBB condition and contact rubbing with X-FEM

Date:
04/05/06
Author (S):
S. GENIAUT, Key P. MASSIN
:
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3
Results of modeling A

3.1 Values
tested

One tests the value of the contact pressure at the point P of co-ordinates (0, 10, 17.5). This value is useful
of reference for other modelings.

2

9.5284410-
= -
Pa
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HT-62/06/005/A

4
Modeling b: pentahedrons (without algorithm)

4.1
Characteristics of the grid

The structure is modelled by a regular grid composed of pentahedrons.

Appear 4.1-a: Grid of pentahedrons

4.2 Functionalities
tested

One uses the diagram of integration reduced to 4 points of Gauss per facet of contact.
Friction is taken into account and the contact is active as of the 1st iteration of active constraints.
The algorithm aiming at restricting the space of the multipliers of Lagrange is not activated.

Orders

DEFI_FISS_XFEM CONTACT
INTEGRATION=' FPG4'

CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' NON'

5
Results of modeling B

5.1 Values
tested

One tests the value of the contact pressure at the point P of co-ordinates (0, 10, 17.5).

Identification Reference
***Aster** %*
difference
Not P
-9.52844 10-2
-0.186853
96.0

One carries out also a test of not-regression (compared to version 8.1.20).

Identification Reference
***Aster** %*

difference
Not P
-0.186853
-0.186853
0.00

5.2 Comments

This modeling shows that without the algorithm aiming at restricting the space of the multipliers of Lagrange of pressure, the values of contact pressures are completely false (see also [Figure 12.2-a]).

6
Modeling C: pentahedrons (algorithm version 1)

6.1
Characteristics of the grid

The grid is identical to that of modeling B.

6.2 Functionalities tested

One uses the diagram of integration reduced to 4 points of Gauss per facet of contact.
Friction is taken into account and the contact is active as of the 1st iteration of active constraints.

The algorithm aiming at restricting the space of the multipliers of Lagrange is the n°1.

Orders

DEFI_FISS_XFEM CONTACT
INTEGRATION=' FPG4'

CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' VERSION1'

7
Results of modeling C

7.1 Values
tested

One tests the value of the contact pressure at the point P of co-ordinates (0, 10, 17.5).

Identification Reference
***Aster** %*
difference
Not P
-9.52844 10-2
-9.5188 10-2
0.10

7.2 Comments

This modeling shows that the algorithm set up makes it possible to reduce them efficiently oscillations. However, it is observed that the algorithm version 1 tends to introduce P0 approximations per pieces of contact pressures on the interface (see also it [Figure 12.2-a] and it [Figure 12.2-b]).

8
Modeling D: pentahedrons (algorithm version 2)

8.1
Characteristics of the grid

The grid is identical to that of modeling B.

8.2 Functionalities
tested

One uses the diagram of integration reduced to 4 points of Gauss per facet of contact.
Friction is taken into account and the contact is active as of the 1st iteration of active constraints.
The algorithm aiming at restricting the space of the multipliers of Lagrange is the n°2.

Orders

DEFI_FISS_XFEM CONTACT
INTEGRATION=' FPG4'

CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' VERSION2'

9
Results of modeling D

9.1 Values tested

One tests the value of the contact pressure at the point P of co-ordinates (0, 10, 17.5).

Identification	**Reference**	**Aster**	**% difference**
Not P	*-9.52844 10-2*	*-9.5188 10-2*	*0.10*

9.2 Comments

This modeling shows that the algorithm version 2 makes it possible to reduce them efficiently oscillations. It is observed that the algorithm version 2 tends to introduce P1 approximations by pieces of contact pressures on the interface, which makes it more precise than the version1 (see too [Figure 12.2-a] and it [Figure 12.2-b]).

---

10 Modeling E: tetrahedrons (algorithm version 1)

This test brings into play a free grid made up of tetrahedrons. In order to reduce the number of elements and
thus the computing time, the length of the structure along axis OX is LX = 1 Mr.

10.1 Characteristics of the grid

The grid considered is a free grid carried out with GMSH. It consists of 3629 TETRA4.
[Figure 10.1-a] the grid in the Oyz plan represents. The interface is traced there, only at ends of visualization.

Appear 10.1-a: Free grid

10.2 Boundary conditions and loadings

The lower face is embedded.
The higher face is subjected to a uniform pressure:
E
pressure = 100
Pa
éq
10.2-1
6
10

Following displacements axes X and are blocked there for the nodes of the upper surface.

10.3 Functionalities tested

One uses the diagram of integration reduced to 4 points of Gauss per facet of contact.
The contact is active as of the 1st iteration of active constraints but friction is not taken in count
The algorithm aiming at restricting the space of the multipliers of Lagrange is the n°1.

Orders

DEFI_FISS_XFEM CONTACT
INTEGRATION=' FPG4'

CONTACT_INIT=' OUI'

ALGO_LAGR=' VERSION1'

11 Results of modeling E

11.1 Values tested

One tests the value of contact pressures for all the points of the interface. The analytical solution is quite simply:
= = - pressure
éq
11.1-1
zz

Identification Reference
Aster %
difference

MAX (LAGS_C)
-0.1
0.0979 -2.08
MIN (LAGS_C)
-0.1
-0.1016 1.62

To test all the points of contact in only once, the MIN and the MAX of the column are tested.

11.2 Comments

This test makes it possible to validate the robustness of the algorithm of restriction of the space of the multipliers of
Lagrange of pressure, in a free case of grid in 3D. Even on a structure subjected to
constant pressure, the algorithm is essential bus of the oscillations of contact pressures
can appear (it is the case here if the algorithm is not activated).

---

12 Summaries of the results 3D

12.1 Summary

Within the framework of method X-FEM, one showed that, without particular treatment, a structure with a grid with pentahedrons subjected to a non-uniform loading can present the strong ones

oscillations of contact pressures (modeling B), whereas the same structure with a grid with hexahedrons subjected to the same loading does not have such oscillations (being useful modeling A of reference).

One proposed two algorithms allowing to reduce these oscillations significantly. The first (modeling C) seems less precise than the second (modeling D).

Moreover even under uniform loading, of the oscillations can appear and it is essential to use an algorithm of reduction of the space of the multipliers of Lagrange of pressure (modeling E).

12.2 Curves of comparison

[Figure 12.2-a] gathers the curves of contact pressures along axis OY for the first 4 modelings presented. It is noticed that the oscillations for modeling B are if strong that in certain points the value of the contact pressure becomes positive, which would like to say that there is separation of the interface. The two algorithms allow a visible reduction of oscillations, and one finds the curve of reference obtained with the grid of hexahedrons.

0,00
0
2
4
6
8
10
12
14
16
18
20
-0,05
-0,10
lambda
-0,15
-0,20
y
modeling A
modeling B
modeling C
modeling D

Appear 12.2-a: Comparison of contact pressures following modelings
Handbook of Validation

[Figure 12.2-b] compares in details the effects of the two algorithms. It is noticed that the first often imply constant contact pressures per pieces, whereas the second tends to to linearize the pressures. It is obvious that such differences are reduced by refining the grid.

-0,05
0
2
4
6
8
10
12
14
16
18
20
-0,055
-0,06
-0,065
-0,07
-0,075
lambda
-0,08
-0,085
-0,09

-0,095
-0,1
y
modeling C
modeling D

Appear 12.2-b: Comparison of the 2 algorithms

---

13 Modeling F: quadrangles 2D

This modeling is the equivalent in 2D of modeling A (reference). This case does not present oscillations of contact pressures. Just like in modeling A, the quadrangles are half-compartments by an interface parallel to the edges, and numbers it contact pressures (one by cut edge) is compatible with the discretization of the field of displacement [bib1] [bib2]. The LBB condition is then observed and there are no oscillations of contact pressures.

13.1 Characteristics of the grid

The structure is then modelled by a regular grid composed of 20x20 QUAD4 (See Appear 13.1-a]).

Appear 13.1-a: Grid of quadrangles

13.2 Functionalities tested

Friction is taken into account and the contact is active as of the 1st iteration of active constraints. The algorithm aiming at restricting the space of the multipliers of Lagrange is decontaminated.

Orders

DEFI_FISS_XFEM CONTACT
CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' NON'

14 Results of modeling F

14.1 Values tested

One tests the value of the contact pressure at the point P of co-ordinates (10, 17.5).

Identification Reference
Aster %
difference
Not P
-9.52844 10-2
-9.52844 10-2 2.41
10-4

14.2 Comments

This case test makes it possible to find the values of reference of contact pressures calculated in modeling A, and to check that in the case of quadrangles cut their faces parallel to, these contact pressures do not have oscillations (see [Figure 19.2-a]).

15 Modeling G: triangles (algorithm version 1)

15.1 Characteristics of the grid

The structure is modelled by a regular grid composed of triangles. The test is the equivalent in 2D of modeling B (See [Figure 15.1-a]).

Appear 15.1-a: Grid of triangles

15.2 Functionalities tested

Friction is taken into account and the contact is active as of the 1st iteration of active constraints. The algorithm aiming at restricting the space of the multipliers of Lagrange is the n°1.

Orders

DEFI_FISS_XFEM CONTACT
CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' VERSION1'

16 Results of modeling G

16.1 Values tested

One tests the value of the contact pressure at the point P of co-ordinates (10, 17.5).

Identification	Reference	Aster	% difference
Not P	-9.52844 10-2	-9.59082 10-2	0.655

16.2 Comments

This modeling shows that the algorithm set up makes it possible to reduce them effectively oscillations. (see [Figure 19.2-a]).

17 Modeling H: triangles (algorithm version 2)

17.1 Characteristics of the grid

The grid is identical to that of modeling G.

17.2 Functionalities tested

Friction is taken into account and the contact is active as of the 1st iteration of active constraints. The algorithm aiming at restricting the space of the multipliers of Lagrange is the n°2.

Orders

DEFI_FISS_XFEM CONTACT
CONTACT_INIT=' OUI'

FROTTEMENT=' COULOMB'

ALGO_LAGR=' VERSION2'

18 Results of modeling H

18.1 Values

tested

One tests the value of the contact pressure at the point P of co-ordinates (10, 17.5).

Identification Reference
Aster %
difference
Not P
-9.52844 10-2
-9.59082 10-2
0.655

18.2 Comments

This modeling shows that in 2D, the algorithm version 2 has a behavior very close to that of version 1. Indeed, put aside the first contact pressures measured on the left of grid, the actual values are identical, and the curves obtained with the two algorithms cover almost completely. (see [Figure 19.2-a]).

---

19 Summaries of the results 2D

19.1 Summary

It, initially, was checked that the behavior of the structure of reference (modeling

With) could be found in 2D (modeling F). After having observed the phenomenon of oscillations in 2D, similar to that obtained in modeling B, one tested on cases in 2D both algorithms which make it possible to reduce these oscillations in 3D.

The two algorithms tested in modelings G and H give, in 2 dimensions, of the results very close, and allow consequently to reduce the oscillations introduced by the grid.

19.2 Curves of comparison

[Figure 19.2-a] represents the curves of contact pressures along axis OX for 3 modelings in 2D presented. It is noticed that the curves representative of both algorithms overlap almost completely. The two algorithms are thus about too efficient one that the other in 2D. It make it possible nevertheless to reduce the oscillations effectively.

Appear 19.2-a: Comparison of contact pressures following modelings 2D

It is it should be noted that a refinement of grid increases obviously the precision of the results obtained.

---

20 Bibliography

[1]
Massin P., Ben Dhia H., ZarrougG Mr.: Elements of contacts derived from a formulation

continuous hybrid, Manual of reference of Code_Aster, [R5.03.52]
[2]
Massin P., Geniaut S.: Method X-FEM, Handbook of reference of Code_Aster, [R7.02.12]
[3]
Babuska I.: The finite element method with lagrangian multipliers, Numerische Maths 20, 179-192, 1973
[4]
Barbosa H., Hugues T.: Finite element method with lagrange multipliers one the boundary. Circumventing the Babuska-Brezzi condition, comp. Meth. Applied Mech Engrg. 85 (1), 109-128, 1991
[5]
Vault D., Bathe K.J.: The Inf-sup test, Computers & Structures 47 (4/5), 537-545, 1993
[6]
Moës NR., Béchet E., Peaty Mr.: Imposing essential boundary conditions in the X-FEM, Int. J. Numer. Meth. Engng, 2005, submitted.

Titrate:
SSNV200 - Tensile test shearing with method VISC_TAHERI Dates:
06/09/02
Author (S):
Key J.M. PROIX
:
V6.04.200-A Page:
1/6

Organization (S): EDF/AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.200

SSNV200 - Tensile test shearing
with model VISC_TAHERI

Summary:

The problem is quasi-static nonlinear in mechanics of the structures.

One analyzes the response of an element of volume to a loading in traction-shearing, carried out of such
way that that imposes a uniform state of stress-strain in the element. There is only one modeling voluminal 3D.

This test is inspired by the SSNV102, which tests the behavior of S.Taheri in elastoplasticity. Here, one takes in
count viscosity.

:
V6.04.200-A Page:
2/6

1
Problem of reference

1.1 Geometry

y
Face YZ: (1, 3, 5, 7)
1
2

Face XZ: (3, 4, 7, 8)

Face 1YZ: (2, 4, 6, 8)
5
6

Face 1XZ: (1, 2, 5, 6)
(T) O
Face 1

X Z
3
4
(T) imposed shearing
(T)
O

O
Face 1

Y Z
X
(T) imposed pressure
O
Face YZ
(T)
function of effort
7
8
Z

1.2
Material properties

isotropic elasticity
E = 200.000 MPa
= 0,3

plasticity Said Taheri Cinf = 0.065 MPa C1 = -0.012 Mpa
S = 450
B = 30

m = 0.1
has = 312
= 0.3
Ro = 72
Viscosity:
N=11
UN_SUR_K = 3.28410E-04 UN_SUR_M = 0.17857
LEMAITRE

1.3
Boundary conditions and loadings

N04
dx = Dy = 0
Face YZ:
FX = FY = - F (T)
N08
dx = Dy = dz = 0
Face XZ:
FX = - F (T)
N02, N06
dx = 0
Face 1YZ:
FY = F (T)

Face 1XZ:
FX = F (T)

F (NR)

88.
T (S)
0.
1.

1.4 Conditions
initial

Null constraints and deformations with T = 0.

2
Reference solution

2.1
Method of calculation used for the reference solution

The test is of nonregression. One thus notes the values obtained by Code_Aster, with the version 5.10

2.2
Results of reference

Values of,
p
p p and p with the nodes with T = 1 S.

2.3
Uncertainty on the solution

2.4 References
bibliographical

[1]
S. ANDRIEUX - P. SCHOENBERGER - S. TAHERI: With three dimensional cyclic constitutive law for metals with has semi-discrete memory variable - HI-71/8147 (1992)
[2]
P. GEYER - J.M. PROIX - P. SCHOENBERGER - S. TAHERI: Modeling of phenomena of progressive deformation - Collection of the notes intern DER 93NB00153

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D:

Cubic elementary with a grid using a hexahedron with 8 nodes.

F
y
22 NR
F
1
2
F
T
F
1s
5
F
6
2F
3
has
X
4
F
2F
7
8
F
Z

3.2 Characteristics of the grid

1 mesh HEXA8, width side has = 1.

3.3 Functionalities tested

Order
Key word factor
Simple key word
Argument
DEFI_MATERIAU
TAHERI

DEFI_MATERIAU
LEMAITRE
STAT_NON_LINE
COMP_INCR
RELATION
VISC_TAHERI
NEWTON
STAMP
“TANGENT”

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
in all nodes

2.10-5 2.10-5 0

2.610-5 2.610-5 0

0. 0. 0
p

0 0 0
p
p
0 0 0

64.8 64.8 0
p

4.2 Remarks

The loading used here does not reveal of plasticization, whereas without viscosity, this same loading leads the structure in elastoplastic mode.

---

5 Summary of the results

This test of nonregression allows a minimal checking of the correct operation of the model VISC_TAHERI. It would ask to be supplemented by a test implementing a true solution of reference.

HT-66/02/001/A

Code_Aster ®
Version
4.0
Titrate:
Thermal SSNV301 Shock and mechanical loading
Date: 01/12/98
Author (S)
:
E. LORENTZ, L. LAMMERANT, H. DRION
Key:
V6.04.301-A Page:
1/12
Organization (S): EDF/IMA/MMN, SAMTECH SA
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.301
SSNV301 - Cylindrical ring in subjected rotation
with a thermal shock and an internal pressure -
Von Mises (isotropic Work hardening)
Summary:
This test of quasi-static mechanics non-linear 3D relates to the modeling of a piece of ring cylindrical and the resumption of a field of deformation checks after a transitory linear thermal calculation (shock thermics: application of a heat flux inside the cylindrical ring). Then, one takes calculation and one again check the transfer of the field of thermal deformation of origin and the use of a following loading (force centrifugal). Then, one takes again calculation once again by applying a pressure interns (change of boundary conditions). One uses the criterion of Von Mises with isotropic work hardening defined by a function which depends on the temperature.
Comparison with the numerical results of a modeling with the SAMCEF software V7.0 (module THERNL for calculation of the field of temperature transitory and taken again with module MECANL for mechanical calculation non-linear geometrical ("Green") and material).
Modeling with elements 3D of the meca_hexa20 type and axisymmetric elements of meaxtr6 type. One use a rather fine grid in order to check the robustness and the performances of Code_Aster.
In two modelings A and B, the pressure applied is not following. Results obtained by The SAMCEF software are provided with and without following pressure.
Handbook of Validation

V6.04 booklet: Nonlinear statics of the voluminal structures
HI-75/98/040 - Ind A

---

1 Problem of reference

1.1 Geometry

Roll with:
Interior ray
IH = 0.04 m
External ray
Re = 0.08 m
Height
L = 0.04 m
Re
IH
L

1.2 Material properties

The material is homogeneous isotropic, thermoelastic linear. Material mechanical properties depend on the temperature. The properties vary linearly between the 2 extreme temperatures: 0°C and 100°C.

Law of behaviour to linear isotropic work hardening:

Temperature = 0 °C
Temperature = 100 °C
E
E = 195000 MPa
E = 175500 MPa
T

= 0.3
= 0.3
y
y = 181 MPa

y = 145 MPa

AND = 2857.504 MPa
AND = 1979.695 MPa
Thermal properties and density:
=
J
72 *msK*
=
kg
7860
3
m
J
CP = 452 *kgK*
=
1
12.E - 6 *K*

1.3
Boundary conditions and loadings

The thermal shock is modelled by a heat flux of 300000 W/m2s inside the cylinder.
structure has an initial temperature of 0°C.
At the same time a centrifugal force is applied: on an interval of 15 S, the number of revolutions is increased up to 2400 rad/s, then kept constant.
. (rad/s)
2400
T (S)

15
25
After 15 S, an internal pressure is applied: the pressure increases linearly up to a value
from 5.5 MPa which is reached to 20 S, then the pressure goes down to zero.
p (Mpa)
5.5
T (S)
5
10
15
20
25
Thermal calculation and mechanical calculation are carried out with 50 steps of identical times.
A quarter of the cylinder is modelled by fixing the transverse components of displacements at both
cross sections of the cylinder. Moreover, the degree of translation according to the length of the cylinder
is
fixed on the interior ray of the with dimensions inferior of the cylinder.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

Comparison with the numerical results of a voluminal modeling with the SAMCEF software V7.0 with
50
no time (module THERNL for the calculation of the field of temperature transitory and taken again with
modulate MECANL for non-linear mechanical calculation).
An implicit scheme is used for the integration of the equation of heat.
Non-linear mechanical calculation was carried out with the SAMCEF software by using a modeling

axisymmetric with 5 steps of time (geometrical nonlinear modeling (“Green”)) and one voluminal modeling (a quarter of cylinder) with 5 steps of time (modeling nonlinear geometrical (“Green”)).

2.2

Results of reference

Evolution of the field of temperature according to the thickness on with dimensions lower of the cylinder

Axisymmetric calculation with 50 steps of time

Temp = 0.5 dryness

Temp = 25 dryness

1.25355E+01
8.64267E+01
5.71233E+00
7.65695E+01
2.44526E+00
6.77355E+01
1.12189E+00
5.98610E+01
4.83644E-01
5.28476E+01
2.22443E-01
4.66462E+01
9.62036E-02
4.11801E+01
4.43444E-02
3.64106E+01
1.92310E-02
3.22765E+01
8.87973E-03
2.87468E+01
3.85960E-03
2.57723E+01
1.78524E-03
2.33283E+01
7.78650E-04
2.13761E+01
3.63114E-04
1.98963E+01
1.64448E-04
1.88596E+01
8.80577E-05
1.82514E+01
6.54904E-05

1.80507E+01
Voluminal calculation with 50 steps of time
Temp = 0.5 dryness
Temp = 25 dryness
1.26658E+01
8.64175E+01
5.64556E+00
7.65753E+01
2.50690E+00
6.77332E+01
1.10448E+00
5.98571E+01
5.06396E-01
5.28510E+01
2.23330E-01
4.66453E+01
9.98984E-02
4.11819E+01
4.41255E-02
3.64095E+01
2.02976E-02
3.22781E+01
8.97177E-03
2.87460E+01
4.05352E-03
2.57736E+01
1.79338E-03
2.33275E+01
8.25938E-04
2.13766E+01
3.68531E-04
1.98979E+01
1.74367E-04
1.88647E+01
8.91805E-05
1.82450E+01
6.98548E-05
1.80607E+01

Evolution of the longitudinal constraint T

Re
IH
With
L
0.5 L
B
0.25 (R - R)
E
I

Case where the pressure is nonfollowing

Nonlinear voluminal calculation
geometrical with 5 steps of time
T (S)

Not A
Not B
15.0

1.21692E8
1.67285E8
T
20.0

1.39804E8
1.65266E8
T
25.0

1.28967E8
1.57980E8
T
Nonlinear axisymmetric calculation

geometrical with 5 steps of time
T (S)

Not A
Not B
15.0

1.20472E8
1.66917E8
T
20.0

1.39164E8
1.70412E8
T
25.0

1.28421E8
1.63168E8
T

Case where the pressure is following

Nonlinear voluminal calculation
geometrical with 5 steps of time
T (S)

Not A
Not B
15.0

1.21692E8
1.67285E8
T
20.0

1.39894E8
1.65313E8
T
25.0

1.29032E8
1.58007E8
T
Nonlinear axisymmetric calculation
geometrical with 5 steps of time
T (S)

Not A
Not B
15.0

1.20472E8
1.65934E8
T
20.0

1.39252E8
1.64075E8
T
25.0

1.28485E8
1.56886E8
T

2.3
Uncertainty on the solution

Uncertainty lower than 1% for thermal calculation, uncertainty lower than 0.5% for calculation mechanics.

---

3 Modeling
With

3.1
Characteristics of modeling A

A quarter of cylinder with a regular grid.

3.2
Characteristics of the grid

A number of nodes:
4037
A number of meshs and types:
800 MECA_HEXA20 (8 meshs on
the thickness, 10 meshs on
length and 10 meshs on the quarter
of circle)

3.3 Functionalities
tested

Orders
Keys
THER_LINE
PARM_THETA
1.
[U4.33.01]
DEF_MATERIAU
ECRO_LINE_FO
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
DEFORMATION
PETIT_REAC

---

4 Results of modeling A

4.1 Values tested

Identification	**Moment**	**Reference**	**Aster**	**% difference**
Temperature (N21)	0.5s	1.266580E1	1.266584E1	0.
Temperature (N201)	0.5s	5.645560E0	5.645554E0	0.
Temperature (N202)	0.5s	2.506900E0	2.506894E0	0.

Temperature (N203)
0.5s
1.104480E0
1.104478E0
0.
Temperature (N204)
0.5s
5.063960E1
5.063949E1
0.
Temperature (N205)
0.5s
2.233300E1
2.233298E1
0.
Temperature (N206)
0.5s
9.989840E2
9.989826E2
0.
Temperature (N207)
0.5s
4.412550E2
4.412536E2
0.
Temperature (N208)
0.5s
2.029760E2
2.029754E2
0.
Temperature (N209)
0.5s
8.971770E3
8.971745E3
0.
Temperature (N210)
0.5s
4.053520E3
4.053507E3
0.
Temperature (N211)
0.5s
1.793380E3

1.793372E3
0.
Temperature (N212)
0.5s
8.259380E4
8.259340E3
0.
Temperature (N213)
0.5s
3.685310E4
3.685292E4
0.
Temperature (N214)
0.5s
1.743670E4
1.743665E4
0.
Temperature (N215)
0.5s
8.918050E5
8.918007E5
0.
Temperature (N28)
0.5s
6.985480E5
6.985445E5
0.
Temperature (N21)
25s
8.641750E1
8.641753E1
0.
Temperature (N201)
25s
7.657530E1
7.657529E1
0.
Temperature (N202)
25s
6.773320E1
6.773321E1
0.
Temperature (N203)

25s
5.985710E1
5.985709E1
0.
Temperature (N204)
25s
5.285100E1
5.285104E1
0.
Temperature (N205)
25s
4.664530E1
4.664533E1
0.
Temperature (N206)
25s
4.118190E1
4.118188E1
0.
Temperature (N207)
25s
3.640950E1
3.640950E1
0.
Temperature (N208)
25s
3.227810E1
3.227812E1
0.
Temperature (N209)
25s
2.874600E1
2.874597E1
0.
Temperature (N210)
25s
2.577360E1
2.577356E1
0.
Temperature (N211)
25s
2.332750E1
2.332747E1

0.
Temperature (N212)
25s
2.137660E1
2.137655E1
0.
Temperature (N213)
25s
1.989790E1
1.989793E1
0.
Temperature (N214)
25s
1.886470E1
1.886472E1
0.
Temperature (N215)
25s
1.824500E1
1.824500E1
0.
Temperature (N28)
25s
1.806070E1
1.806074E1
0.
SIYY (M473, N2931)
15s
1.216920E8
1.212172E8
0.390
SIYY (M74, N204)
15s
1.672850E8
1.672363E8
0.029
SIYY (M473, N2931)
20s
1.398040E8
1.396296E8
0.390
SIYY (M74, N204)
20s

1.652660E8
1.654056E8
0.029
SIYY (M473, N2931)
25s
1.289670E8
1.287516E8
0.390
SIYY (M74, N204)
25s
1.579800E8
1.580668E8
0.029

4.2 Parameters of execution

Version: 3.09
Machine:
System:
Obstruction memory:
16 megawords
Time CPU To use: 4971.07 seconds

---

5 Modeling B

5.1 Characteristics of modeling B

5.2 Characteristics of the grid

A number of nodes:
357
A number of meshs and types: 160 MEAXTR6
(8 meshs on the thickness, 10 meshs over the length)

5.3 Functionalities
tested

Orders
Keys
THER_LINE
PARM_THETA
1.
[U4.33.01]
DEF_MATERIAU
ECRO_LINE_FO
D_SIGM_EPSI
[U4.23.01]
SY
STAT_NON_LINE
COMP_INCR
DEFORMATION
PETIT_REAC
[U4.32.01]
RELATION
VMIS_ISOT_LINE

6
Results of modeling B

6.1 Values

tested
Identification
Moment
Reference
Aster
% difference
Temperature (N1)
0.5s
1.25355E1
1.253935E1
0.031
Temperature (N161)
0.5s
5.712330E0
5.710409E0
0.034
Temperature (N162)
0.5s
2.445260E0
2.446690E0
0.058
Temperature (N163)
0.5s
1.121890E0
1.121793E0
0.009
Temperature (N164)
0.5s
4.836440E1
4.839514E1
0.064
Temperature (N165)
0.5s
2.224430E1
2.224511E1
0.004
Temperature (N166)
0.5s
9.620360E2
9.626885E2
0.068
Temperature (N167)
0.5s

4.434440E2
4.434991E2
0.012
Temperature (N168)
0.5s
1.923100E2
1.924445E2
0.070
Temperature (N169)
0.5s
8.879760E3
8.881443E3
0.019
Temperature (N170)
0.5s
3.859600E3
3.862363E3
0.072
Temperature (N171)
0.5s
1.785240E3
1.785670E3
0.024
Temperature (N172)
0.5s
7.786500E4
7.792119E3
0.072
Temperature (N173)
0.5s
3.631140E4
3.632162E4
0.028
Temperature (N174)
0.5s
1.644480E4
1.645681E4
0.073
Temperature (N175)
0.5s
8.805770E5
8.808440E5
0.030

Temperature (N14)
0.5s
6.549040E5
6.553566E5
0.069
Temperature (N1)
25s
8.642670E1
8.642786E1
0.001
Temperature (N161)
25s
7.656950E1
7.656903E1
0.01
Temperature (N162)
25s
6.773550E1
6.773627E1
0.001
Temperature (N163)
25s
5.986100E1
5.986069E1
0.001
Temperature (N164)
25s
5.284760E1
5.284816E1
0.001
Temperature (N165)
25s
4.664620E1
4.664591E1
0.001
Temperature (N166)
25s
4.118010E1
4.118056E1
0.001
Temperature (N167)
25s
3.641060E1

3.641040E1
0.001
Temperature (N168)
25s
3.227650E1
3.227691E1
0.001
Temperature (N169)
25s
2.874680E1
2.874659E1
0.001
Temperature (N170)
25s
2.577230E1
2.577260E1
0.001
Temperature (N171)
25s
2.332830E1
2.332814E1
0.001
Temperature (N172)
25s
2.137660E1
2.137655E1
0.001
Temperature (N173)
25s
1.989790E1
1.989793E1
0.
Temperature (N174)
25s
1.886470E1
1.886472E1
0.001
Temperature (N175)
25s
1.824500E1
1.824500E1
0.
Temperature (N14)

25s
1.806070E1
1.806074E1
0.001
SIYY (M90, N222)
15s
1.204720E8
1.200544E8
0.347
SIYY (M101, N164)
15s
1.659340E8
1.661848E8
0.151
SIYY (M90, N222)
20s
1.391640E8
1.383875E8
0.558
SIYY (M101, N164)
20s
1.640310E8
1.643171E8
0.174
SIYY (M90, N222)
25s
1.284210E8
1.275833E8
0.652
SIYY (M101, N204)
25s
1.568610E8
1.570781E8
0.138

6.2 Parameters of execution

Version: 3.09
Machine:
System:
Obstruction memory:
16 megawords
Time CPU To use: 58.37 seconds
Handbook of Validation

Code_Aster ®
Version
4.0
Titrate:
Thermal SSNV301 Shock and mechanical loading
Date: 01/12/98
Author (S)
:
E. LORENTZ, L. LAMMERANT**,** H. DRION
Key:
V6.04.301-A Page:
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7 Summary of the results

It was checked that one obtains the same results with or without recovery, with or without modification of boundary conditions.

It should be noted that the nodal efforts that one provides to Aster are divided by 2 compared to those which one provides to the SAMCEF software into axisymmetric.

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Organization (S): EDF-R & D /AMA, Delta CAD

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.501

SSNV501 Stamping of a sheet by one
hemispherical punch (test of Wagonner)

Summary:

This test represents a calculation of stamping of a sheet by a rigid hemispherical punch in the presence of great plastic deformations. This test is very much used in the simulation of working sheet.

The analyzed results are the vertical displacement of the punch according to the imposed force. They are compared with a numerical reference solution.

Three axisymmetric modelings are carried out. The contact blank/punch and blank/die are of the type node-mesh.

· Modélisation a: the coefficient of friction, contact blank/punch and blank/matrix is null.
· Modélisation b: the coefficient of friction, contact blank/punch and blank/matrix is equal to 0.15.
· Modélisation C: modeling similar to modeling A with a finer grid for the blank.

1
Problem of reference

1.1 Geometry

Y
L

Stamp
Blank (sheet)
R2
X

With
E
Axis of symmetry
R1 = 50.8 mm
Punch
R2 = 6.35 mm (Ray of entry)
L = 59.18 mm
R1
E = 1. mm
p

1.2
Properties of material

Blank:
· E = 69004. N/mm ²
Young modulus
· = 0.3
Poisson's ratio
.
0

· =

(-4
589 10
p
+

Law of work hardening
0
) 216

Punch, die
· E = 107 N/mm ²
Young modulus
· = 0.3
Poisson's ratio

Zones of contact: punch/blank, die/blank
· μ = 0.15
Coefficient of friction

1.3
Boundary conditions and loadings

C.L. :
· the matrix is embedded
· the periphery of the blank is embedded

Loading: pressure p = 12.33N/mm ² => force of stamping of 100 kN

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2 Reference solution

2.1 Method of calculation used for the reference solution

The method of calculation used to simulate the behavior in the zone of contact is presented in detail in the references [bib1] and [bib2].

2.2 Results of reference

Loading (KN)	*Displacement μ=0, (mm)*	*Displacement μ=0.15 (mm)*
10	*10.6*	*10.6*
20	*15.4*	*15.4*
30	*20.0*	*20.0*
40	*24.7*	*23.8*
50	*28.2*	*27.1*
60	*33.0*	*30.8*
70	*37.4*	*35.2*
75	*44.0*	*36.5*
80		*38.3*
90		*50.0*

Displacements are extracted from [1].

2.3 Uncertainties on the solution

<5% graphic results

2.4 References

bibliography

[1]
P. CHABRAND, F. DUBOIS, J.C. GELIN: "Modelling drawbeads in sheet metal forming", Int. J. Mechanics, flight 38 n°1 pp 99-77 (1996)
[2]
R. WAGONER, E. NAKAMACHI and J.K. LEE: With benchmark test for sheet metal forming analysis. Technical RepT. No ERC/NSM-S-90-22, Ohio State University (1988)

---

3 Modeling
With

3.1
Characteristics of modeling

Solid: Modeling AXIS (QUAD4)
Solid meshs
Contact: CONTACT (SEG2)
- Blank
. 2 elements in the thickness
Stamp
. 14 elements according to the ray
Y
- Punch
Surfaces slaves
G

. 20 elements on AE
F
- Matrix
6
. 6 elements on CF
D
C2
A1
C1
A2
Zones of contact
B
R - DC1/C2F
- A2B/A1E

Surfaces Masters
Points:
Punch
- A1 and A2 are geometrically confused
- C1 and C2 are geometrically confused
- A1, C1 with the blank
- A2 with the punch
E
H
- C2 with the ray entered/matrix
Boundary conditions
p=12.334N/mm ²
- dimensioned GF, C2G, BC1: DX=0, DY=0.
- dimensioned DA1, A2H: DX=0.

To avoid the rigid movements of body, one forces that displacements DY of the A1 points (pertaining to the blank) and A2 (pertaining to the punch) are identical.

3.2
Characteristics of the grid

A number of nodes: 182
A number of meshs: 131 QUAD4, 12 TRIA3 and 84 SEG2

3.3 Functionalities tested

Orders Key word
factor
Key word

MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"

DEFI_MATERIAU TRACTION
SIGM

AFFE_CHAR_MECA CONTACT
APPARIEMENT=' MAIT_ESCL',

RECHERCHE=' NOEUD_BOUCLE',
METHODE=' CONTRAINTE',
STAT_NON_LINE
COMP_INCR
RELATION = "VMIS_ISOT_TRAC"

DEFORMATION = "SIMO_MIEHE"

4
Results of modeling A

4.1 Values tested

Identification
Loading
Reference
Aster %
difference
(Displacement)
(x103 NR)
DX (N87)
10.
10.6
9.98 -5.88
DX (N87)
20.
15.4
15.09 -2.01
DX (N87)
30.
20.0
19.34 -3.28
DX (N87)
40.
24.7
23.60 -4.47
DX (N87)
50.
28.2
27.62 -2.04
DX (N87)
60.
33.0
32.01 -3.01
DX (N87)
70.
37.4
37.10 -0.80
DX (N87)
75.
44.0
40.71 -7.47

4.2 Remarks

· The law of behavior of material constituting sheet is given linearized under-form.
· Calculation does not converge any more beyond 75% of the total load.

5 Modeling
B

5.1
Characteristics of modeling

Solid: Modeling AXIS (QUAD4)
Solid meshs
Contact: CONTACT (SEG2)
- Blank
. 2 elements in the thickness
Stamp
. 14 elements according to the ray
Y
- Punch
Surfaces slaves
G
. 20 elements on AE
F
- Matrix

6
. 6 elements on CF
D
C2
A1
C1
A2
Zones of contact
B
R - DC1/C2F
- A2B/A1E

Surfaces Masters
Points:
Punch
- A1 and A2 are geometrically confused
- C1 and C2 are geometrically confused
- A1, C1 with the blank
- A2 with the punch
E
H
- C2 with the ray entered/matrix
Boundary conditions
p=12.334N/mm ²
- dimensioned GF, C2G, BC1: DX=0, DY=0.
- dimensioned DA1, A2H: DX=0.

To avoid the rigid movements of body, one forces that displacements DY of the A1 points (pertaining to the blank) and A2 (pertaining to the punch) are identical.

5.2
Characteristics of the grid

A number of nodes: 182
A number of meshs: 131 QUAD4, 12 TRIA3 and 84 SEG2

5.3 Functionalities
tested

Orders Key word
factor
Key word

MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = “AXIS”

DEFI_MATERIAU TRACTION
SIGM

AFFE_CHAR_MECA CONTACT
APPARIEMENT=' MAIT_ESCL',

RECHERCHE=' NOEUD_BOUCLE',
METHODE=' LAGRANGIEN',
FROTTEMENT=' COULOMB',
COULOMB=0.15
STAT_NON_LINE
COMP_INCR
RELATION = “VMIS_ISOT_TRAC”

DEFORMATION = “SIMO_MIEHE”

6
Results of modeling B

6.1 Values
tested

Identification
Loading
Reference
Aster %
difference
(Displacement)
(x104 NR)
DX (N87)
0.3
5.00
4.84
-3.14
DX (N87)
0.6
7.00
7.39
5.60

6.2 Remarks

· The law of behavior of material constituting sheet is given in linearized form.
· Calculations were carried out up to 6% of the loading, they can continue without problem up to 78% of the total load, beyond calculation does not converge any more.

---

7 Modeling
C

7.1
Characteristics of modeling

Solid: Modeling AXIS (QUAD4)
Solid meshs
Contact: CONTACT (SEG2)
- Blank
. 2 elements in the thickness
Stamp
. 30 elements according to the ray
Y
- Punch
Surfaces slaves
G
. 20 elements on AE
F
- Ray entered/matrix
6
. 6 elements on CF
D
C2
A1
C1
A2
Zones of contact
B
R - DC1/C2F
- A2B/A1E

Surfaces Masters
Points:
Punch
- A1 and A2 are geometrically confused
- C1 and C2 are geometrically confused
- A1, C1 with the blank
- A2 with the punch
E
H
- C2 with the ray entered/matrix
Boundary conditions
$p=12.334N/mm^2$

- dimensioned GF, C2G, BC1: DX=0, DY=0.
- dimensioned DA1, A2H: DX=0.

To avoid the rigid movements of body, one forces that displacements DY of the A1 points (pertaining to the blank) and A2 (pertaining to the punch) are identical.

7.2
Characteristics of the grid

A number of nodes: 230
A number of meshs: 291 meshs (163 QUAD4, 12 TRIA3 and 116 SEG2)

7.3 Functionalities
tested

Orders Key word
factor
Key word

MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"

DEFI_MATERIAU TRACTION
SIGM

AFFE_CHAR_MECA CONTACT
APPARIEMENT=' MAIT_ESCL',

RECHERCHE=' NOEUD_BOUCLE',
METHODE=' CONTINUE',
MODL_AXIS = "YES",
STAT_NON_LINE
COMP_INCR
RELATION = "VMIS_ISOT_TRAC"

DEFORMATION = "SIMO_MIEHE"

8 Results of modeling C

8.1 Values tested

Identification
Loading
Reference
Aster
% difference
(Displacement)
(x104 NR)
DX (N87)
1.
10.6
8.35
-21.18
DX (N87)
2.
15.4
14.07
-8.66
DX (N87)
3.
20.0
18.58

-7.11
DX (N87)
4.
24.7
22.69
-8.13
DX (N87)
5.
28.2
26.74
-5.20
DX (N87)
6.
33.0
31.01
-6.03
DX (N87)
7.
37.4
36.05
-3.62
DX (N87)
7.5
44.0
39.72
-9.71

8.2 Remarks

· The law of behavior of material constituting sheet is given linearized under-form.
· Calculation does not converge any more beyond 75% of the total load.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-62/06/005/A

9
Summary of the results

On the figure below we present, for modeling A, the deformation of the blank, the position of the matrix and of the punch for a loading of 75kN.

One notes a variation compared to the references [bib1] and [bib2]. For a loading reaching 75% total specified in these references, we have:

· for A, 7,5% of error on displacement,
· for C, 9,7% of error on displacement.

For modeling B (with friction), the error with 75% of the load given by the references [bib1] and [bib2] is 6%.

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:
V6.04.503-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.503

SSNV503 - Shoe slipping on a rigid level

Summary:

This test represents a calculation of contact of a shoe slipping on a rigid level. The objective of this test is of to allow to validate in an unquestionable way calculation of the criterion of Coulomb and the good transmission of pressure.

Various modelings of the zone of contact tested are as follows:

· Modélisation A (2D): contact node-mesh, Lagrangian method for the contact and friction, play

geometrical.
· Modélisation B (2D): contact node-mesh with Lagrangian method and play defined by a function.
· Modélisation C (2D): contact node-mesh, method Lagrangian for the contact and penalized for friction, geometrical play.
· Modélisation D (2D): contact node-mesh, method penalized for the contact and friction, play geometrical.
· Modélisation E (3D): contact node-mesh, method Lagrangian for the contact and penalized for friction, geometrical play.
· Modélisation F (3D): contact node-mesh, method Lagrangian for the contact and penalized for friction, play defined by a function.
· Modélisation G (3D): contact node-mesh, method penalized for the contact and friction, play geometrical.
· Modélisation H (2D): contact node-mesh, method continues for the contact and friction, play geometrical.

1
Problem of reference

1.1 Geometry

Dimensions in mm
Shoe: thickness = 20.mm
Y
width = 20.mm

Pn
Rigid plan: thickness = 5.mm
width = 60.mm
Play: 2.mm

Pt
Shoe
2.
20.
The shoe is located in the middle of
X
rigid plan
5.
10.
40.
10.
Rigid plan

1.2
Properties of material

Shoe:
E = 2.1.106 N/mm ²
Young modulus
= 0
Poisson's ratio

Rigid plan by conditions kinematics.

Zone of contact:

μ = 0.3
Coefficient of friction

1.3
Boundary conditions and loadings

Boundary conditions:
· All the nodes of the rigid plan are embedded.

3 cases of loading:
· Normal Pression Pn = 300N/mm ²
· Normal Pression Pn = 300N/mm ² and tangential pressure Pt = 178.2 N/mm ²

· *Normal Pression Pn = 300N/mm ² and tangential pressure Pt = 181.8 N/mm ²*

1.4 Conditions initial

None.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

Y
P
F
N
T = µFt
Ft
D
C

K

Pt
Shoe
X
WITH B
Fn

Design assumption: The deformation of the shoe is neglected.

· ***Chargement 1 (normal Pressure Pn: 300N/mm ²):*** *one checks:*

- good transmission of the normal efforts on the level of the zone of contact: pressure normal on the level of the zone of contact is equal to the pressure applied (
contact
P = P

N
N
)
-
that the vertical displacement of the shoe on the level of the zone of contact AB is equal to the play.

· ***Chargement 2 (Pn: 300N/mm ² and Pt = 178.2N/mm ²):*** *it is checked that the nodes of the shoe located*
in the zone of slip (AB) do not move tangentially:

μ N
P SCD
P =
0.99
T

S AD

· ***Chargement 3 (Pn: 300N/mm ² and Pt = 181.8N/mm ²):*** *it is checked that the nodes of the shoe located*
in the zone of slip (AB) 9mm move according to X.

μ N
P SCD
P =
1.01
T

S AD

Determination of the stiffness K of the spring: one wants to determine the stiffness of the spring according to
desired displacement. At the time of the slip, the force in the spring is of:

Fr = Ft µ Fn = 0,01 µ Fn with (Ft = 181.8x20, Fn = 300x40)

Fr = K C
: force in the spring
Ft = PtxSAD:
force
tangential
Fn = PnxSCD: force
normal
C:
displacement
tangential
SAD:
surface
SDC:
surface

For a displacement of 9. mm rigidity K within the competence must-to be of 0.01µFn/9 = 4N/mm

---

2.2
Results of reference

· ***Chargement 1 (normal Pressure Pn):*** *Pcontact*
300N/mm ²
N
=

· ***Chargement 2 (Pn: 300N/mm ² and Pt = 178.2N/mm ²):*** *it is checked that there is at least a node of the surface of contact which does not slip. One test that at least one of the nodes located on the face opposed to the application of the side loading does not slip.*
· ***Chargement 3 (Pn: 300N/mm ² and Pt = 181.8/mm ²):*** *it is checked that all the nodes of the surface of contact slip. One tests that all the nodes located on the face opposed to the application of side loading slip.*

2.3 Uncertainties on the solution

< 0,1%

2.4 References bibliographical

Without Object

3 Modeling
With

3.1
Characteristics of modeling

A modeling "D_PLAN" with elements QUAD4 testing the functionalities of contact node net with friction treated with the Lagrangian method was implemented.

The play between the shoe and the frame is defined by the geometrical co-ordinates of the grid.

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 2 N/mm
RES_HAUT
: K = 0,005 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=0.
Frame: DX=DY=0.

3.2
Characteristics of the grid

A number of nodes: 53
Numbers and types of meshs: 33 QUAD4, 32 SEG2

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

3.3 Functionalities
tested

Orders Key word
factor
Key word

MODI_MAILLAGE
ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING: "D_PLAN"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "LAGRANGIAN"
FRICTION: "COULOMB"
COULOMB: 0.3
STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"

4
Results of modeling A

4.1 Values
tested

Identification Reference Aster
% difference
Loading 1

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.69E04
Tangential force of contact
0. NR
1.999547 E05 NR
2.00E05
DX (not A)
1.000 mm
1.000000 E+00 mm
1.01E07
DY (not A)
1.732 mm
1.732051 E+00 mm
0.003
DX (not B)
1.000 mm
1.000000 E+00 mm
1.42E08
DY (not B)
1.732 mm
1.732055 E+00 mm
0.003
Loading 2

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.68E04
Tangential force of contact
3.564000 E+04 NR
3.563962 E+03 NR
-0.001
DX (not A)
1.000 mm
1.021344 E+00 mm
2.134
DY (not A)

1.732 mm
1.719728 E+00 mm
-0.709
DX (not B)
1.000 mm
1.000000 E+00 mm
4.48E11
DY (not B)
1.732 mm
1.732051 E+00 mm
0.003
Loading 3

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.70E04
Tangential force of contact
3.624000 E+04 NR
3.599992 E+03 NR
-0.662
DX (not A)
8.787 mm
8.809533 E+00 mm
0.177
DY (not A)
2.768 mm
2.776785 E+00 mm
0.317
DX (not B)
8.787 mm
8.786943 E+00 mm
-0.080
DY (not B)
2.768 mm
2.763743 E+00 mm
-0.154

4.2 Remarks

· The play is defined in this case in a geometrical way. One with the possibility of defining it via the words

keys "DIST_1" and "DIST_2". This is done in the following model.
· The pressures normal and tangential on the level of the zone of contact are checked while testing total force of contact in the normal and tangential direction:

F CTAC = p S
= 300 40*1 = 12000N*
N
N cd.
F CTAC = p S
=
2
.
*178 * 20 *1 = 35640N*
T
T AD
(Loading 2)
F CTAC = p S
=
8
.
*181 * 20 *1 = 36240N*
T
T AD
(Loading 3)

---

5 Modeling
B

5.1
Characteristics of modeling

A modeling "D_PLAN" with elements QUAD4 testing the functionalities of contact node net with friction treated with the Lagrangian method was implemented.

The play between the shoe and the frame is defined by a function using key word "DIST_2".

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 2 N/mm
RES_HAUT
: K = 0,005 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=0.
Frame: DX=DY=0.

5.2
Characteristics of the grid

A number of nodes: 53
Numbers and types of meshs: 33 QUAD4, 32 SEG2

5.3 Functionalities tested

Orders Key word factor
Key word

MODI_MAILLAGE
ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING: "D_PLAN"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "LAGRANGIAN"
FRICTION: "COULOMB"
COULOMB: 0.3
DIST_2: -2.
STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"

6 Results of modeling B

6.1 Values tested

Identification Reference Aster
% difference

Loading 1

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.71E04
Tangential force of
0. NR
7.724662 E05 NR
7.72E05
contact
DX (not A)
1.000 mm
9.999999 E01 mm
3.83E09
DY (not A)
1.732 mm
1.732055 E+00 mm
0.003
DX (not B)
1.000 mm
1.000000 E+00 mm
3.32E08
DY (not B)
1.732 mm
1.732055 E+00 mm
0.003

Loading 2

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.70E04
Tangential force of
3.564000 E+04 NR
3.563962 E+03 NR
-0.001
contact
DX (not A)
1.000 mm

1.021344 E+00 mm
2.134
DY (not A)
1.732 mm
1.719727 E+00 mm
-0.709
DX (not B)
1.000 mm
1.000000 E+00 mm
1.81E08
DY (not B)
1.732 mm
1.732051 E+00 mm
0.003
Loading 3

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.70E04
Tangential force of
3.624000 E+04 NR
3.599992 E+03 NR
-0.662
contact
DX (not A)
8.787 mm
8.809533 E+00 mm
0.177
DY (not A)
2.768 mm
2.776785 E+00 mm
0.317
DX (not B)
8.787 mm
8.786943 E+00 mm
-0.080
DY (not B)
2.768 mm
2.763743 E+00 mm
-0.154

6.2 Notice

The play is defined in this case by a function. There is no difference with the preceding model where the play is defined in a geometrical way.

---

7 Modeling
C

7.1
Characteristics of modeling

A modeling "D_PLAN" with elements QUAD4 testing the functionalities of contact node net with friction treated with the method Lagrangian for the contact and penalized for friction was implemented.

The play between the shoe and the frame is defined by the geometrical co-ordinates of the grid.

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 2 N/mm
RES_HAUT
: K = 0,005 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=0.
Frame: DX=DY=0.

7.2
Characteristics of the grid

A number of nodes: 53
Numbers and types of meshs: 33 QUAD4, 32 SEG2

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

7.3 Functionalities tested

Orders Key word factor Key word

MODI_MAILLAGE
ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING: "D_PLAN"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "PENALIZATION"
E_T: 1.E+05
FRICTION: "COULOMB"
COULOMB: 0.3
COEF_MATR_FROT: 0.9
STAT_NON_LINE

COMP_ELAS
RELATION: "ELAS"

8
Results of modeling C

8.1 Values
tested

Identification Reference Aster
% difference
Loading 1

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.69E04
Tangential force of
0. NR
7.731180 E06 NR
7.73E06
contact
DX (not A)
1.000 mm
9.999999 E01 mm
6.84E08
DY (not A)
1.732 mm
1.732055 E+00 mm
0.003
DX (not B)
1.000 mm
1.000000 E+00 mm
1.07E04
DY (not B)
1.732 mm
1.732055 E+00 mm
0.003
Loading 2

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.69E04
Tangential force of
3.564000 E+04 NR
3.563959 E+03 NR
-0.001
contact
DX (not A)
1.000 mm
1.026850 E+00 mm
2.185
DY (not A)
1.732 mm
1.719435 E+00 mm
-0.725
DX (not B)
1.000 mm
1.000506 E+00 mm
0.051
DY (not B)
1.732 mm
1.731759 E+00 mm
-0.014
Loading 3

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.69E04
Tangential force of
3.624000 E+04 NR
3.599992 E+03 NR
-0.662
contact
DX (not A)
8.787 mm
8.809533 E+00 mm
0.177
DY (not A)

2.768 mm
2.776785 E+00 mm
0.317
DX (not B)
8.787 mm
8.786944 E+00 mm
-0.080
DY (not B)
2.768 mm
2.763743 E+00 mm
-0.154

8.2 Notice

The play is defined in this case in a geometrical way. One with the possibility of defining it via the key words
"DIST_1" and "DIST_2". After checking, this second case does not change anything with the result.

---

9 Modeling
D

9.1
Characteristics of modeling

A modeling "D_PLAN" with elements QUAD4 testing the functionalities of contact node *net with friction treated with the method penalized for the contact and friction was put in work.*

The play between the shoe and the frame is defined by the geometrical co-ordinates of the grid.

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 2 N/mm
RES_HAUT
: K = 0,005 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=0.
Frame: DX=DY=0.

9.2
Characteristics of the grid

A number of nodes: 53
Numbers and types of meshs: 33 QUAD4, 32 SEG2

9.3 Functionalities

tested

Orders Key word
factor
Key word

MODI_MAILLAGE
ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING: "D_PLAN"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "PENALIZATION"
E_T: 1.E+05
E_N: 1.E+05
FRICTION: "COULOMB"
COULOMB: 0.3
COEF_MATR_FROT: 0.9
STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"

10 Results of modeling D

10.1 Values tested

Identification Reference Aster
% difference
Loading 1

Force normal contact

1.200000 E+04 NR
1.199998 E+04 NR
1.70E-04
Tangential force of
0. NR
7.484511 E-06 NR
7.48E-06
contact
DX (not A)
1.000 mm
1.004111 E+00 mm
0.411
DY (not A)
1.732 mm
1.741004 E+00 mm
0.520
DX (not B)
1.000 mm
1.005698 E+00 mm
0.570
DY (not B)
1.732 mm
1.740088 E+00 mm
0.467
Loading 2

Force normal contact
1.200000 E+04 NR
1.199979 E+04 NR
1.70E-04
Tangential force of
3.564000 E+04 NR
3.563930 E+03 NR
-0.002
contact
DX (not A)
1.000 mm
1.025709 E+00 mm
-2.571
DY (not A)
1.732 mm
1.723129 E+00 mm

-0.512
DX (not B)
1.000 mm
1.013353 E+00 mm
1.335
DY (not B)
1.732 mm
1.742276 E+00 mm
0.593
Loading 3

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.70E-04
Tangential force of
3.624000 E+04 NR
3.599992 E+03 NR
-0.662
contact
DX (not A)
8.787 mm
8.807222 E+00 mm
0.150
DY (not A)
2.768 mm
2.769538 E+00 mm
0.056
DX (not B)
8.787 mm
8.793625 E+00 mm
-0.004
DY (not B)
2.768 mm
2.749434 E+00 mm
-0.671

***10.2** Notice*
The play is defined in this case in a geometrical way. One with the possibility of defining it via the key words
“DIST_1” and “DIST_2”. After checking, this second case does not change anything with the result.

---

11 Modeling E

11.1 Characteristics of modeling

A modeling 3D with elements CUB8 testing the functionalities of contact node-mesh with friction treated with the method Lagrangian for the contact and penalized for friction has summer implemented.

The play between the shoe and the frame is defined by the geometrical co-ordinates of the grid.

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 1 N/mm
RES_FOND
: K = 1 N/mm
RES_HAUT
: K = 20 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=DZ=0.
Frame: DX=DY=DZ =0.

11.2 Characteristics of the grid

A number of nodes: 269
Numbers and type of meshs: 129 CUB8, 103 QUAD4
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

11.3 Functionalities
tested

Orders Key word
factor
Key word

MODI_MAILLAGE
ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING: "3D"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT

PAIRING: “MAIT_ESCL”

SEEK: “NOEUD_BOUCLE”
METHOD: “PENALIZATION”
E_T: 1.E+06
FRICTION: “COULOMB”
COULOMB: 0.3
COEF_MATR_FROT: 0.9
STAT_NON_LINE
COMP_ELAS
RELATION: “ELAS”

12 Results of modeling E

12.1 Values tested

Identification Reference Aster % difference
Loading 1

Force normal contact
2.0784 E+05 NR
2.078391 E+05 NR
4.05E04
Tangential force of
1.2000 E+05 NR
1.199959 E+05 NR
0.003E06
contact
DX (not A)
1.000 mm
9.999999 E01 mm
3.33E06
DY (not A)
1.732 mm
1.731051 E+00 mm
0.003
DX (not B)
1.000 mm
1.000001 E+00 mm

3.32E06
DY (not B)
1.732 mm
1. 731051 E+00 mm
0.003
DX (point C)
1.000 mm
1.000001 E+00 mm
3.32E06
DY (point C)
1.732 mm
1. 731051 E+00 mm
0.003
DX (not D)
1.000 mm
9.999999 E01 mm
3.33E06
DY (not D)
1.732 mm
1.731051 E+00 mm
0.003
Loading 2

Force normal contact
1.7220 E+05 NR
1.721992 E+05 NR
4.12E04
Tangential force of
1.8173 E+05 NR
1.817260 E+05 NR
-0.002
contact
DX (not A)
1.000 mm
1.004172 E+00 mm
0.417
DY (not A)
1.732 mm
1.729642 E+00 mm
-0.136
DX (not B)
1.000 mm

1.002000 E+00 mm
0.200
DY (not B)
1.732 mm
1.730896 E+00 mm
-0.064
DX (point C)
1.000 mm
1.002000 E+00 mm
0.200
DY (point C)
1.732 mm
1.730896 E+00 mm
-0.064
DX (not D)
1.000 mm
1.004172 E+00 mm
0.417
DY (not D)
1.732 mm
1.729642 E+00 mm
-0.136
Loading 3

Force normal contact
1.714896 E+05 NR
1.718404 E+04 NR
0.207
Tangential force of
1.829770 E+05 NR
1.823477 E+05 NR
-0.344
contact
DX (not A)
8.79 mm
8.821717 E+00 mm
0.315
DY (not A)
2.77 mm
2.783820 E+00 mm
0.572
DX (not B)

8.79 mm
8.819386 E+00 mm
0.289
DY (not B)
2.77 mm
2.782474 E+00 mm
0.523
DX (point C)
8.79 mm
8.819386 E+00 mm
0.289
DY (point C)
2.77 mm
2.782474 E+00 mm
0.523
DX (not D)
8.79 mm
8.821717 E+00 mm
0.315
DY (not D)
2.77 mm
2.783820 E+00 mm
0.572

12.2 Remarks

· The play is defined in this case in a geometrical way, the results are identical to those found in preceding modeling.
· The pressures normal and tangential on the level of the zone of contact are checked while testing total force of contact in the normal and tangential direction:

CTAC
F
p S

N
= N cd. = 300x40x20 = 000N
4
2
CTAC
T
F
= Pt SAD =
2
.
178 x20x20 =
NR
71280 (Loading 2)
CTAC
F
p S
(Loading 3)
T
= T AD =
8
.
181 x20x20 = 72720N

---

13 Modeling
F

13.1 Characteristics of modeling

A modeling 3D with elements CUB8 testing the functionalities of contact node-mesh with friction treated with the method Lagrangian for the contact and penalized for friction has summer implemented.

The play between the shoe and the frame is defined by the function using key word "DIST_2".

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 1 N/mm
RES_FOND
: K = 1 N/mm
RES_HAUT
: K = 20 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=DZ=0.
Frame: DX=DY=DZ =0.

13.2 Characteristics of the grid

A number of nodes: 269
Numbers and types of meshs: 129 CUB8, 103 QUAD4

13.3 Functionalities
tested

Orders Key word
factor
Key word

MODI_MAILLAGE
ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING: "3D"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "PENALIZATION"
E_T: 1.E+06
FRICTION: "COULOMB"
COULOMB: 0.3
COEF_MATR_FROT: 0.9
DIST_2: "- 2."
STAT_NON_LINE

COMP_ELAS
RELATION: “ELAS”

14 Results of modeling F

14.1 Values
tested

Identification Reference Aster
% difference
Loading 1

Force normal contact
2.0784 E+05 NR
2.078391 E+05 NR
4.05E04
Tangential force of
1.2000 E+05 NR
1.199959 E+05 NR
0.003E06
contact
DX (not A)
1.000 mm
9.999999 E-01 mm
3.33E06
DY (not A)
1.732 mm
1.731051 E+00 mm
0.003
DX (not B)
1.000 mm
1.000001 E+00 mm
3.32E06
DY (not B)
1.732 mm
1.731051 E+00 mm
0.003
DX (point C)
1.000 mm
1.000001 E+00 mm

3.32E06
DY (point C)
1.732 mm
1.731051 E+00 mm
0.003
DX (not D)
1.000 mm
9.999999 E-01 mm
3.33E06
DY (not D)
1.732 mm
1.731051 E+00 mm
0.003
Loading 2

Force normal contact
1.7220 E+05 NR
1.721992 E+05 NR
4.12E04
Tangential force of
1.8173 E+05 NR
1.817260 E+05 NR
-0.002
contact
DX (not A)
1.000 mm
1.004172 E+00 mm
0.417
DY (not A)
1.732 mm
1.729642 E+00 mm
-0.136
DX (not B)
1.000 mm
1.002000 E+00 mm
0.200
DY (not B)
1.732 mm
1.730896 E+00 mm
-0.064
DX (point C)
1.000 mm

1.002000 E+00 mm
0.200
DY (point C)
1.732 mm
1.730896 E+00 mm
-0.064
DX (not D)
1.000 mm
1.004172 E+00 mm
0.417
DY (not D)
1.732 mm
1.729642 E+00 mm
-0.136
Loading 3

Force normal contact
1.714896 E+05 NR
1.718404 E+04 NR
0.207
Tangential force of
1.829770 E+05 NR
1.823477 E+05 NR
-0.344
contact
DX (not A)
8.79 mm
8.821717 E+00 mm
0.315
DY (not A)
2.77 mm
2.783820 E+00 mm
0.572
DX (not B)
8.79 mm
8.819386 E+00 mm
0.289
DY (not B)
2.77 mm
2.782474 E+00 mm
0.523
DX (point C)

8.79 mm
8.819386 E+00 mm
0.289
DY (point C)
2.77 mm
2.782474 E+00 mm
0.523
DX (not D)
8.79 mm
8.821717 E+00 mm
0.315
DY (not D)
2.77 mm
2.783820 E+00 mm
0.572

14.2 Notice

In this modeling, the play is defined using a function, the results are identical to those found in preceding modeling.

15 Modeling G

15.1 Characteristics of modeling

A modeling 3D with elements CUB8 testing the functionalities of contact node-mesh with friction treated with the method penalized for the contact and friction was implemented.

The play between the shoe and the frame is defined by the geometrical co-ordinates of the grid.

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 1 N/mm
RES_FOND
: K = 1 N/mm
RES_HAUT
: K = 20 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=DZ=0.
Frame: DX=DY=DZ =0.

15.2 Characteristics of the grid

A number of nodes: 269

Numbers and types of meshs: 129 CUB8, 103 QUAD4

15.3 Functionalities tested

Orders Key word factor Key word

MODI_MAILLAGE
ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING: "3D"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "PENALIZATION"
E_T: 1.E+06
E_N: 1.E+06
FRICTION: "COULOMB"
COULOMB: 0.3
COEF_MATR_FROT: 0.9
STAT_NON_LINE
COMP_ELAS
RELATION: "ELAS"

---

16 Results of modeling G

16.1 Values tested

Identification Reference Aster
% difference
Loading 1

Force normal contact
2.0784 E+05 NR
2.078391 E+05 NR
4.12E04
Tangential force of
1.2000 E+05 NR
1.199959 E+05 NR
-0.003
contact
DX (not A)
1.000 mm
1.001612 E+00 mm
0.161
DY (not A)
1.732 mm
1.735714 E+00 mm
0.214

DX (not B)
1.000 mm
1.002367 E+00 mm
0.237
DY (not B)
1.732 mm
1.735279 E+00 mm
0.189
DX (point C)
1.000 mm
1.002367 E+00 mm
0.237
DY (point C)
1.732 mm
1.735279 E+00 mm
0.189
DX (not D)
1.000 mm
1.001612 E+00 mm
0.161
DY (not D)
1.732 mm
1.735714 E+00 mm
0.214
Loading 2

Force normal contact
1.7220 E+05 NR
1.721992 E+05 NR
4.12E04
Tangential force of
1.8173 E+05 NR
1.817260 E+05 NR
-0.002
contact
DX (not A)
1.000 mm
1.004302 E+00 mm
0.430
DY (not A)
1.732 mm
1.732257 E+00 mm

0.015
DX (not B)
1.000 mm
1.004636 E+00 mm
0.464
DY (not B)
1.732 mm
1.736183 E+00 mm
0.242
DX (point C)
1.000 mm
1.004636 E+00 mm
0.464
DY (point C)
1.732 mm
1.736183 E+00 mm
0.242
DX (not D)
1.000 mm
1.004302 E+00 mm
0.430
DY (not D)
1.732 mm
1.732257 E+00 mm
0.015
Loading 3

Force normal contact
1.714896 E+05 NR
1.718404 E+04 NR
0.207
Tangential force of
1.829770 E+05 NR
1.823477 E+05 NR
-0.344
contact
DX (not A)
8.79 mm
8.821530 E+00 mm
0.313
DY (not A)
2.77 mm

2.781029 E+00 mm
0.471
DX (not B)
8.79 mm
8.821622 E+00 mm
0.314
DY (not B)
2.77 mm
2.776938 E+00 mm
0.323
DX (point C)
8.79 mm
8.821622 E+00 mm
0.314
DY (point C)
2.77 mm
2.776938 E+00 mm
0.323
DX (not D)
8.79 mm
8.821530 E+00 mm
0.313
DY (not D)
2.77 mm
2.781029 E+00 mm
0.471

16.2 Notice

The play is defined in this case in a geometrical way. The results are worse than those obtained with the penalization only on friction. Moreover, this method is longer.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
6.4

Titrate:
SSNV503 - Shoe slipping on a rigid level

17 Modeling
H

17.1 Characteristics of modeling

A modeling "D_PLAN" with elements QUAD4 testing the functionalities of contact node net with friction treated with the method continues for the contact and friction was put in work.

The play between the shoe and the frame is defined by the geometrical co-ordinates of the grid.

To avoid the movements of rigid body, the shoe is maintained by springs of low rigidity:
RES_LAT
: K = 2 N/mm
RES_HAUT
: K = 0,005 N/mm

Boundary conditions:
Loose lead of the springs: DX=DY=0.
Frame: DX=DY=0.

17.2 Characteristics of the grid

A number of nodes: 53
Numbers and types of meshs: 33 QUAD4, 32 SEG2

17.3 Functionalities tested

Orders Key word factor
Key word

MODI_MAILLAGE
ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING: "D_PLAN"

DEFI_MATERIAU
ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING: "MAIT_ESCL"

SEEK: "NOEUD_BOUCLE"
METHOD: "CONTINUES"
COEF_REGU_CONT: 1.E+02
COEF_REGU_FROT: 1.E+02
FRICTION: "COULOMB"
COULOMB: 0.3
COEF_MATR_FROT: 0.9
ITER_CONT_MAXI: 30
ITER_FROT_MAXI: 2
ITER_GEOM_MAXI: 1
INTEGRATION: "NODE"
STAT_NON_LINE

COMP_ELAS
RELATION: "ELAS"

---

18 Results of modeling H

18.1 Values
tested

Identification Reference Aster
% difference
Loading 1

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.70E04
Tangential force of
0. NR
2.20752 E-06 NR
2.21E07
contact

DX (not A)
1.000 mm
1.00000 E+00 mm
0.0
DY (not A)
1.732 mm
1.73205 E+00 mm
0.003
DX (not B)
1.000 mm
1.00000 E+00 mm
0.0
DY (not B)
1.732 mm
1.73205 E+00 mm
0.003
Loading 2

Force normal contact
1.200000 E+04 NR
1.199979 E+04 NR
1.70E04
Tangential force of
3.564000 E+04 NR
3.563961 E+03 NR
-0.001
contact
DX (not A)
1.000 mm
1.021308 E+00 mm
-2.131
DY (not A)
1.732 mm
1.719748 E+00 mm
-0.707
DX (not B)
1.000 mm
1.000000 E+00 mm
0.0
DY (not B)
1.732 mm
1.7320508 E+00 mm

0.003
Loading 3

Force normal contact
1.200000 E+04 NR
1.199998 E+04 NR
1.70E04
Tangential force of
3.624000 E+04 NR
3.599992 E+03 NR
-0.662
contact
DX (not A)
8.787 mm
8.809505 E+00 mm
0.256
DY (not A)
2.768 mm
2.7767695 E+00 mm
0.317
DX (not B)
8.787 mm
8.7869527 E+00 mm
-0.180
DY (not B)
2.768 mm
2.7637484 E+00 mm
5.15 E04

---

19 Summary of the results

Whatever is modeling (2D or 3D) and the method of treatment of contact-friction, them results obtained are satisfactory. They are very close to the analytical results.

Code_Aster ®
Version
8.3

Titrate:
SSNV504 - Extrusion of a piece

Date:
04/05/06
Author (S):
Mr. KHAM, Key P. MASSIN
:
V6.04.504-B Page:
1/20

Organization (S): EDF-R & D /AMA, DeltaCAD

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.504

SSNV504 - Extrusion of a piece

Summary:

This test simulates the extrusion (without friction) of a piece, case frequently encountered in the industrial studies
of working. The interest of this test is mainly to validate the "passage" of geometrical singularities (acute angles and blunt) and to test the taking into account of two zones of contact (contact multi-zones).

Modelings selected are as follows:

.
Modeling A (AXIS):
CONTACT node nets, associated with meshs SEG2,
.
Modeling B (3D):
CONTACT node nets, associated with meshs QUAD4,
.
Modeling C (AXIS): CONTACT node nets SLIDE, associated with meshs SEG2,
.
Modeling D (AXIS): CONTACT, method CONTINUES associated with meshs SEG2,
.
Modeling E (AXIS):
CONTACT node nets SLIDE, associated with meshs SEG3,
.
Modeling F (3D):
CONTACT node nets SLIDE, associated with meshs QUAD4,
.

Modeling G (3D):
CONTACT node nets SLIDE, associated with meshs QUAD8,
.
Modeling H (2D):
CONTACT, method CONTINUES associated with SEG3

Modelings with SLIDE make it possible to maintain the contact throughout extrusion, in way mathematics. The result is physically close to modeling without slide, since it is about one extrusion without friction.

1
Problem of reference

1.1 Geometry

70. 15.
30. 20.
70.
15.10.
Dimension in mm
65.
NR
K
Z
G

H
50.
45.
48.
Axis of symmetry
Piece
L
M
C
D
F
With
B
E
Die
I
J
R

1.2
Properties of material

Piece:

- ***E = 5000. MPa***
Young modulus
- ***= 0.45***
Poisson's ratio

Die:

- ***E = 200.000. MPa***
Young modulus
- ***= 0.3***
Poisson's ratio

Piece/die

- ***μ = 0***

Coefficient of friction

1.3 Boundary conditions and loadings

- C.L. : lines HI, IJ and JA embedded

- Loading: Piloting in displacement imposed on the back face of the piece

1.4 Conditions initial

Without object.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The objective of this case-test is to analyze the feasibility of calculation into axisymmetric and 3D.

2.2 Results of reference

No value of reference is available. The values of reference which will be retained to test the future versions of Code_Aster are those obtained during the first execution with modeling A and which will be considered to be acceptable. The analyzed values of reference are:

- ***displacements of the front face of the piece,***
- ***the maximum iteration count to converge.***

Piece (localization)	*Déplacemen T (mm)*	*Comments*
K	*5.000*	*Piece in the vicinity of the point B of the die*
K	*20.825*	*Piece in the vicinity of the point C of the die*
K	*55.880*	*Piece in the vicinity of the point D of the die*
K	*78.690*	*Piece in the vicinity of the point E of the die*
K	*144.895*	*Piece in the vicinity of the point F of the die*
K	*155.096*	*Piece at the point G of the die*

2.3 Uncertainties on the solution

< 0.1%

2.4 References
bibliographical

None

---

3 Modeling
With

3.1
Characteristics of modeling

Solid: Modeling AXIS (TRIA3)
Contact: CONTACT (SEG2)
G
Y
H
M
K
Surface slave
Surface main
4
5

5
L
C
D
NR
3
4
3
E
With
F
7
B
5
I
J
X
Zone of contact n°1: NL/ABCDEF
Zone of contact n°2: LK/FG
Limiting conditions:
- dimensioned JA, IJ, HI: DX=0., DY=0.
- dimensioned MN: DY=1.

3.2
Characteristics of the grid

A number of nodes: 333
A number of meshs: 510 TRIA3 and 152 SEG2

3.3 Functionalities
tested

Orders Key word
factor
Key word
MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = “MAIT_ESCL”
NOEUD_BOUCLE
METHOD = “FORCED”
FRICTION = “WITHOUT”
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

4
Results of modeling A

4.1 Values
tested

Identification
Reference
Aster %
difference
Piece at the point B

•
Displacement at the point K (mm) 5.000
5.000 0.
•
Numbers iterations
1
1
0.
Piece at the point C

•
Displacement at the point K (mm) 20.825
20.825 0.
•
Numbers iterations
1
1
0.
Piece at the point D

•
Displacement at the point K (mm) 55.880
55.880 0.
•
Numbers iterations
1
1
0.
Piece at the point E

•
Displacement at the point K (mm) 78.690
78.690 0.
•

Numbers iterations
1
1
0.
Piece at the point F

.
Displacement at the point K (mm) 144.895
144.895 0.
.
Numbers iterations
1
1
0.
Piece at the point G

.
Displacement at the point K (mm) 155.096
155.096 0.
.
Numbers iterations
1
1
0.

4.2 Remarks

.
Calculation is carried out by imposing a displacement on the back face of the piece (MN). displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with

20.mm in 5 steps
-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 5 steps
-
of
70.mm with
140.mm in 5 steps
-
of
140.mm with
155.mm in 5 steps

.

Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

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5 Modeling B

5.1 Characteristics of modeling

Solid: Modeling 3D (HEXA8, PENTA6)
Contact: CONTACT (QUAD4)
M
G
H
Z
Z
K
Surface slave
Surface main
4
5
Y
NR
5
L
C
D
3
4
3

E
With
F
7
B
5
J
I
X
Zone of contact n°1: NL/ABCDEF
X
Discretization: grid ¼ of the structure
Zone of contact n°2: LK/FG
Boundary conditions on the groups of following nodes:

- "FIL_EXT": group nodes located on surface external of die (HI, IJ, JA)
=> DX=0., DY =0., DZ=0.
- "FIL_SYM1": Group nodes of the die located in plan XOY: DZ=0.
- "FIL_SYM2": Group nodes of the die located in plan YOZ: DX=0.

- "LOP_SYM1": Group nodes of the piece located in plan XOY: DZ=0.
- "LOP_SYM2": Group nodes of the piece located in plan YOZ: DX=0
- "LOP_DDL": Group nodes located on the back face of the piece: DY =1

5.2
Characteristics of the grid

A number of nodes: 3292
A number of meshs: 2150 HEXA8, 260 PENTA6, 1814 QUAD4 and 68 TRIA3

5.3 Functionalities
tested

Orders Key word
factor
Key word

MODI_MAILLAGE ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

METHOD = "FORCED"
FRICTION = "WITHOUT"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

6
Results of modeling B

6.1 Values
tested

Identification
Reference
***Aster** %*
difference
Piece at the point B

.
Displacement at the point K (mm) 5.000
5.000
0.
.
Numbers iterations
1
1
0.
Piece at the point C

.
Displacement at the point K (mm) 20.825
20.796
-0.14
.
Numbers iterations
1
1
0.
Piece at the point D

.
Displacement at the point K (mm) 55.880
55.642
-0.425
.
Numbers iterations
1
1
0.
Piece at the point E

.
Displacement at the point K (mm) 78.690

78.627
-0.081
.
Numbers iterations
1
1
0.
Piece at the point F

.
Displacement at the point K (mm) 144.895
144.983 0.061
.
Numbers iterations
1
1
0.
Piece at the point G

.
Displacement at the point K (mm) 155.096
155.065 -0.02
.
Numbers iterations
1
1
0.

6.2 Remarks

.
Calculation is carried out by imposing a displacement on the back face of the piece (MN).
displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps

-
of
5.mm with
15.mm in 10 steps
-
of
5.mm with
20.mm in 5 steps
-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 10 steps
-
of
70.mm with
140.mm in 35 steps
-
of
140. mm with
155.mm in 15 step

.
Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.
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Code_Aster ®
Version
8.3

Titrate:
SSNV504 - Extrusion of a piece

Date:

7 Modeling
C

7.1
Characteristics of modeling

Solid: Modeling AXIS (TRIA3)
Contact: CONTACT (SEG2)
G
Y
H
M
K
Surface slave
Surface main
4
5
5
L
C
D
NR
3
4
3
E
With
F
7
B
5
I
J
X

Zone of contact n°1: NL/ABCDEF
Limiting conditions:
- dimensioned JA, IJ, HI: DX=0., DY=0.
- dimensioned MN: DY=1.

One uses here the function SLIDE which makes it possible to maintain the contact throughout extrusion, of
mathematical way. The result is physically close to modeling without slide, since it
acts of an extrusion without friction.

7.2
Characteristics of the grid

A number of nodes: 333
A number of meshs: 510 TRIA3 and 152 SEG2

7.3 Functionalities
tested

Orders Key word
factor
Key word
MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"
NOEUD_BOUCLE
METHOD = "FORCED"
FRICTION = "WITHOUT"
SLIDE = "YES"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"
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8
Results of modeling C

8.1 Values
tested

Identification
Reference
***Aster** %*
difference
Piece at the point B

.
Displacement at the point K (mm) 5.000
5.000 0.
.
Numbers iterations
1
1
-
Piece at the point C

.

Displacement at the point K (mm) 20.825
20.585
-1.152
.
Numbers iterations
1
1
-
Piece at the point D

.

Displacement at the point K (mm) 55.880
55.541
-0.847
.
Numbers iterations
1
3
-
Piece at the point E

.

Displacement at the point K (mm) 78.690
78.372
-0.404
.
Numbers iterations
1
3
-
Piece at the point F

.

Displacement at the point K (mm) 144.895
144.224 -0.463
.
Numbers iterations
1
3
-

8.2 Remarks

.
Calculation is carried out by imposing a displacement on the back face of the piece (MN). displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with
20.mm in 5 steps
-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 5 steps
-
of
70.mm with
140.mm in 5 steps

.
Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

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9 Modeling D

9.1 Characteristics of modeling

Solid: Modeling AXIS (TRIA3)
Contact: CONTACT (SEG2)
G
Y
H
M
K
Surface slave
Surface main
4
5
5
L
C
D
NR
3

4
3
E
With
F
7
B
5
I
J
X
Zone of contact n°1: NL/ABCDEF
Zone of contact n°2: LK/FG
Limiting conditions:
- dimensioned JA, IJ, HI: DX=0., DY=0.
- dimensioned MN: DY=1.

9.2
Characteristics of the grid

A number of nodes: 333
A number of meshs: 510 TRIA3 and 152 SEG2

9.3 Functionalities
tested

Orders Key word
factor
Key word
MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"
NOEUD_BOUCLE
METHOD = "CONTINUES"

FRICTION = “WITHOUT”
SLIDE = “NOT”
ITER_GEOM_MAXI = 1
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

---

10 Results of modeling D

10.1 Values tested

Identification
Reference
Aster %
difference
Piece at the point B

.
Displacement at the point K (mm) 5.000

5.000 0.

.

Numbers iterations

1

1

0.

Piece at the point C

.

Displacement at the point K (mm) 20.825

20.790

-0.167

.

Numbers iterations

1

1

0.

Piece at the point D

.

Displacement at the point K (mm) 55.880

55.831

-0.088

.

Numbers iterations

1

1

0.

Piece at the point E

.

Displacement at the point K (mm) 78.690

78.684

-0.008

.

Numbers iterations

1
1
0.
Piece at the point F

.
Displacement at the point K (mm) 144.895
144.893 -0.002
.
Numbers iterations
1
1
0.
Piece at the point G

.
Displacement at the point K (mm) 155.096
155.071 -0.016
.
Numbers iterations
1
1
0.

10.2 Remarks

.
Calculation is carried out by imposing a displacement on the back face of the piece (MN).
displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with
20.mm in 5 steps

-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 5 steps
-
of
70.mm with
140.mm in 5 steps
-
of
140.mm with
155.mm in 5 steps

.
Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

---

11 Modeling
E

11.1 Characteristics of modeling

Solid: Modeling AXIS (TRIA6)
Contact: CONTACT (SEG3)
G
Y
H
M
K
Surface slave
Surface main
4
5
5
L
C
D
NR
3
4
3
E
With
F
7
B
5
I
J
X
Zone of contact n°1: NL/ABCDEF
Limiting conditions:
- dimensioned JA, IJ, HI: DX=0., DY=0.
- dimensioned MN: DY=1.

11.2 Characteristics of the grid

A number of nodes: 333
A number of meshs: 510 TRIA6 and 152 SEG3

11.3 Functionalities
tested

Orders Key word
factor
Key word
MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"
NOEUD_BOUCLE
METHOD = "FORCED"
FRICTION = "WITHOUT"
SLIDE = "YES"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

:
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12 Results of modeling E

12.1 Values tested

One uses here the function SLIDE which makes it possible to maintain the contact throughout extrusion, of
mathematical way. The result is physically close to modeling without slide, since it
acts of an extrusion without friction. The values of reference are regarded as being those
modeling C.

Identification
Reference
Aster %
difference
Piece at the point B

.
Displacement at the point K (mm) 5.000
5.000 0.
.
Numbers iterations
1
1
0.
Piece at the point C

.
Displacement at the point K (mm) 20.585
20.612
-0.001
.
Numbers iterations
1

2
-
Piece at the point D

.
Displacement at the point K (mm) 55.407
55.412 0.
.
Numbers iterations
3
2
-
Piece at the point E

.
Displacement at the point K (mm) 78.372
78.379 0.
.
Numbers iterations
3
2
-
Piece at the point F

.
Displacement at the point K (mm) 144.224
144.224 0.
.
Numbers iterations
3
2
-

12.2 Remarks

.

Calculation is carried out by imposing a displacement on the back face of the piece (MN). displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with
20.mm in 5 steps
-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 5 steps
-
of
70.mm with
140.mm in 5 steps

.
Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

---

13 Modeling
F

13.1 Characteristics of modeling

Solid: Modeling 3D (HEXA8, PENTA6)
Contact: CONTACT (QUAD4)
M
G
H
Z
Z
K
Surface slave
Surface main
4
5
Y
NR
5
L
C
D
3
4
3
E
With
F
7
B
5
J
I
X
Zone of contact n°1: NL/ABCDEF

X
Discretization: grid ¼ of the structure
Boundary conditions on the groups of following nodes:

- "FIL_EXT": group nodes located on surface external of die (HI, IJ, JA)
=> DX=0., DY =0., DZ=0.
- "FIL_SYM1": Group nodes of the die located in plan XOY: DZ=0.
- "FIL_SYM2": Group nodes of the die located in plan YOZ: DX=0.

- "LOP_SYM1": Group nodes of the piece located in plan XOY: DZ=0.
- "LOP_SYM2": Group nodes of the piece located in plan YOZ: DX=0
- "LOP_DDL": Group nodes located on the back face of the piece: DY =1

13.2 Characteristics of the grid
A number of nodes: 3292
A number of meshs: 2150 HEXA8, 260 PENTA6, 1814 QUAD4 and 68 TRIA3

13.3 Functionalities
tested
Orders Key word
factor
Key word

MODI_MAILLAGE ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

METHOD = "FORCED"
FRICTION = "WITHOUT"
SLIDE = "YES"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

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14 Results of modeling F

14.1 Values tested

One uses here the function SLIDE which makes it possible to maintain the contact throughout extrusion, of mathematical way. The result is physically close to modeling without slide, since it acts of an extrusion without friction. The values of reference are regarded as being those modeling C.

Identification
Reference
Aster %
difference
Piece at the point B

.
Displacement at the point K (mm) 5.000
5.000
0.
.

Numbers iterations
1
1
0.
Piece at the point C

.
Displacement at the point K (mm) 20.585
20.612
0.001
.
Numbers iterations
1
2
-
Piece at the point D

.
Displacement at the point K (mm) 55.407
55.412 0.
.
Numbers iterations
3
2
-
Piece at the point E

.
Displacement at the point K (mm) 78.372
78.379 0.
.
Numbers iterations
3
2
-
Piece at the point F

.
Displacement at the point K (mm) 144.224
144.224 0.
.
Numbers iterations
3
2
-

14.2 Remarks

.
Calculation is carried out by imposing a displacement on the back face of the piece (MN).
displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with
15.mm in 10 steps
-
of
5.mm with
20.mm in 5 steps
-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 10 steps
-
of
70.mm with
140.mm in 35 steps

.

Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

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15 Modeling G

15.1 Characteristics of modeling

Solid: Modeling 3D (HEXA20, PENTA15)
Contact: CONTACT (QUAD8)
M
G
H
Z
Z
K
Surface slave
Surface main
4
5
Y
NR
5
L
C
D
3
4
3
E

With
F
7
B
5
J
I
X
Zone of contact n°1: NL/ABCDEF
X
Discretization: grid ¼ of the structure
Boundary conditions on the groups of following nodes:

- "FIL_EXT": group nodes located on surface external of die (HI, IJ, JA)
=> DX=0., DY =0., DZ=0.
- "FIL_SYM1": Group nodes of the die located in plan XOY: DZ=0.
- "FIL_SYM2": Group nodes of the die located in plan YOZ: DX=0.

- "LOP_SYM1": Group nodes of the piece located in plan XOY: DZ=0.
- "LOP_SYM2": Group nodes of the piece located in plan YOZ: DX=0
- "LOP_DDL": Group nodes located on the back face of the piece: DY =1

15.2 Characteristics of the grid
A number of nodes: 12213
A number of meshs: 2150 HEXA20, 260 PENTA15, 1814 QUAD8 and 68 TRIA6

15.3 Functionalities
tested
Orders Key word
factor
Key word

MODI_MAILLAGE ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

METHOD = “FORCED”
FRICTION = “WITHOUT”
SLIDE = “YES”
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

16 Results of modeling G

16.1 Values tested

One uses here the function SLIDE which makes it possible to maintain the contact throughout extrusion, of
mathematical way. The result is physically close to modeling without slide, since it
acts of an extrusion without friction. The values of reference are regarded as being those
modeling C.

Identification
Reference
Aster %
difference
Piece at the point B

•
Displacement at the point K (mm) 5.000
5.221
0.044
•
Numbers iterations
1
1
-
Piece at the point C

•
Displacement at the point K (mm) 20.585
20.822
0.012
•
Numbers iterations
1
1
-
Piece at the point D

•
Displacement at the point K (mm) 55.407
55.532
0.002
•
Numbers iterations
3
1
-
Piece at the point E

·
Displacement at the point K (mm) 78.372
78.476
0.001
·
Numbers iterations
3
1
-
Piece at the point F

·
Displacement at the point K (mm) 144.224
144.364 0.001
·
Numbers iterations
3
1
-

16.2 Remarks

·
Calculation is carried out by imposing a displacement on the back face of the piece (MN). displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with
15.mm in 10 steps
-
of
5.mm with
20.mm in 5 steps
-
of

20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 10 steps
-
of
70.mm with
140.mm in 35 steps

.
Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining (forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

---

17 Modeling
H

17.1 Characteristics of modeling

Modeling with quadratic elements of contact (SEG3) by the method CONTINUES. It *case-test presents phenomena of flip-flop (oscillations of the statute of the contact related to difficulties of zero numerical), solved here by an internal test on the maximum number of flip-flop (transparent with the user, and fixed at 15), i.e. the maximum number of changes of statute of the contact. One message of alarm indicates to the user that the maximum number of changes of statute (15) was reached.*

Solid: Modeling AXIS (TRIA6)
Contact: CONTACT (SEG3)
G
Y
H
M
K
Surface slave
Surface main
4
5
5
L
C
D
NR
3
4
3
E
With
F
7
B
5
I
J
X
Zone of contact n°1: NL/ABCDEF
Limiting conditions:
- dimensioned JA, IJ, HI: DX=0., DY=0.
- dimensioned MN: DY=1.

17.2 Characteristics of the grid

A number of nodes: 1174
A number of meshs: 510 TRIA6 and 152 SEG3

17.3 Functionalities
tested

Orders Key word
factor
Key word
MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "AXIS"
DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"
SEEK = "NOEUD_VOISIN"
METHOD = "CONTINUES"
FRICTION = "WITHOUT"
SLIDE = "NOT"
ITER_GEOM_MAXI = 3
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

---

18 Results of modeling H

18.1 Values tested

Identification
Reference
Aster %
difference
Piece at the point B

.
Displacement at the point K (mm) 5.000
5.000 0.
.
Numbers iterations
1
0
100.
Piece at the point C

.
Displacement at the point K (mm) 20.825
20.801
-0.115
.
Numbers iterations
1
1
0.
Piece at the point D

•

Displacement at the point K (mm) 55.880
55.678
-0.361

•

Numbers iterations
1
1
0.
Piece at the point E

•

Displacement at the point K (mm) 78.690
78.691
-0.002

•

Numbers iterations
1
1
0.
Piece at the point F

•

Displacement at the point K (mm) 144.895
144.949 -0.037

•

Numbers iterations
1
1
0.
Piece at the point G

•

Displacement at the point K (mm) 155.096
154.674 -0.272
.
Numbers iterations
1
1
0.

18.2 Remarks

.
Calculation is carried out by imposing a displacement on the back face of the piece (MN). displacement is imposed in the following way:

-
of
0.mm with
5.mm in 5 steps
-
of
5.mm with
20.mm in 5 steps
-
of
20.mm with
50.mm in 5 steps
-
of
50.mm with
70.mm in 5 steps
-
of
70.mm with
140.mm in 5 steps
-
of
140.mm with
155.mm in 5 steps

.
Although the data file passes without problem in linear statics (MECA_STATIQUE), them calculations do not converge with the key words by defect used for convergence in STAT_NON_LINE, because the default value of RESI_GLOB_RELA = 1.E-6 is too constraining

(forces to which the piece is subjected being at the beginning relatively weak). To mitigate it problem, it is necessary to use the key word RESI_GLOB_MAXI = 1.E-6.

19 Summary of the results

Two modelings (Axisymmetric and 3D) pass without problem. Convergence is fast.
The results between modeling AXIS and modeling 3D are similar.

In the same way, the methods of the CONSTRAINTS and CONTINUOUS also give results satisfactory. On this example, the method CONTINUES seems to converge more quickly than that CONSTRAINTS, in particular in 3D with SLIDE.

The particular case of the contact slide is attached to this case-test: modeling C is then taken like reference. By the method CONTINUES, one obtains solutions close to these values of reference, with generally a lower iteration count.

On the figure above we present the position of the piece for a displacement of the face postpones piece of 20, 70, 155 mm

20mm 70mm 155mm

This test made it possible to validate:

.

the "passage" of geometrical singularities (acute angles and blunt),
·
the taking into account of two zones of contact (contact multi-zones),
·
the modeling of a contact-slide.

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.505

SSNV505 - Contact of 2 beams into large displacements

Summary:

This test represents a calculation of contact without friction between two beams in great displacements subjected to
a specific displacement. Initially the beams are not in contact, it occurs for a level of
loading given and then the two beams slip one on the other.

The analyzed result is the normal reaction of contact according to displacement. Results obtained with
various modelings are compared between them.

.

Modeling a: the structure is modelled with elements of COQUE_3D associated with a mesh
QUAD9, with the FORCED method.

.

Modeling b: the structure is modelled in 3D plane deformations using elements HEXA8,
with the FORCED method.

.

Modeling C: the structure is modelled in 2D plane deformations using elements QUAD4,
with the FORCED method.

.

Modeling D: the structure is modelled in 3D plane deformations using elements HEXA8,
with the method CONTINUES.

.

Modeling E: the structure is modelled in 2D plane deformations using elements QUAD4,
with the method CONTINUES.

.

Modeling F: the structure is modelled in 3D using elements of beam POU_D_E associated with
meshs SEG2, with the methods LAGRANGIAN and CONTINUOUS. This modeling is distinguished
others, in what it is carried out in small transformations, while all the others are
carried out in great transformations.

.

Modeling G: the structure is modelled in 3D using elements of beam POU_D_E associated with
meshs SEG2, with the LAGRANGIAN method with friction. This modeling validates
possibility of taking into account the ray of the section of beam like initial play.

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V6.04 booklet: Nonlinear statics of the voluminal structures
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1
Problem of reference

1.1 Geometry

Section

2032

Y

Uy
1320.8

Y
Z

C
B
63.5

508

X
With

10.16

2032
914.4

1.2
Properties of material

E = 6.8948x109 Pa
Young modulus
= 0.3333
Poisson's ratio
μ = 0.
Coefficient of friction

1.3
Boundary conditions and loadings

.
C.L. : Sections at embedded points A and B

.
Loading: vertical displacement of the point C: D = -790 mm

1.4 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

One does not have reference solution, one makes only tests of not-regression.

3 Modeling With

3.1 Characteristics of modeling

Y
LBB1

Z

C1
Poutre1

X

C
Poutre2

LAA3

Boundary conditions:

This modeling is carried out in COQUE_3D. In fact, the finite elements used are QUAD9.
When one models contact between this type of elements, one binds the nodes mediums to the nodes

tops. If the user does not take guard there, that can easily cause the appearance of null pivots (with cause redundant conditions of Dirichlet). Also one tried to specify the conditions well with following limits:

- *sides LAA3 and LBB1: DX=DY=DZ=DRX=DRY=DRZ=0*
- *Nodes tops C and C1: DY=-790 mm*
- *All the nodes tops of the structure: DZ=0, DRX=0*

Conditions of contact:

- *surface main: group meshs POUTRE1 minus the group of meshs whose edge is embedded according to LBB1,*
- *surface slave: group meshs POUTRE2 minus the group of meshs whose edge is embedded according to LAA3.*

3.2 Characteristics of the grid

A number of nodes:
261
A number of meshs:
158
SEG3 107
QUAD8 51

3.3 Functionalities tested

Orders Key word factor Key word

MODI_MAILLAGE MODI_MAILLE
QUAD8_9

ORIE_NORM_COQUE
VECT_NORM
AFFE_MODELE
AFFE
MODELING = "COQUE_3D"

DEFI_MATERIAU ELAS

AFFE_CARA_ELEM HULL
THICK

COEF_RIGI_DRZ=0.001
AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

NOEUD_BOUCLE
METHOD = "FORCED"
FRICTION = "WITHOUT"
DIST_1 = 31.75
DIST_2 = 31.75
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

DEFORMATION = ' GREEN_GR'

4

Results of modeling A

4.1 Values
tested

One tests the reaction to the displacement imposed on the hull. To obtain it, one calculates the reactions to
embeddings in LBB1 and LAA3 (one cannot simply measure the reaction to the nodes C and C1 because it contains also the forces due to the connections of the nodes mediums to the nodes tops).

Identification	Moments	Reference Aster
Reaction	0.2	Not-regression 4.37897E+02
Reaction	0.4	Not-regression 1.65012E+03
Reaction	0.6	Not-regression 3.35705E+03
Reaction	0.8	Not-regression 3.01163E+03
Reaction	1.	Not-regression 3.14692E+03

---

5 Modeling
B

5.1
Characteristics of modeling

Y
LCC1

Z

Poutre2

SA
SMAI

X

SB

SESC

Poutre1

Boundary conditions:

- ***Surfaces SA and SB: DX=DY=DZ= 0***
- ***Lines LCC1: DY=-790 mm***
- ***All the nodes tops of the structure: DZ=0***

Conditions of contact:

- ***surface main: group meshs SMAI***
- ***surface slave: group meshs SESC***

5.2
Characteristics of the grid

A number of nodes:
662
A number of meshs:
1247
POI1 1
SEG2 351
QUAD4 655
HEXA8 240
Handbook of Validation
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5.3 Functionalities tested

Orders Key word
factor Key word

MODI_MAILLAGE ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

NOEUD_BOUCLE
METHOD = "FORCED"
FRICTION = "WITHOUT"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

DEFORMATION = "GREEN"

6
Results of modeling B

6.1 Values tested

One tests the reaction to the displacement imposed on the POUTRE2. To obtain it, the reactions are calculated
with embeddings in SA and SB.

Identification	Moments	Reference	Aster
Reaction	0.2	Not-regression	4.36995E+02
Reaction	0.4	Not-regression	1.66834E+03
Reaction	0.6	Not-regression	3.26454E+03
Reaction	0.8	Not-regression	2.73716E+03
Reaction	1.	Not-regression	3.09524E+03

7 Modeling C

7.1 Characteristics of modeling

Modeling is made in 2D plane deformations to find blocking in DZ imposed on the model 3D.

C

Poutre2
LB3B

LA3A
Poutre1

Boundary conditions:

- *sides LA3A and LB3B: DX=DY= 0*
- *Nodes C: DY=-790 mm*

Conditions of contact:

- *surface main: group of mesh SMAI*
-

surface slave: group of mesh SESC

7.2
Characteristics of the grid

A number of meshs:
415
SEG2 175
QUAD4 240

7.3 Functionalities
tested

Orders Key word
factor Key word

MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = "2D"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

NOEUD_BOUCLE
METHOD = "FORCED"
FRICTION = "WITHOUT"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

DEFORMATION = "GREEN"

8
Results of modeling C

8.1 Values tested

One tests the reaction to the displacement imposed on the hull. To obtain it, one calculates the reactions to embeddings in LB3B and LA3A

Identification Moments Reference Aster

Reaction 0.2
Not-regression
4.35668E+01
Reaction 0.4
Not-regression
1.69598E+02
Reaction 0.6
Not-regression
3.23491E+02
Reaction 0.8
Not-regression
2.67162E+02
Reaction 1.
Not-regression

3.09623E+02

8.2 Notice

To obtain in 2D results comparable with results COQUE_3D and 3D, it is necessary to multiply them *preceding reactions by the width of the beam, is 10.16 Misters.*

---

9 Modeling
D

9.1
Characteristics of modeling

Y
LCC1

Z

Poutre2

SA
SMAI

X

SB

SESC

Poutre1

Boundary conditions:

·
Surfaces SA and SB: DX=DY=DZ= 0
·
Line LCC1: DY=-790 mm
·
All the nodes tops of the structure: DZ=0

Conditions of contact:

·
surface main: group meshs SMAI
·
surface slave: group meshs SESC

9.2
Characteristics of the grid

A number of nodes:
662
A number of meshs:
1247
POI1 1
SEG2 351
QUAD4 655
HEXA8 240

9.3 Functionalities tested

Orders Key word factor Key word

MODI_MAILLAGE ORIE_PEAU_3D

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = "MAIT_ESCL"

METHOD = "CONTINUES"
FRICTION = "WITHOUT"
STAT_NON_LINE
COMP_ELAS
RELATION = "ELAS"

DEFORMATION = "GREEN"

10 Results of modeling D

10.1 Values

tested

One tests the reaction to the displacement imposed on the POUTRE2. To obtain it, the reactions are calculated
with embeddings in SA and SB. The percentage of difference indicates the difference between this modeling
and equivalent modeling with the FORCED method.

Identification Moments Reference
Aster
% difference

Reaction 0.2
Not-regression 4.36995E+02
4.25E-05
Reaction 0.4
Not-regression 1.668034E+03 -0.018
Reaction 0.6
Not-regression 3.26453E+03
-3.13E-04
Reaction 0.8
Not-regression 2.74197E+03 0.176
Reaction 1.
Not-regression 3.09252E+03 -0.088

---

11 Modeling
E

11.1 Characteristics of modeling

Modeling is made in 2D plane deformations to find blocking in DZ imposed on the model 3D.

C

Poutre2
LB3B

LA3A
Poutre1

Boundary conditions:

- *sides LA3A and LB3B: DX=DY= 0*
- *Nodes C: DY=-790 mm*

Conditions of contact:

- *surface main: group of mesh SMAI*
- *surface slave: group of mesh SESC*

11.2 Characteristics of the grid

A number of meshs:
415
SEG2 175
QUAD4 240

11.3 Functionalities
tested

Orders Key word
factor Key word

MODI_MAILLAGE ORIE_PEAU_2D

AFFE_MODELE
AFFE
MODELING = “2D”

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
PAIRING = “MAIT_ESCL”

METHOD = “CONTINUES”
FRICTION = “WITHOUT”
STAT_NON_LINE
COMP_ELAS
RELATION = “ELAS”

DEFORMATION = “GREEN”
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Code_Aster ®
Version
8.3

Titrate:
SSNV505 - Contact of two beams in great displacements
Date:

12 Results of modeling E

12.1 Values tested

One tests the reaction to the displacement imposed on the hull. To obtain it, one calculates the reactions to embeddings in LB3B and LA3A. The percentage of difference indicates the difference between this modeling and equivalent modeling with the FORCED method.

Identification	Moments	Reference	Aster	% difference
Reaction	0.2	Not-regression	4.35668E+01	6.9E-07
Reaction	0.4	Not-regression	1.69562E+02	-0.021
Reaction	0.6	Not-regression	3.23491E+02	9.1E-05
Reaction	0.8	Not-regression	2.67527E+02	0.14
Reaction	1.	Not-regression	3.09623E+02	1.7E-04

---

13 Modeling
F

13.1 Characteristics of modeling

One carries out here a modeling using elements beam in 3D. Deformations being plane in the plan (DX, DY), one imposes DZ = 0 on the model 3D. The goal of this case-test is to compare deformation of the beams with a formulation in small rotations with that obtained with the large ones rotations. The first model is of course abusive (forgery) compared to the second (true), but allows to illustrate the difference of the results obtained in one or the other case. The true motivation of this case test is however of exhiber an example of validation of the contact between beams with the method continue for the preliminary stage of the small transformations. The test will be enriched soon of a modeling in great rotations, more delicate to implement.

C
B

B1

POU2

A1
With

POU1

Boundary conditions:

.

Nodes A and b: DX=DY= 0

.

Nodes C: DY=-790 mm

Conditions of contact:

.

surface main: group of mesh POU1

.

surface slave: group of mesh POU2

13.2 Characteristics of the grid

A number of meshs:
4
SEG2 4

13.3 Functionalities tested

Orders Key word
factor Key word

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = "CONTINUES"

VECT_Y = (0,0, - 1)
DIST_MAIT=31.75
DIST_ESCL=31.75
STAT_NON_LINE
COMP_INCR
RELATION = "ELAS"

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Titrate:
SSNV505 - Contact of two beams in great displacements
Date:
04/05/06
Author (S):
Mr. KHAM, Mr. Key ABBAS
:
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14 Results of modeling F

14.1 Values tested

One tests the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to embeddings in A and B. the percentage of difference indicates the difference between this modeling and equivalent modeling with the LAGRANGIAN method.

On the curve of bottom, one represented the force at the point B (embedding of the higher beam) in function of the evolution of the loading. One compares the methods Lagrangian and continues with solution obtained in great rotations. It appears that the two methods give results almost identical, but that the latter differ notably from those obtained into large rotations. This point is rather logical, since within the framework of small rotations where calculations were carried out, one neglects the terms of deformation of the second order, which as one notes it are not not negligible in great rotations.

Identification Moments Reference
Aster
% difference

Reaction 0.2
Not-regression 3.07483D+02
8.47E-11
Reaction 0.4
Not-regression 1.25148D+03
-5.07E-09
Reaction 0.6
Not-regression 3.02391D+03
-2.23E-07
Reaction 0.8
Not-regression 4.82957D+03
-7.10E-07
Reaction 1.
Not-regression 6.65614D+03
-1.12E-06

SSNV505F: NODAL REACTIONS

---

15 Modeling G

15.1 Characteristics of modeling

One carries out here a modeling using elements beam in 3D. Deformations being plane in
the plan (DX, DY), one imposes DZ = 0 on the model 3D. The goal of this case-test is to validate the catch in
count real section of the beam, that the user informed by the keyword "BEAM" in AFFE_CARA_ELEM.

C
B

B1

POU2

A1
With

POU1

Boundary conditions:

·
Nodes A and b: DX=DY= 0
·
Nodes C: DY=-790 mm

Conditions of contact:

·
surface main: group of mesh POU1
·
surface slave: group of mesh POU2

Characteristics of the beam:

· tubular section of ray 31.75 mm and thickness 1mm

15.2 Characteristics of the grid

A number of meshs:
4
SEG2 4

15.3 Functionalities tested

Orders Key word
factor Key word

DEFI_MATERIAU ELAS

AFFE_CHAR_MECA
CONTACT
METHOD = "LAGRANGIAN"

VECT_Y = (0,0, - 1)
DIST_MAIT=31.75
DIST_POUTRE = "YES"
STAT_NON_LINE
COMP_INCR
RELATION = "ELAS"

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---

16 Results of modeling G

16.1 Values tested

One tests the reaction to the displacement imposed on the beam. One compares the case where the section of beam entered via a constant play DIST_ESCL and the case where one takes the real section via keyword DIST_POUTRE.

Identification Moments	***Aster (DIST_ESCL)***	***Aster (DIST_POUT)***	***% difference***
Reaction 0.16	***2.45986E+02***	***2.45986E+02***	*0*
Reaction 0.4	***1.25149D+03***	***1.25149D+03***	*0*

17 Summary of the results

The graph below presents the evolution of the component DY of the force of reaction to displacement imposed according to this last.
One notices a very good agreement between various modelings up to 500 mm then the curve COQUE_3D separates from the 2D and of the 3D before meeting with 700 Misters This variation is normal: it
appears when the end of beam 2 is orthogonal with beam 1.

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Titrate:
SSNV506 - Elastoplastic indentation of a half-plane by a indentor Dates
:
15/02/06
Author (S):
P. MASSIN, Key Mr. KHAM
:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
Document: V6.04.506

SSNV506 - Elastoplastic indentation of a block by an elastic spherical indentor

Summary:

This test relates to the modeling of the indentation of an elastic sphere on a half-plane with the behavior
elastoplastic. The objective is to test the functionalities related to the contact on an example comprising one
non-linearity material.

1
Problem of reference

1.1 Geometry

Ray of the sphere
R = 500 mm
Imposed displacement
100 mm

1.2
Properties of material

Two different modelings to represent the rigid sphere:

Material rigidification: E=2,1E9 Mpa and = 0,3
Rigidification by conditions kinematics

Block: Steel, law of perfect elastoplastic behavior.

Modulate Young
E=210000 MPa
Poisson's ratio
= 0,3
Modulate work hardening
And = 0
Yield stress
y = 50 MPa

1.3
Boundary conditions and loadings

The deformations are axisymmetric and the block forming the plan is supposed to be embedded on its basis.

An imposed displacement is applied:

·
Loading from 0 to 100 mm on the higher part of the sphere in the models A and D
·
Loading from 0 to 100 mm on the surface of contact of the sphere in the models B and C

2
Reference solution

2.1
Method of calculation used for the reference solution

The results of reference result from the book quoted below [bib1].
pm = 3 0 with pm the contact pressure (page 171).
Rjohnson = pm has = 3 0 A if A is the surface of contact.
However in perfect plasticity = 0,368 A ² /R according to the analysis of Richmond (page 200)

Finally, one obtains:
Rjohnson = 3 R 0/0,368

Rjohnson: Normal reaction of contact of the solid mass on the sphere
R: Ray of the sphere
: Displacement of the top of the solid mass
0: Yield stress of the solid mass

This result is valid under the following assumptions:
axisymmetric problem,
perfectly plastic material (coefficient 0,368 results from this assumption)
small deformations
rigid sphere.

2.2
Results of reference

The results of reference are obtained starting from the preceding formula. It is valid for complete model in 3D.

Note:

In our study, Rjohnson depends only on displacement, one can write the relation under the following form thanks to the facts of the case: Rjohnson = 640.270 with Rjohnson in newton and in millimetre. is directly connected to the moment of calculation.

The value of the normal resultant of contact coming from ASTER is given on a district of 1 radian of opening in axisymmetric 2D and on a district of /2 for the model 3D (by symmetry, it is enough to model the quarter of the problem).

Thus, the values of reference are:
in axisymmetric 2D: Rref = Rjohnson/2 = 101902,1
in 3D
: Rref = Rjohnson/4 = 160067,5

2.3 Uncertainties on the solution

Analytical solution.

2.4 Reference bibliographical

[1]
“Contact Mechanics” - K.L. JOHNSON - Cambridge University Press - chapter 6 p. 153-201

3 Modeling
With

3.1
Characteristics of modeling

The symmetry of revolution of the problem allows an axisymmetric modeling: The sphere and the block
are represented respectively by a half disc and the cut of half of the block, with a grid with axisymmetric elements 2D.
A contact of the node-mesh type is defined between the two structures.
A loading in imposed displacement is applied to the higher part of the sphere rigidified by
a high Young modulus.

Boundary condition:

.
symmetry of revolution: the nodes located on the axis Y (group of nodes "LB" and "LS") are blocked according to direction X (DX = 0),
.
embedding of the base: the nodes of group "PLANX" are blocked according to directions X and Y (DX = DY = 0),
.
the rigid movements of body are removed by imposing a connection following there enters it node E pertaining to the sphere and the node D pertaining to the solid mass.

Loadings:

An imposed displacement is applied to the higher part of the sphere (group of nodes "NDPL") according to the direction Y: Loading from 0 to 100. mm

---

3.2 Characteristics of the grid

A number of nodes: 916
A number of meshs and type: 625 QUAD4 and 289 SEG2

3.3 Functionalities tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING = "AXIS"

DEFI_MATERIAU ECRO_LINE
SY

D_SIGM_EPSI
AFFE_CHAR_MECA CONTACT
METHOD = "FORCED"

STAT_NON_LINE COMP_ELAS
RELATION = "ELAS"

COMP_INCR
RELATION = "VMIS_ISOT_LINE"
NEWTON
STAMP = "TANGENT"
REAC_ITER = 1

4 Results of modeling A

4.1 Values tested

Identification	*Displacement (mm)*	*Reference*	*Aster*	*% difference*
Reaction (NR)	*20*	*2.03804E+06*	*2.06806E+06*	*1.473*
Reaction (NR)	*40*	*4.07608E+06*	*4.04698E+06*	*-0.714*
Reaction (NR)	*60*	*6.11412E+06*	*5.82730E+06*	*-4.691*
Reaction (NR)	*80*	*8.15217E+06*	*7.66632E+06*	*-5.960*
Reaction (NR)	*100*	*1.01902E+07*	*9.11899E+06*	*-10.512*

4.2 Remarks

The most important error is for the last result. It remains acceptable nevertheless.
We illustrated the deformation of the solid mass to the step of final time:

---

5 Modeling B

5.1 Characteristics of modeling

The symmetry of revolution of the problem allows an axisymmetric modeling: The block is represented by the cut of its half and the sphere is represented by its surface potentially in contact, they are with a grid with axisymmetric elements 2D.
A contact of the node-mesh type is defined between the two structures.
A loading in imposed displacement is applied to all the meshs representing the sphere, rigidified by conditions kinematics.

Boundary condition:

- *Conditions of symmetry:*
nodes of the frame located on the axis Y (group of nodes "LB") are blocked according to direction X (DX = 0).

All nodes belonging to the sphere (group of nodes "MAT1") are blocked according to direction X (DX = 0).

- *Embedding of the base: the nodes of "PLANX" are blocked according to directions X and Y (DX = DY = 0).*
- *The rigid movements of body are removed by imposing a rigid connection, following y,*

between the node E pertaining to the sphere and the node D pertaining to the solid mass.

Loadings:

An imposed displacement is applied to the part representing the sphere (group of node "MAT1") according to the direction Y: Loading from 0 to 100. mm
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Code_Aster ®
Version
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Titrate:
SSNV506 - Elastoplastic indentation of a half-plane by a indentor Dates
:
15/02/06
Author (S):
P. MASSIN, Key Mr. KHAM
:
V6.04.506-B Page:
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5.2
Characteristics of the grid

A number of nodes: 458
A number of meshs and type: 419 QUAD4 and 171 SEG2.

5.3 Functionalities
tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING = "AXIS"

DEFI_MATERIAU ELAS

ECRO_LINE

SY

D_SIGM_EPSI
AFFE_CHAR_MECA CONTACT
METHOD = “FORCED”

STAT_NON_LINE COMP_ELAS
RELATION = “ELAS”

COMP_INCR
RELATION = “VMIS_ISOT_LINE”
NEWTON
STAMP = “TANGENT”
REAC_ITER = 1

6
Results of modeling B

6.1 Values
tested

Identification Displacement
(mm)
Reference
Aster
% difference
Reaction (NR)
D = -20 mm
2.06771E+06
2.31620E+06
1.456
Reaction (NR)
D = -40 mm
4.04742E+06
4.23518E+06
-0.703
Reaction (NR)
D = -60 mm
5.82779E+06
6.07847E+06
-4.683
Reaction (NR)

D = -80 mm
7.66673E+06
7.91027E+06
-5.955
Reaction (NR)
D = 100 mm
9.11942E+06
9.79599E+06
-10.508

6.2 Remarks

The results are almost identical to those of modeling A.
One notices a computing time reduced by modelling only the surface of contact of the sphere rigidified by conditions kinematics.

---

7 Modeling
C

7.1
Characteristics of modeling

The symmetry of the problem makes it possible to represent in 3D only one quarter of the model: the sphere and the block
are represented respectively by the surface of contact of the sphere and a quarter of cylinder, with a

grid
with solid elements 3D CUB8.
A contact node-mesh is defined between the sphere and the block.
A loading in imposed displacement is applied to all the surface of the sphere rigidified by conditions kinematics.

Boundary condition:

.
Conditions of symmetry:
nodes located in plan (O, y, Z) (group of nodes "SBYZ") are blocked according to direction X (DX = 0),

nodes located in the plan (O, X, y) (group of nodes "SBXY") are blocked according to direction Z (DZ = 0),

the nodes of the sphere (group of nodes "SPHSUP") are blocked according to directions X and Z (DX = DZ = 0)
.
Embedding of the base: the nodes of the group "BASES" (plane Y=0.) are blocked according to directions X, Y, and Z (DX = DY = DZ = 0).
.
The rigid movements of body are removed by imposing a connection following there enters it node E pertaining to the sphere and the node S pertaining to the solid mass.

Loadings:

An imposed displacement is applied to all surface representing the sphere (group of nodes "SPHSUP") according to the direction Y: Loading from 0 to 100. mm

7.2
Characteristics of the grid

A number of nodes: 6852
A number of meshs and type: 5326 HEXA8, 387 PENTA6 and 183 QUAD4.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
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Code_Aster ®
Version
8.2

Titrate:
SSNV506 - Elastoplastic indentation of a half-plane by a indentor Dates

7.3 Functionalities
tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

ECRO_LINE
SY

D_SIGM_EPSI
AFFE_CHAR_MECA
CONTACT
METHOD = "FORCED"

STAT_NON_LINE COMP_ELAS
RELATION = "ELAS"

COMP_INCR
RELATION = "VMIS_ISOT_LINE"
NEWTON
STAMP = "TANGENT"
REAC_ITER = 1

8
Results of modeling C

8.1 Values

tested

Identification Reference Displacements
Aster
% difference
Reaction (NR)
D = 20 mm
3.201351E+06
3.986829E+06
24.536
Reaction (NR)
D = 40 mm
6.402702E+06
7.608190E+06
18.828
Reaction (NR)
D = 60 mm
9.604053E+06
1.107936E+07
15.361
Reaction (NR)
D = 80 mm
1.280540E+07
1.355198E+07
5.830
Reaction (NR)
D = 100 mm
1.600675E+07
1.643281E+07
2.662

8.2 Remarks

The results are less precise than those resulting from modelings 2D. The grid in 3D makes lose it exact character of the axisymmetric case. Moreover, for savings of time of calculation and space memory, the grid 3D is refined less than that in 2D.
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-62/06/005/A

---

9 Modeling D

9.1 Characteristics of modeling

The symmetry of the problem makes it possible to represent in 3D only one quarter of the model: The sphere and the block
are represented respectively by a quarter of sphere and a quarter of cylinder, with a grid with solid elements 3D CUB8.
A contact node-mesh is defined between the sphere and the block.
A loading in imposed displacement is applied to the higher part of the sphere rigidified by a high Young modulus.

Boundary condition:

·

Conditions of symmetry:
nodes located in plan (O, y, Z) (groups of nodes "SBYZ" and "SSYZ") are blocked according to direction X (DX = 0),

nodes located in the plan (O, X, y) (groups of nodes "SBXY" and "SSXY") are blocked according to direction Z (DZ = 0).

·

Embedding of the base: the nodes of "BASE" (plane Y=0.) are blocked according to directions X, Y, and Z (DX = DY = DZ = 0).

·

The rigid movements of body are removed by imposing a connection following there enters it node E pertaining to the sphere and the node S pertaining to the solid mass.

Loadings:

An imposed displacement is applied to the higher part of the sphere (group of nodes "CHIMPO") according to the direction Y: Loading from 0 to 100. mm
Handbook of Validation
V6.04 booklet: Nonlinear statics of the voluminal structures
HT-62/06/005/A

9.2
Characteristics of the grid

A number of nodes: 6993
A number of meshs and type: 5544 HEXA8, 407 PENTA6 and 191 QUAD4

9.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

ECRO_LINE
SY

D_SIGM_EPSI
AFFE_CHAR_MECA CONTACT
METHOD = “FORCED”

STAT_NON_LINE COMP_ELAS
RELATION = “ELAS”

COMP_INCR
RELATION = “VMIS_ISOT_LINE”
NEWTON
STAMP = “TANGENT”
REAC_ITER = 1

10 Results of modeling D

10.1 Values tested

Identification Reference Displacements
Aster
% difference
Reaction (NR)
D = 20 mm
3.201351E+06
3.963968E+06
23.822
Reaction (NR)
D = 40 mm
6.402702E+06
7.653342E+06
19.533
Reaction (NR)
D = 60 mm
9.604053E+06
1.111985E+07
15.783
Reaction (NR)
D = 80 mm

1.280540E+07
1.337793E+07
4.471
Reaction (NR)
D = 100 mm
1.600675E+07
1.628419E+07
1.733

10.2 Remarks

The results are almost identical to those of modeling C. But calculation is even more tiresome because a quarter of the sphere is with a grid.

---

11 Modeling E

11.1 Characteristics of modeling

The symmetry of revolution of the problem allows an axisymmetric modeling: The block is represented by the cut of its half and the sphere is represented by its surface potentially in contact, they are with a grid with axisymmetric elements 2D.
A contact of the node-mesh type is defined between the two structures.
A loading in imposed displacement is applied to the higher part of the sphere rigidified by a high Young modulus.

Boundary condition:

.
symmetry of revolution: the nodes located on the axis Y (group of nodes "LB" and "LS") are blocked according to direction X (DX = 0),
.
embedding of the base: the nodes of group "PLANX" are blocked according to directions X and Y (DX = DY = 0),
.
the rigid movements of body are removed by imposing a connection following there enters it node E pertaining to the sphere and the node D pertaining to the solid mass.

Loadings:

An imposed displacement is applied to the higher part of the sphere (group of nodes "NDPL") according to the direction Y: Loading from 0 to 100. mm

11.2 Characteristics of the grid

A number of nodes: 688
A number of meshs and type: 625 QUAD4 and 241 SEG2.

11.3 Functionalities tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING = "AXIS"

DEFI_MATERIAU ELAS

ECRO_LINE
SY

D_SIGM_EPSI
AFFE_CHAR_MECA CONTACT
METHOD = "CONTINUES"

STAT_NON_LINE COMP_ELAS
RELATION = "ELAS"

COMP_INCR
RELATION = "VMIS_ISOT_LINE"
NEWTON
STAMP = "TANGENT"
REAC_ITER = 1

12 Results of modeling E

12.1 Values
tested

Identification Displacement
(mm)
Reference
Aster
% difference
Reaction (NR)
20
2.03804E+06
2.09057E+06
2.577
Reaction (NR)
40

4.07608E+06
4.09426E+06
0.446
Reaction (NR)
60
6.11412E+06
5.84817E+06
-4.350
Reaction (NR)
80
8.15217E+06
7.68357E+06
-5.748
Reaction (NR)
100
1.01902E+07
9.13216E+06
-10.383

12.2 Remarks

The results are slightly better than those of modeling A.
One notices a computing time 5 times higher than the latter, using the FORCED method.

---

13 Modeling
F

13.1 Characteristics of modeling

The symmetry of the problem makes it possible to represent in 3D only one quarter of the model: the sphere and the block
are represented respectively by the surface of contact of the sphere and a quarter of cylinder, with a grid
with solid elements 3D CUB8.
A contact node-mesh is defined between the sphere and the block.
A loading in imposed displacement is applied to all the surface of the sphere rigidified by conditions kinematics.

Boundary condition:

.

Conditions of symmetry:
nodes located in plan (O, y, Z) (group of nodes
"SBYZ") are blocked according to direction X (DX = 0),

nodes located in the plan (O, X, y) (group of nodes
"SBXY") are blocked according to direction Z (DZ = 0),

the nodes of the sphere (group of nodes "SPHSUP") are
blocked according to directions X and Z (DX = DZ = 0)
.
Embedding of the base: the nodes of the group "BASES" (plane Y=0.) are blocked
according to directions X, Y, and Z (DX = DY = DZ = 0).
.
The rigid movements of body are removed by imposing a connection following there enters it
node E pertaining to the sphere and the node S pertaining to the solid mass.

Loadings:

An imposed displacement is applied to all surface representing the sphere (group of nodes
"SPHSUP") according to the direction Y: Loading from 0 to 100. mm

13.2 Characteristics of the grid

A number of nodes: 2236
A number of meshs and type: 1638 HEXA8, 126 PENTA6, 725 QUAD4, 27 TRIA3 and 26 SEG2.

13.3 Functionalities tested

Orders Key word
factor Key word

AFFE_MODELE
AFFE
MODELING = "3D"

DEFI_MATERIAU ELAS

ECRO_LINE
SY

D_SIGM_EPSI
AFFE_CHAR_MECA
CONTACT
METHOD = "CONTINUES"

STAT_NON_LINE COMP_ELAS
RELATION = "ELAS"

COMP_INCR
RELATION = "VMIS_ISOT_LINE"
NEWTON
STAMP = "TANGENT"
REAC_ITER = 1

14 Results of modeling F

14.1 Values tested

Identification Reference Displacements
Aster
% difference
Reaction (NR)
D = 20 mm
3.201351E+06
3.986829E+06
24.536
Reaction (NR)
D = 40 mm
6.402702E+06
7.608190E+06
18.828
Reaction (NR)
D = 60 mm
9.604053E+06
1.107936E+07
15.361
Reaction (NR)
D = 80 mm
1.280540E+07
1.355198E+07
5.830
Reaction (NR)
D = 100 mm
1.600675E+07
1.643281E+07
2.662

14.2 Remarks

The results are less precise than those resulting from modelings 2D. The grid in 3D makes lose it exact character of the axisymmetric case. Moreover, for savings of time of calculation and space memory, the grid 3D is refined less than that in 2D.

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8.2

Titrate:
SSNV506 - Elastoplastic indentation of a half-plane by a indentor Dates
:
15/02/06
Author (S):
P. MASSIN, Key Mr. KHAM
:
V6.04.506-B Page:
16/16

15 Summary of the results

The results obtained are good. However, a more important variation enters the reference and the results
3D exists. It is possible to fill it by refining even more the grid but it should be paid in
place memory and in computing times.

The size of the elements is very important. If they are too large, one can see appearing on the curve reaction according to the displacement of the "waves" (loss of linearity of this curve). Each "vague" corresponds to the setting in contact of an element. Moreover, if the grid is not sufficiently refined, the reaction given by Aster moves away appreciably from that of reference.

To model only the sphere by its surface of contact rigidified by conditions kinematics
a saving of time allows.

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Version 5.0

Titrate:
Nonlinear SSNS100 Behavior of a tablecloth of reinforcements
Date:

Organization (S): EDF/AMA

Handbook of Validation
V6.05 booklet: Nonlinear statics
Document: V6.05.100

SSNS100 - Nonlinear behavior of a tablecloth
reinforcements under thermal loading

Summary:

A tablecloth of reinforcements not offset compared to the layer average and embedded on its four sides east
subjected to a thermal loading. The orientations of the reinforcements are confused with the axes (X, Y) of
total reference mark.

The principal interest of this test is to validate the numerical integration of the models of behavior
elastoplastic GRILLE_ISOT_LINE, GRILLE_CINE_LINE and GRILLE_PINTO_MEN of a
tablecloth of reinforcements

associated the finite element GRID (orthotropic plate with offsetting compared to the datum-line), in the algorithm general STAT_NON_LINE.

In order to obtain reference solutions, analytical solutions were established for both elastoplastic behaviours with linear and kinematic work hardening isotropic linear. The behavior of Pinto-Menegotto is validated by nonregression of the numerical results obtained with Aster in version 5-3 (cf [§1.3.3]).

---

1 Problem of reference

1.1 Geometry of the plate

Y
NO4
NO3
X
X
1m
ref.
NO 1
1 m
NR O2

Z
Y
X
E

1.2
Characteristics of modelings

This case test is composed of 7 modelings. The table below summarizes their characteristics:

Offsetting = 0 Thickness = 0,01m
Orientation of the reinforcements
longitudinal direction (L): OX
transverse direction (T): OY

Modeling Law of behavior
% braces
% braces
Mode of application of
longitudinal
the temperature
L
transversal T
With
isotropic linear
1

0,1
with the nodes
B
linear kinematics
1
0,1
with the nodes
C
Pinto Menegotto
1
0,1
with the nodes
D
Pinto Menegotto
1
0,1
with the elements
E
Pinto Menegotto
1
0
with the elements
F
isotropic linear
1
0
with the nodes
G
linear kinematics
1
0
with the nodes

1.3
Properties of materials

1.3.1 Properties common to all modelings

Young modulus:
E = 2 1011
.
MPa

Poisson's ratio:
= 0

Elastic limit:
y = 2 108
.
MPa

Thermal dilation coefficient: =
-
10 5 (°C-1)

1.3.2 Behavior
isotropic and kinematic plastic

For the behaviors isotropic (GRILLE_ISOT_LINE) and kinematics (GRILLE_CINE_LINE)
Slope of work hardening: AND = 2 1010
.
MPa

1.3.3 Behavior of Pinto Menegotto

For behavior PINTO MENEGOTTO (GRILLE_PINTO_MEN)

EPSI_ULTM: 3,0.
10-2
SIGM_ULTM: 2,58.
108
EPSP_HARD: 0,0023
R_PM
: 20,0
EP_SUR_E
: 0,01
A1_PM
: 18,5
A2_PM
: 0,15
DASH
: 4,9
A6_PM
: 620,0
C_PM
: 0,5
A_PM

: 0,008

1.4
Boundary conditions and loading

The plate is entirely embedded.
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The loading is of thermal origin. The change of the temperature according to time is given for each modeling in the following table. The temperature is applied to the nodes or to elements, according to modeling.

Moment Evolution
With Evolution B
Evolution C
T°
T°
T°
0 50 50 50
1 -50 -50 -300
2 -250 -250 -100
3 -150 -150
50
4 -250 -250 -150
5 -50 -50 -350
6 350 350 -200
7 50 150

8 -450 -450

9 -110 -250

10 550 650

11 50 450

600
Evol_A

400
Evol_B
Evol_C
200
.
éf
Tr
0
T
-200
-400
-600
1
2
3
4
5
6
7
8
9
10
11
12

One took for all the tests a temperature of reference of 50°.

2
Reference solutions

2.1
Isotropic plastic behavior

The reference solution is calculated analytically.
One notes T +
+
, p+
+
, p
, the temperature, plastic deformation, cumulated plastic deformation
and total deflection at the moment of calculation, and T -
-
, p
, p
same quantities at the moment
precedent. Tréf indicates the temperature of reference.

The solution is calculated in the following way:

+
+
-
E = E [- (T - R
T ef) - p]
E. AND
R (p) =
p + y
E - AND
if
-
E R (p)
+ = -; p+ = p; + =
p
p
E
if not
if
-
E > R (p)

E - *E*

+
T
=

+ -
y
E
+
T
-
-
p
(T - reTf) - + *[p - p]*
E
E
E

p+ = *p* + + - -
p
p
+ = *R (p*+*)*
if not
E - *E*

+
T
E
=
+

- +
y
T
+
[- -
p + *p]*
p
(T - reTf) +
E
E
E

p+ = p - +
-
p + p
+
= - R (p+)

This calculation is made in each direction. For the treated case, + = 0 at any moment.
In the longitudinal direction, the constraint memorized in Aster is the real constraint existing in each grid of this direction.
In the transverse direction, the constraint memorized in Aster is the real constraint existing

in each grid of this direction multiplied by the coefficient T
.
L

2.2
Kinematic plastic behavior

The reference solution is calculated analytically.
One notes T +
+
+
, X +
, p
the temperature, plastic deformation and the variable of work hardening

kinematics at the moment of calculation, and T -
- X -
, p
same quantities at the previous moment.

The solution is calculated in the following way:

+
+
-
E = E [- (T - R
T ef) - p]
if - X -
E
y
+ = -; X + = X -; + =
p
p
E
if not
if - X - >
E
y
E - E

+
T
=

+ -
y
+
p
(T - reTf) -
E
E

X + = E
+ -
y

+
T
(T - rTef) -
E

E - E
+
+
+
T
= AND [- (T - rTef)]+
y
E
if not
E - E

+
T
=
+

-
y
+
p
(T - reTf) +
E
E

y
+
X = AND +
- (+
T - Tref) +

E
E -
+
E
= E

T
T [+
- (+
T - Tref)] -

E
y

This calculation is made in each direction. For the treated case, + = 0 at any moment.
In the longitudinal direction, the constraint memorized in Aster is the real constraint existing
in each grid of this direction.
In the transverse direction, the constraint memorized in Aster is the real constraint existing

in each grid of this direction multiplied by the coefficient T
.
L

2.3
Behavior Pinto Ménégotto

The reference solution is that obtained by an Aster calculation with the same grid on which one apply cycles of load/discharge, in imposed displacement, allowing to recreate them deformations resulting from thermomechanical calculations presented hereafter. The test corresponding is not thus that a test of nonregression, by comparing the constraints obtained by these two types of modeling: on the one hand mechanical, and on the other hand thermomechanical.

In the longitudinal direction, the constraint memorized in Aster is the real constraint existing

in each grid of this direction.
In the transverse direction, the constraint memorized in Aster is the real constraint existing

in each grid of this direction multiplied by the coefficient T
.
L

3 Modeling
With

The test-tube is with a grid with two elements `GRID `with three nodes.

NO3
NO4
NO1
NO2

4 Functionalities
tested

Orders

AFFE_CARA_ELEM ROASTS

DEFI_MATERIAU ECRO_LINE

PINTO_MENEGOTTO
STAT_NON_LINE COMP_INCR
RELATION
“GRILLE_ISOT_LINE”
“GRILLE_CINE_LINE”
“GRILLE_PINTO_MEN”
NEWTON
STAMP
“TANGENT”

CALC_ELEM OPTION

SIGM_ELNO_VARI

5
Results modeling A (linear isotropic work hardening)

5.1
Thermal loading for modeling A

Temperature of reference: 50
History of the loading: Evolution_A (cf [§1.4])
The temperatures returned like a field to the nodes.

5.2 Results

Variable: SIGXX and SIGYY with node NO1

SIGXX
SIGYY
Moment Code_Aster Reference
Variation Code_Aster Reference
Variation (%)
1 2,00000E+08 2,00000E+08 0 2,00000E+07 2,00000E+07 0
2 2,40000E+08 2,40000E+08 0 2,40000E+07 2,40000E+07 0
3 4,00000E+07 4,00000E+07 0 4,00000E+06 4,00000E+06 0
4 2,40000E+08 2,40000E+08 0 2,40000E+07 2,40000E+07 0
5 1,60000E+08 1,60000E+08 0 1,60000E+07 1,60000E+07
0

6 3,12000E+08 3,12000E+08 0 3,12000E+07 3,12000E+07
0
7 2,88000E+08 2,88000E+08 0 2,88000E+07 2,88000E+07 0
8 4,09600E+08 4,09600E+08 0 4,09600E+07 4,09600E+07 0
9 2,70400E+08 2,70400E+08 0 2,70400E+07 2,70400E+07
0
10 5,27680E+08 5,27680E+08 0 5,27680E+07 5,27680E+07
0
11 4,72320E+08 4,72320E+08 0 4,72320E+07 4,72320E+07 0

Note:

The results presented are given in the reference mark of reference (Xref, Yref) forming an angle of 0° compared to (X, Y).
Constraints SIGYY are equal to constraints SIGXX multiplied by the report/ratio of percentages of reinforcement enters the directions transversal and longitudinal.
The case studied test corresponds to the diagrams following in a plan forced deformation:

5,000E+08
4,000E+08
3,000E+08
2,000E+08
1,000E+08
0,000E+00
-1,000E+08
-2,000E+08
-3,000E+08
-4,000E+08
-5,000E+08
-6,000E+08
-6,00E-03 -4,00E-03 -2,00E-03 0,00E+00
2,00E-03
4,00E-03
6,00E-03

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Code_Aster ®
Version 5.0

Titrate:
Nonlinear SSNS100 Behavior of a tablecloth of reinforcements

6 Results modeling B (kinematic work hardening linear)

6.1 Thermal loading for modeling B

Temperature of reference: 50°C
History of the loading: Evolution_B (cf [§1.4)
The temperatures returned like a field to the nodes.

6.2 Results

Variable: SIGXX and SIGYY with node NO1

SIGXX
SIGYY
Moment Code_Aster Reference
Variation Reference
Code_Aster Variation
(%)
1 2,00E+08
2,00E+08 0 2,00E+07 2,00E+07
0
2 2,40E+08
2,40E+08 0 2,40E+07 2,40E+07
0
3 4,00E+07
4,00E+07 0 4,00E+06 4,00E+06
0
4 2,40E+08
2,40E+08 0 2,40E+07 2,40E+07
0
5 1,60E+08
1,60E+08

0 1,60E+07 1,60E+07
0
6 2,40E+08
2,40E+08
0 2,40E+07 2,40E+07
0
7 1,60E+08
1,60E+08 0 1,60E+07 1,60E+07
0
8 2,80E+08
2,80E+08 0 2,80E+07 2,80E+07
0
9 1,20E+08
1,20E+08
0 1,20E+07 1,20E+07
0
10 3,00E+08 3,00E+08
0 3,00E+07 3,00E+07
0
11 1,00E+08 1,00E+08
0 1,00E+07 1,00E+07
0

Note:

The results presented are given in the reference mark of reference (Xref, Yref) forming an angle of 0° compared to (X, Y).
Constraints SIGYY are equal to constraints SIGXX multiplied by the report/ratio of percentages of reinforcement enters the directions transversal and longitudinal.
The case studied test corresponds to the following diagram in a plan forced deformation:

3,00E+08
2,00E+08
1,00E+08
0,00E+00
-1,00E+08
-2,00E+08
-3,00E+08
-6,00E-03 -4,00E-03 -2,00E-03 0,00E+00
2,00E-03
4,00E-03
6,00E-03
Handbook of Validation

7
Results modeling C (model of Pinto Menegotto)

7.1
Thermal loading for modeling C

Temperature of reference: 50°C
History of the loading: Evolution_C (cf [§1.4])
The temperatures returned like a field to the nodes.

7.2 Results

Variable: SIGXX and SIGYY with node NO1

SIGXX
SIGYY
Code_Aster moment

Code_Aster

1
2.00000E+08

2.00000E+07

2
2.09416E+08

2.09416E+07

3
1.21555E+08
1.21555E+07

4
1.82862E+08
1.82862E+07

5
1.52164E+08

1.52164E+07

6
2.02506E+08

2.02506E+07

7
7.59307E+07
7.59307E+06

Note:

The results presented are given in the reference mark of reference (Xref, Yref) forming an angle of 0° compared to (X, Y).
Constraints SIGYY are equal to constraints SIGXX multiplied by the report/ratio of percentages of reinforcement enters the directions transversal and longitudinal.

The case studied test corresponds to the following diagram in a plan forced deformation:

2,50E+08
2,00E+08
1,50E+08
1,00E+08
5,00E+07
0,00E+00
-5,00E+07
-1,00E+08
-1,50E+08

-2,00E+08
0,0E+00 5,0E-04 1,0E-03 1,5E-03 2,0E-03 2,5E-03 3,0E-03 3,5E-03 4,0E-03

8
Results modeling D (model of Pinto-Menegotto)

Modeling D is the same one as modeling C, with the difference which the temperatures are defined by a chart.
The results are identical.

9
Results modeling E (model of Pinto-Menegotto)

Modeling E approaches modeling D, with the difference that it there not of reinforcement transversal (T = 0).

9.1 Results

Variable: SIGXX and SIGYY with node NO1

SIGXX SIGYY
Moment
Code_Aster

Code_Aster

1
2.00000E+08

0,0

2
2.09416E+08

0,0

3
1.21555E+08

0,0

4
1.82862E+08

0,0

5
1.52164E+08

0,0

6
2.02506E+08

0,0

7
7.59307E+07

0,0

Note:

The results presented are given in the reference mark of reference (Xref, Yref) forming an angle of 0° compared to (X, Y).
Constraints SIGYY are null, since there are not any more transverse reinforcements.

Handbook of Validation
V6.05 booklet: Nonlinear statics
HT-66/02/001/A

Code_Aster ®
Version 5.0

Titrate:
Nonlinear SSNS100 Behavior of a tablecloth of reinforcements
Date:
05/02/02
Author (S):
C. CHAVANT Key
:
V6.05.100-A Page:
12/14

10 Results modeling F (linear isotropic work hardening)

Modeling F approaches modeling A, with the difference that it there not of reinforcement transversal (T = 0).

10.1 Results

Variable: SIGXX and SIGYY with node NO1

SIGXX SIGYY
Moment
Code_Aster

Code_Aster

1
2.00000E+08

0,0

2
2.40000E+08

0,0

3
4.00000E+07

0,0

4
2.40000E+08

0,0

5
1.60000E+08

0,0

6
3.12000E+08

0,0

7
2.88000E+08

0,0

8
4.09600E+08

0,0

9
2.70400E+08

0,0

10
5.27680E+08

0,0

11
4.72320E+08

0,0

Note:

The results presented are given in the reference mark of reference (Xref, Yref) forming an angle of 0° compared to (X, Y).
Constraints SIGYY are null, since there are not any more transverse reinforcements.

10.2 Parameters of execution

Version: 5.03.13

Machine: SGI ORIGIN 2000 - R 12000

Obstruction memory: 32 Mo
Time CPU To use: 6, 43 S

---

11 Results modeling G (linear kinematic model)

Modeling F approaches modeling B, with the difference that it there not of reinforcement transversal (T = 0).

11.1 Results

Variable: SIGXX and SIGYY with node NO1

SIGXX
SIGYY
Moment
Code_Aster

Code_Aster

1
2,00E+08
0,0
2
2,40E+08
0,0
3
4,00E+07
0,0
4
2,40E+08
0,0
5
1,60E+08
0,0
6
2,40E+08
0,0
7
1,60E+08
0,0
8
2,80E+08
0,0
9
1,20E+08
0,0
10
3,00E+08

0,0

11
1,00E+08

0,0

Note:

The results presented are given in the reference mark of reference (Xref, Yref) forming an angle of 0° compared to (X, Y).
Constraints SIGYY are null, since there are not any more transverse reinforcements.

11.2 Parameters
of execution

Version: 5.03.13

Machine: SGI ORIGIN 2000 - R 12000

Obstruction memory: 32 Mo
Time CPU To use: 7, 52 S
Handbook of Validation
V6.05 booklet: Nonlinear statics
HT-66/02/001/A

---

12 Summary of the results

For elastoplastic behaviours with linear work hardening, the analytical solution is perfectly found.

The behavior of Pinto-Menegotto is validated by nonregression.

Organization (S): EDF-R & D /AMA, INSA LYON

Handbook of Validation
V6.05 booklet: Nonlinear statics
Document: V6.05.101

SSNS101 Breakdown of a cylindrical panel
under specific force

Summary:

This test of nonlinear quasi-static mechanics makes it possible to validate elements SHB8 into nonlinear
geometrical and material.

Three modelings make it possible to study various configurations:

.
linear modeling a: elastic behavior, great displacements, support on average surface
.
linear modeling b: elastic behavior, great displacements, support on surface
lower
.
modeling C: elastoplastic behavior of Von Mises with linear isotropic work hardening, large displacements, support on average surface.

1
Problem of reference

1.1 Geometry

F

2L

2

One models a quarter of the panel because of symmetries:

SU0

L31290

P2 ·

L4590

SUSUP
·
Cylindrical panel
- Angle 2 = 0.1 rad
- L=254mm
- R=2450mm
- Thickness h=12.7mm

1.2
Properties of material

The fixed characteristics are as follows:

Elastic characteristics:
E=3102.75 MPa
NU=0.3

Traction diagram:
Eps
Sig

1.e-03
3.102,

0.1 33.5,

1.3
Boundary conditions and loadings

Conditions of symmetry on coasts SU0 and SUSUP

Embedding on the side L31290 (what returns in a simple support) for modelings A and C.
Embedding on the line L4590 (simple support on the lower part of the hull) for
modeling B.

Nodal force FX=-0.25 NR on the P2 point. (total resultant by taking of account symmetries: 1N).

The loading is controlled by the value of displacement following X of the P2 point. The amplitude of the force
(ETA coefficient of piloting) is increased so that displacement crosses until 45mm by
no the 1mm.

2
Reference solution

2.1
Method of calculation

Numerical solution [bib1] [bib2]: values of the parameter of piloting (thus of the force F) according to
time (thus of displacement DX of the P2 point).

2.2
Sizes and results of reference

Coefficient of piloting (coef. Multiplier of the force applied) according to displacement DX of
not P2

In the case of simple modeling a: support on the average surface of the hull: results
obtained by the code INCA [bib1].

In the case of modeling B, with conditions of simple support on the lower edge of the hull,
the curve of reference given in [bib2], is:

Displacement	*Force (NR) [bib1]*	*Force (NR) [bib2]*
2	*0.706*	*0.730*
4	*1.273*	*1.315*
6	*1.707*	*1.760*
8	*2.007*	*2.066*

10 2.160 2.221
12 2.129 2.189
14 1.827 1.876
16 1.180 1.178
18 0.677 0.654
20 0.592 0.582

In the case of modeling C: simple support on the average surface of the hull, in elastoplasticity, the results are obtained by the code INCA [bib1].

2.3
Uncertainties on the solution

Without object

2.4 References

[1]
"Elastoplastic Stability analysis oh shells using the physically stabilised finite element SHB8PS " A.Legay, A.Combescure, International Newspaper for Numerical Methods in Engineering, 20 1-6, 2000,
[2]
"A geometrical non-linear brig element based one the eas method" Kinkel S, Wagner W., International Newspaper for Numerical Methods in Engineering, 40 4529-4545 1997,

---

3 Modeling
With

3.1
Characteristics of modeling

Simple support on the average line. Linear elasticity in great displacements.

3.2
Characteristics of the grid

A number of nodes: 242
A number of meshs and types: 100 HEXA8.

3.3 Functionalities
tested

Orders

AFFE_MODELE MODELING
SHB8

STANDARD STAT_NON_LINE PILOTING
DDL_IMPO

4
Results of modeling A

4.1
Sizes tested and results

Identified parameters: displacement in X of the P2 point, and coefficient of piloting (values of not regression):

Identification (moment)
Values of displacement DX
Aster
P2 point
1.00000E+00 -1.00000E+00 4.32117E+02
2.00000E+00 -2.00000E+00 8.34401E+02
3.00000E+00 -3.00000E+00 1.20919E+03
4.00000E+00 -4.00000E+00 1.55870E+03
5.00000E+00 -5.00000E+00 1.88499E+03

6.00000E+00 -6.00000E+00 2.18993E+03
7.00000E+00 -7.00000E+00 2.47513E+03
8.00000E+00 -8.00000E+00 2.74194E+03
9.00000E+00 -9.00000E+00 2.99133E+03
1.00000E+01 -1.00000E+01 3.22392E+03
1.10000E+01 -1.10000E+01 3.43983E+03
1.20000E+01 -1.20000E+01 3.63865E+03
1.30000E+01 -1.30000E+01 3.81934E+03
1.40000E+01 -1.40000E+01 3.98007E+03
1.50000E+01 -1.50000E+01 4.11808E+03
1.60000E+01 -1.60000E+01 4.22949E+03
1.70000E+01 -1.70000E+01 4.30899E+03
1.80000E+01 -1.80000E+01 4.34962E+03
1.90000E+01 -1.90000E+01 4.34249E+03
2.00000E+01 -2.00000E+01 4.27684E+03
2.10000E+01 -2.10000E+01 4.14064E+03
2.20000E+01 -2.20000E+01 3.92259E+03
2.30000E+01 -2.30000E+01 3.61577E+03
2.40000E+01 -2.40000E+01 3.22226E+03
2.50000E+01 -2.50000E+01 2.75610E+03
2.60000E+01 -2.60000E+01 2.24175E+03
2.70000E+01 -2.70000E+01 1.70911E+03
2.80000E+01 -2.80000E+01 1.18864E+03
2.90000E+01 -2.90000E+01 7.08393E+02
3.00000E+01 -3.00000E+01 2.92100E+02
3.10000E+01 -3.10000E+01 -4.24886E+01
3.20000E+01 -3.20000E+01 -2.84670E+02

6/10

3.30000E+01 -3.30000E+01 -4.30543E+02
3.40000E+01 -3.40000E+01 -4.81447E+02
3.50000E+01 -3.50000E+01 -4.41876E+02
3.60000E+01 -3.60000E+01 -3.17650E+02
3.70000E+01 -3.70000E+01 -1.14685E+02
3.80000E+01 -3.80000E+01 1.61662E+02
3.90000E+01 -3.90000E+01 5.06865E+02
4.00000E+01 -4.00000E+01 9.17273E+02
4.10000E+01 -4.10000E+01 1.39005E+03

5 Modeling B

5.1 Characteristics of modeling

Simple support on the lower line. Linear elasticity in great displacements.

5.2 Characteristics of the grid

A number of nodes: 242

A number of meshs and types: 100 HEXA8.

5.3 Functionalities tested

Orders

AFFE_MODELE MODELING SHB8

STANDARD STAT_NON_LINE PILOTING DDL_IMPO

6 Results of modeling B

6.1 Sizes tested and results

Identified parameters: displacement in X of the P2 point, and coefficient of piloting (values of not regression):

Identification
Values of
Reference
Aster %
difference
(moment)
displacement DX
P2 point
1.00000E+00 -1.00000E+00

3.62356E+02

2.00000E+00 -2.00000E+00
718
6.90827E+02
3.7
3.00000E+00 -3.00000E+00

9.86370E+02

4.00000E+00 -4.00000E+00

1273
1.24973E+03
1.2
5.00000E+00 -5.00000E+00

1.48135E+03

6.00000E+00 -6.00000E+00
1707
1.68135E+03
1.5
7.00000E+00 -7.00000E+00

1.84935E+03

8.00000E+00 -8.00000E+00
2007
1.98436E+03
1
9.00000E+00 -9.00000E+00

2.08451E+03

1.00000E+01 -1.00000E+01
2160
2.14675E+03
0.6
1.10000E+01 -1.10000E+01

2.16625E+03

1.20000E+01 -1.20000E+01
2129
2.13546E+03
0.02
1.30000E+01 -1.30000E+01

2.04250E+03

1.40000E+01 -1.40000E+01
1827
1.86895E+03
2.2
1.50000E+01 -1.50000E+01

1.58986E+03

1.60000E+01 -1.60000E+01
1180
1.19840E+03
1.5
1.70000E+01 -1.70000E+01

7.94355E+02

1.80000E+01 -1.80000E+01
677
5.24466E+02
9
1.90000E+01 -1.90000E+01

3.94813E+02

2.00000E+01 -2.00000E+01
592
3.65830E+02
38
2.10000E+01 -2.10000E+01

4.11856E+02

2.20000E+01 -2.20000E+01

5.18868E+02

2.30000E+01 -2.30000E+01

6.79056E+02

2.40000E+01 -2.40000E+01

8.87954E+02

2.50000E+01 -2.50000E+01

1.14302E+03

2.60000E+01 -2.60000E+01

1.44286E+03

2.70000E+01 -2.70000E+01

1.78686E+03

2.80000E+01 -2.80000E+01

2.17489E+03

2.90000E+01 -2.90000E+01

2.60718E+03

Handbook of Validation
V6.05 booklet: Nonlinear statics
HT-66/03/008/A

Code_Aster ®
Version
7.2

Titrate:
SSNS101 Breakdown of a cylindrical panel under specific force
Date:
03/11/03
Author (S):

7 Modeling C

7.1 Characteristics of modeling

Simple support on the average line. Elastoplasticity of Von Mises with linear isotropic work hardening in great displacements.

7.2 Characteristics of the grid

A number of nodes: 242
A number of meshs and types: 100 HEXA8.

7.3 Functionalities tested

Orders

AFFE_MODELE MODELING
SHB8

STANDARD STAT_NON_LINE PILOTING
DDL_IMPO
STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_TRAC

8 Results of modeling C

8.1 Sizes tested and results

Identified parameters: displacement in X of the P2 point, and coefficient of piloting:

Identification (moment)
Values of displacement
Aster
DX of the P2 point

1.00000E+00	-1.00000E+00	4.28527E+02
2.00000E+00	-2.00000E+00	7.21147E+02
3.00000E+00	-3.00000E+00	9.10346E+02
4.00000E+00	-4.00000E+00	1.04103E+03
5.00000E+00	-5.00000E+00	1.13571E+03
6.00000E+00	-6.00000E+00	1.20789E+03
7.00000E+00	-7.00000E+00	1.26591E+03
8.00000E+00	-8.00000E+00	1.31619E+03
9.00000E+00	-9.00000E+00	1.36018E+03
1.00000E+01	-1.00000E+01	1.39699E+03
1.10000E+01	-1.10000E+01	1.42820E+03
1.20000E+01	-1.20000E+01	1.45365E+03
1.30000E+01	-1.30000E+01	1.47285E+03
1.40000E+01	-1.40000E+01	1.48474E+03
1.50000E+01	-1.50000E+01	1.48607E+03

9
Summary of the results

The results obtained by Code_Aster with modeling SHB8 show the capacity of this element to deal with problems of thin hulls with nongeometrical and behavioral linearities.

Organization (S): EDF-R & D /AMA, INSA LYON

Handbook of Validation
V6.05 booklet: Nonlinear statics
Document: V6.05.102

SSNS102 Buckling of a cylindrical hull with stiffener

Summary:

This test of nonlinear quasi-static mechanics makes it possible to validate elements SHB8 into nonlinear
geometrical, with or without taking into account of the following pressures and buckling of Euler. He shows them
capacities of this element to deal with problems of thin hulls with stiffener.

1
Problem of reference

1.1 Geometry

Cylindrical hull (which one will be able to represent a quarter), comprising a stiffener surfaces intern of it.

The section (axisymmetric) is following form:

Lr
L

R
SU90
Z
y
X
SU0
SUINF
Geometry: Ray R = 2.488m
Height L = 600m
Thickness H = 0.024m
Heart la=0.156m, H = 0.01m
Stiffener Lr = 0.120m, H = 0.024m

1.2
Properties of material

Material:
E = 2.1011Pa

= 0.3

1.3
Boundary conditions and loadings

Boundary conditions of symmetry: with SU90: DX = 0

SU0:
DY = 0

on
SUINF: DZ = 0
Loading:
External pressure uniform P = 1Pa regarded as nonfollowing pressure then following

---

2

Reference solution

2.1
Method of calculation

Numerical solution [bib1]: values of the moment (thus of the external pressure) according to radial displacement of the P2 point (with nonfollowing pressure).

2.2
Sizes and results of reference

The critical loads of Euler found by INCA [bib1] are:

Mode Size Unit
Reference
:
(INCA)
1 Pcr
(Pa) 1.27522
2 Pcr
(Pa) 2.70735
3 Pcr
(Pa) 2.81099
4 Pcr
(Pa) 2.83234
5 Pcr
(Pa) 3.11185
6 Pcr
(Pa) 3.25732
7 Pcr
(Pa) 3.61713
8 Pcr
(Pa) 3.99700
9 Pcr
(Pa) 4.07395
10 Pcr
(Pa) 4.10499

In great displacements, without following pressure, the solution found by INCA is:

Moment = pressure
Radial displacement point
1.000E-01 6.414E-04

2.000E-01 1.288E-03
3.001E-01 1.942E-03
4.000E-01 2.604E-03
4.999E-01 3.279E-03
5.996E-01 3.971E-03
6.987E-01 4.688E-03
7.964E-01 5.443E-03
8.909E-01 6.256E-03
9.768E-01 7.142E-03
1.056E+00 8.254E-03
1.103E+00 9.278E-03
1.130E+00 1.020E-02
1.148E+00 1.106E-02
1.160E+00 1.189E-02
1.169E+00 1.271E-02
1.175E+00 1.351E-02
1.181E+00 1.430E-02
1.185E+00 1.509E-02
1.188E+00 1.587E-02
1.191E+00 1.681E-02
1.194E+00 1.774E-02
1.196E+00 1.866E-02
1.197E+00 1.959E-02
1.199E+00 2.051E-02
1.200E+00 2.144E-02
1.201E+00 2.236E-02
1.201E+00 2.328E-02
1.202E+00 2.420E-02

1.202E+00 2.512E-02
1.203E+00 2.622E-02
1.203E+00 2.732E-02
1.203E+00 2.843E-02
1.204E+00 2.953E-02
1.204E+00 3.063E-02
1.204E+00 3.172E-02
1.204E+00 3.282E-02
1.203E+00 3.391E-02
1.203E+00 3.500E-02
1.203E+00 3.608E-02
1.203E+00 3.737E-02
1.203E+00 3.866E-02
1.202E+00 3.992E-02
1.202E+00 4.115E-02
1.202E+00 4.234E-02
1.202E+00 4.347E-02
1.201E+00 4.450E-02
1.201E+00 4.540E-02
1.201E+00 4.609E-02
1.202E+00 4.644E-02

2.3
Uncertainties on the solution

Without object

2.4 References

[1]
"Elastoplastic Stability analysis oh shells using the physically stabilised finite element SHB8PS " A.Legay, A.Combescure, International Newspaper for Numerical Methods in Engineering, 20 1-6, 2000,

3 Modeling With

3.1 Characteristics of modeling

1/4 of the stiffened cylinder:

3.2 Characteristics of the grid

966 nodes, 440 SHB8,
180 QUAD4 (external skin)

3.3 Functionalities tested

Orders

AFFE_MODELE MODELING
SHB8

CALC_MATR_EE% OPTION
RIGI_GEOM
STAT_NON_LINE COMP_ELAS DEFORMATION
GREEN
STAT_NON_LINE EXCIT

TYPE_CHARGE
SUIV

4
Results of modeling A

4.1
Sizes tested and results

The 1st critical load of Euler calculated in "linear elasticity (small displacements) is worth:

Size mode
Reference
:
Aster %différence
(INCA)
1 Pcr
(Pa)
1.27522 1.24 -2.8%

In great displacements, without and with following pressure, the curve pressure-displacement calculated
is as follows:

The reference solution (INCA calculation without following pressure) is compared with the Aster solution in *the following table:*

Dx moment

Dx moment	reference	Aster	%différence
1.00000E01	6.4140000000000D04	6.3028161362598D04	1.733
2.00000E01	1.2880000000000D03	1.2633755411986D03	1.912
3.00100E01	1.9420000000000D03	1.9008128106875D03	2.121
4.00000E01	2.6040000000000D03	2.5419377905484D03	2.383
4.99900E01	3.2790000000000D03	3.1900306901409D03	2.713
5.99600E01	3.9710000000000D03	3.8469948518654D03	3.123
6.98700E01	4.6880000000000D03	4.5156706481172D03	3.676
7.96400E01	5.4430000000000D03	5.2005667509131D03	4.454
8.90900E01	6.2560000000000D03	5.9087504926846D06	5.551

---

5 Summary of the results

The results obtained by Code_Aster with modeling SHB8 show the capacity of this element to deal with problems of thin hulls with nongeometrical linearities.
The results with nonfollowing pressure are close to those of the reference.
The results with following pressure, for which one does not have a reference solution, show all in the same way the good taking into account of this assumption in calculations.

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Version
5.0

Titrate:
SSNS501 - Great displacements of a cylindrical panel
Date:
03/05/02
Author (S):
P. MASSIN, F. LEBOUVIER Key
:
V6.05.501-A Page:
1/10

Organization (S): EDF/AMA, DeltaCAD

Handbook of Validation
V6.05 booklet: Non-linear statics of the hulls and the plates
Document: V6.05.501

SSNS501 - Great displacements of a panel
cylindrical simply supported

Summary:

This test represents a calculation of stability of a cylindrical panel simply supported subjected to an

effort
concentrate in its center. The behavior of the panel changes completely and shows points clearly of return in load and displacement "snap-through/snap-back". In this case a piloting in displacement diverge and a piloting in length of arc must be selected.

It makes it possible to validate modeling finite elements COQUE_3D with meshs TRIA7 and QUAD9 in geometrical non-linear quasi-static field in the presence of strong instabilities.

Displacements and the critical load are compared with a numerical reference solution.

Handbook of Validation
V6.05 booklet: Non-linear statics of the hulls and the plates
HT-66/02/001/A

---

1 Problem of reference

1.1 Geometry

Z, W
Z
P
E
F
With
D
H
B
2L
G
C
L = 0.254 m
R = 2.54 m
R
H = 0.00635 m

y, v
= 0.1 rd
y
X, U
X

1.2
Properties of material

The properties of material constituting the plate are:

E = 3. 10275 X 109 Pa
Young modulus
= 0.3
Poisson's ratio

1.3
Boundary conditions and loadings

- C.L panel simply supported on sides EC and GF (null displacements, free rotations)

- One seeks the successive states of balance under a load P imposed on point A.

1.4 Conditions
initial

Without object

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution was obtained with a finite element of hull DKT24 (grid 4x6) with 4 nodes with 6 degrees of freedom per node in Total Lagrangian Formulation. This solution is described in details in [bib2].

2.2
Results of reference

WA
Charge P Charges
WA
Charge P
Charge

WA
Charge P
Charge
(x103m)
(KN)
P/Pmax
(x103m)
(KN)
P/Pmax
(x103m)
(KN)
P/Pmax
0.0 0.000
0.0000

-16.4 0.480 0.8000 -14.0 -0.295 -0.4916
-1.7 0.150
0.2500

-16.7 0.415 0.6916 -14.3 -0.345 -0.5750
-3.5 0.265
0.4416

-16.9 0.350 0.5833 -15.0 -0.370 -0.6166
-4.9 0.345
0.5750

-17.0 0.290 0.4833 -16.1 -0.380 -0.6333
-6.8 0.410
0.6833

-17.1 0.225 0.3750 -17.3 -0.375 -0.6250
-8.4 0.475
0.7916

-17.1 0.150 0.2500 -18.7 -0.350 -0.5833
-9.8 0.520
0.8666

-17.0 0.090 0.1500 -20.3 -0.305 -0.5083
-11.1 0.555 0.9250

-16.8 0.020 0.0333 -21.8 -0.230 -0.3833
-12.2 0.580 0.9666

-16.4 -0.035 -0.0583 -23.5 -0.120 -0.2000
-13.1 0.595 0.9916

-16.0 -0.085 -0.1416 -25.2 0.025 0.0416
-14.0 0.600 1.0000

-15.3 -0.130 -0.2166 -26.8 0.210 0.3500
-14.9 0.585 0.9750

-14.8 -0.155 -0.2583 -28.5 0.445 0.7416
-15.5 0.565 0.9416

-14.2 -0.195
-0.3250

-16.1 0.525 0.8750

-14.0 -0.240
-0.4000

Not limits 1
0,7
Charge |P| (kN)

0,6
0,5
0,4
Not limits 2
0,3
0,2
0,1
0,0
0
2
4
6
8
10 12 14 16 18 20 22 24 26 28 30
-0,1
|W displacement | (mm)
With
-0,2
Not limits 3
-0,3
-0,4
Not limits 4
-0,5

2.3
Uncertainties on the solution

< 2% numerical solution

2.4 References
bibliographical

[1]
HAMMADI Fodil: Formulation and evaluation of finite elements with C° continuity of the geometry for the linear and non-linear analysis of the hulls.
[2]
JAAMEI S.: Study of various Lagrangian formulations for the nonlinear analysis of plates and thin hulls elastoplastic in great displacements and great rotations,
Thesis of doctorate, University of Technology of Compiegne 1986.
Handbook of Validation
V6.05 booklet: Non-linear statics of the hulls and the plates
HT-66/02/001/A

---

3 Modeling With

3.1 Characteristics of modeling

With
Modeling COQUE_3D (TRIA7)
Boundary conditions:
6
D
- Side CD: U = v = W = 0
Conditions of symmetry:
B
- Side AB:
U = = = 0
y
Z
- Side AD: v = = = 0
X
Z
6
A quarter of the plate is modelled.
C
The successive states of balance are
obtained thanks to a method of
piloting by length of arc.
p
In this case, ETA_PILOTAGE = pmax

3.2
Characteristics of the grid

A number of nodes: 241
A number of meshs and type: 72 TRIA7

3.3 Functionalities
tested

Orders Key word
factor
Key word

AFFE_MODELE AFFE
MODELISATION=' COQUE_3D'

AFFE_CARA_ELEM HULL
THICK

A_CIS=0.833
COEF_RIGI_DRZ = 0.001
AFFE_CHAR_MECA FORCE_NODALE FZ

STAT_NON_LINE PILOTING
TYPE=' LONG_ARC'

4
Results of modeling A

4.1 Values
tested

Identification Moments
Reference
***Aster** %*
difference
Not limits n°1

DZ
1.03

-0.0140
-0.01322
-5.573
Eta_PILOTAGE 1.03
1.0
0.9729
-2.471
Not limits n°2

DZ
1.78
-0.0171
-0.01696
-0.847
Eta_PILOTAGE 1.78
0.375
0.07513 -75.96
0.250
Not limits n°3

DZ
2.3
-0.0140
-0.01458
4.176
Eta_PILOTAGE 2.3
-0.400
-0.533 19.67
-0.492
Not limits n°4

DZ
2.48
-0.0161
-0.01617
0.452

Eta_PILOTAGE 2.48
-0.633
-0.6442
1.717

4.2 Remarks

The strategy of calculation used breaks up into two stages:

- *calculation in loading imposed to P = 582.N correspondent on 97% of the critical load,*
- *calculation in "imposed displacement": then, one imposes a displacement imposed while using technique length of arc imposed on all the structure (option LONG_ARC in STAT_NON_LINE).*

The use of the technique length of arc makes difficult the definition of the value of reference to to introduce into order TEST_RESU, since these values cannot be imposed. For to define the values of reference, we sought the values of the closest possible DZ those listed in the table of [§2.2] and we deferred the values of the parameter of piloting that one was to obtain for the values of DZ in question.

---

5 Modeling B

5.1 Characteristics of modeling

With
Modeling COQUE_3D (QUAD9)
Boundary conditions:
6
D
- Side CD: U = v = W = 0
Conditions of symmetry:
B
- Side AB:
U = = = 0
y
Z
- Side AD: v = = = 0
X
Z
6
C

5.2 Characteristics of the grid

A number of nodes: 169

A number of meshs and type: 36 QUAD9

5.3 Functionalities tested

Orders Key word factor Key word

AFFE_MODELE AFFE
MODELISATION=' COQUE_3D'

AFFE_CARA_ELEM HULL
THICK

A_CIS=0.833
COEF_RIGI_DRZ = 0.001
AFFE_CHAR_MECA FORCE_NODALE FZ

STAT_NON_LINE PILOTING
TYPE=' LONG_ARC'

6
Results of modeling B

6.1 Values tested

Identification Moments
Reference
***Aster** %*
difference
Not limits n°1

DZ
1.03
-0.0140
-0.01318
-5.886
Eta_PILOTAGE 1.03

1.0
0.9724
-2.760
Not limits n°2

DZ
-0.0171
-0.01702
-0.462
Eta_PILOTAGE
0.375
0.101 -67.69
0.250
Not limits n°3

DZ
-0.0140
-0.01446
3.269
Eta_PILOTAGE
-0.400
-0.558 25.177
-0.492
Not limits n°4

DZ
-0.0161
-0.0161
-0.007
Eta_PILOTAGE
-0.633
-0.640
1.120
Handbook of Validation
V6.05 booklet: Non-linear statics of the hulls and the plates
HT-66/02/001/A

6.2 Remarks

The strategy of calculation used breaks up into two stages:

- *calculation in loading imposed to P = 582.N correspondent on 97% of the critical load,*
- *calculation in imposed displacement: then, one imposes a displacement imposed while using technique length of arc imposed (option LONG_ARC in STAT_NON_LINE).*

The use of the technique length of arc makes difficult the definition of the value of reference to to introduce into order TEST_RESU, since these values cannot be imposed. For to define the values of reference, we sought the values of the closest possible DZ those listed in the table of [§2.2] and we deferred the values of the parameter of piloting that one was to obtain for the values of DZ in question.

Code_Aster ®
Version
5.0

Titrate:
SSNS501 - Great displacements of a cylindrical panel
Date:

7 ***Summary of the results***

Normal displacement at the top of the panel according to the force
800
600
400
200
0
Charge (NR)
0
0,005
0,01
0,015
0,02
-200
-400
-600
Displacement W (m)

Appear 7-a: Normal displacement at the top of the panel according to the force applied. Enlarging around the point limits 1

Appear 7-b: Normal displacement at the top of the panel according to the force applied standardized by its maximum value

The results for the two loads limit 1 and 4 are correct. The maximum error is 2.5% for mesh TRIA3 and of 2.8% for mesh QUAD9. On the other hand, the error on vertical displacement is more important. It is 5.6% for mesh TRIA7 and 5.9% for mesh QUAD9.

The results between the two loads limit 1 and 4 are qualitatively correct. They well are detected points limit 2 and 3. Quantitatively the values of displacements for these points are good with less than 1% for the point limits 2 and to less than 5% for the point limits 3. On the level of the loads corresponding, the load at the point limits 2 is very strongly underestimated (about 70%) and that at the point limits 3 strongly over-estimated (about 20%).

Whatever the mesh, the behavior pre-buckling is correctly evaluated. Pace in postbuckling makes it possible to determine displacements at the points correctly limit 2 and 3. loads obtained are further away from the reference solution. From the point limits 4, one find a good agreement between the reference and our solution.

The coefficient of correction of transverse shearing A_CIS was put at 0.833, corresponding to thick hulls. The value (2500=106xH/L) which should have been taken into account does not allow to carry out calculations, because of a bad conditioning of the matrices of rigidity.

Titrate:
SSNS501 - Great displacements of a cylindrical panel
Date:
03/05/02
Author (S):
***P. MASSIN**, F. LEBOUVIER Key*
:
V6.05.501-A Page:

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Handbook of Validation
V6.05 booklet: Non-linear statics of the hulls and the plates
HT-66/02/001/A

Code_Aster ®
Version
6.5

Titrate:
HPLA100 - Thermoelastic hollow roll

Date:
01/12/03
Author (S):
***P. MASSIN**, F. VOLDOIRE Key*
:
V7.01.100-C Page:

1/34

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.01 booklet: Thermomechanical linear of the axisymmetric systems
V7.01.100 document

HPLA100 - Heavy thermoelastic hollow roll
in uniform rotation

Summary

The purpose of this test is to test the second members corresponding to the effects of gravity, of a dilation
thermics and of acceleration due to a uniform rotation. For modelings C and D (hull 3D), a calculation
thermoelastic chained and a thermoelastoplastic calculation without plastic evolution were carried out.

The analytical solution of reference is described in the document [V7.90.03]. One has the results for modelings:

.

axisymmetric 2D: axisymmetric isoparametric finite elements on meshs QUAD8,
.

axisymmetric hulls: axisymmetric isoparametric finite elements on meshs SEG3 (linear grid of the meridian section),

·

hulls 3D: finite elements MEC3QU9H, MEC3TR7H on meshs QUAD9 and TRIA7, respectively,

·

plates DKT: finite elements plans DKQ, DKT on meshs QUAD4 and TRIA3, respectively. One test also the orthotropic hulls of DEFI_COQU_MULT for two layers of the same material isotropic and key word ELAS_COQU of DEFI_MATERIAU for the assignment of characteristics of homogenized plates.

Handbook of Validation

V7.01 booklet: Thermomechanical linear of the axisymmetric systems

HT-66/03/008/A

1
Problem of reference

1.1 Geometry

Z
IH
Re
Interior ray IH = 19.5 mm
External ray Re = 20.5 mm
Not F
R = 20.0 mm
Thickness
H = 1.0 mm
Height
L = 10.0 mm
R
Z
J
D
C
H
+
R
With
B
F

1.2
Properties of material

The material is homogeneous isotropic, thermoelastic linear, the initial state is virgin. Coefficients are: E =
5 NR mm2 =
=
-6 kg mm3 = -5 °C-
2 10
0 3
810
10
1
.
/
.
.
/
(coefficient of
dilation).

1.3
Boundary conditions and loadings

-2
.
gravity:
G = 10. ms, according to axis OZ
force traction on the higher face: -16010 4
. - NR, is one
traction distributed on [CD]: - 810 4
. - N/mm

.
rotation:
=
-
1
1
. S according to axis OZ

.

thermal dilation:
T () - T
=
+
/ 2 +
-
-
/with:
ref. (
) (T T
S
I)
(T T
S
I) (R
R) H
case 1:
T = 0 5
. °C, T = -0 5
. °C, T
= 0. °C
S
I
ref.

case 2:
T = 01
. °C, T = 01
. °C, T
= 0. °C
S
I
ref.

These fields of temperature are calculated with THER_LINEAIRE, using a stationary calculation on the same grid, but with a plane model in order to have a solution refines in the thickness.

Boundary conditions in displacement (and rotation) being different according to modeling considered, they will be described later on (in the paragraphs relating to modelings).

---

2 Reference solution

2.1 Method of calculation used for the reference solution

To refer to the document [V7.90.03] to have the complete analytical solutions.

The analytical results of reference are:

- *displacements and rotations,*
- *axial stress, generalized efforts (in theory of hulls),*

in skins internal and external on the sections AB and CD.

In axisymmetric 2D, the complete solutions given in [V7.90.03] are such as rz = 0 where R and Z are the directions radial and axial cylinder, respectively. For the loadings of rotation uniform and of thermal dilation, the boundary conditions are selected so that them solutions do not depend on Z (there is in particular zz = 0).

For the hulls, with boundary conditions equivalent, rotation around the axis orthoradial is null for the loadings of uniform rotation and thermal dilation, which is not not the case of the loading of gravity where rotation is constant (the cylinder formats then conical). On the other hand in all the cases, the transverse distortion is null; thus theories of Coil-Kirchhoff and those of Hencky-Mindlin provide the same reference solution.

---

3 Modeling With

3.1 Characteristics of modeling

Finite elements 2D axisymmetric

y
D J C
10
0
WITH F B
X
19.5
20.5

The discretized geometry is represented above:

Edge
group_no

BC BC
DA DA
LOW AB
CD HIGH

3.2
Characteristics of the grid

The grid is regular: 4 elements in the height, 8 in the thickness.

A number of nodes: 121

A number of meshs and type: 32 QUAD8

3.3
Boundary conditions in displacement

3.3.1 Gravity

Displacement DY is blocked at the point F alone.

3.3.2 Rotation

Displacement DY is blocked on sides [AB] (GROUP_NO: LOW) and on [CD] (GROUP_NO: HIGH).

3.3.3 Thermal case of dilation n°1

Displacement DY is blocked on all the structure.

3.3.4 Thermal case of dilation n°2

Displacement DY is blocked on sides [AB] (GROUP_NO: LOW) and [CD] (GROUP_NO: HIGH).

3.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
"AXIS"
AFFE_CHAR_MECA GRAVITY

ROTATION
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER

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4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the N78 node
-2.34000 10-8
-2.339999 10-8 -
Displacement DY of the N120 node
-1.185 10-9
-1.184999 10-9 -
Displacement DY of the N13 node
1.2150 10-9
1.214999 10-9 -
Axial stress Siyy with the node N78 (M13)
8.0000 10-4
7.9999 10-4 -
Uniform rotation - centrifugal force

Displacement DX of the N120 node
-2.94240 10-7
2.942374 10-7 0.001
Displacement DX of the N13 node
2.88010 10-7
2.880065 10-7 0.001
Axial stress Siyy with the node N120 (M1)
9.94880 10-4
9.948902 10-4 0.001
Axial stress Siyy with the node N13 (M32)
9.26310 10-4
9.263187 10-4 0.001

Dilation case 1

Displacement DX of the N120 node
1.056145 10-6
1.05625 10-6
0.01
Displacement DX of the N13 node
1.110317 10-6
1.1104166 10-6
0.009
Axial stress Siyy with the node N120 (M1)
1.4321427
1.4321429
-
Dilation case 2

Displacement DX of the N120 node
2.53500 10-5
2.5349999 10-5
-
Axial stress Siyy with the node N120 (M1)
-2.00000 10-1
-1.99999 10-1 -

---

5 Modeling B

5.1 Characteristics of modeling

Elements of axisymmetric hull

y
10
J
5
H
F
0
X
20

The discretized geometry is represented above. One chooses the theory of hulls of Coils-Kirchhoff (for that one takes a transverse coefficient of shearing of 106). One neglects the correction of metric in the thickness. The thickness is: 1 Misters.

node
group_no
J GRNO13
H GRNO14
F GRNO6

5.2 Characteristics of the grid

A number of nodes: 21

A number of meshs and type: 10 SEG3

5.3

Boundary conditions in displacement and rotation

5.3.1 Gravity

Displacement DY is blocked at the point F alone (GRNO6).

5.3.2 Rotation

***Displacement DY is blocked at the point F (GRNO6) at the point J (GRNO13).
Rotation around axis Z is null in these two points.***

5.3.3 Thermal case of dilation n°1

Displacement DY as well as rotation around axis Z. are blocked on all the structure (GROUP_NO: GRNO15)

5.3.4 Thermal case of dilation n°2

Displacement DY is blocked at the point F (GROUP_NO: GRNO6) and at the point J (GROUP_NO: GRNO13). Rotation around axis Z is null on the same groups of nodes.

***5.4 Functionalities
tested***

Orders

AFFE_MODELE AFFE MODELING
“COQUE_AXIS”
AFFE_CARA_ELEM HULL
THICK

A_CIS

MODI_METRIQUE
“NOT”
AFFE_CHAR_MECA GRAVITY

ROTATION
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM

6
Results of modeling B

6.1 Values
tested

Foot-note:

Index X corresponds here to the first direction of the local reference mark of the element.

Identification Reference
Aster %
difference
Gravity

Displacement DX of the node J
-2.40000 10-8 -2.400016
10-8 -

Displacement DY of the node H
5.00000 10-9
5.00000 10-9 -
Rotation DRZ of the node H
2.40000 10-9 2.400015
10-9 -
Normal effort Nxx, M10 mesh, node J
8.00000 10-4
8.00000 10-4
-
Axial stress Sixx, internal skin,
8.00000 10-4
8.00000 10-4 -
net M10, node J

Rotation - centrifugal force

Displacement DX of the node F
2.91200 10-7
2.91201 10-7
-
Normal effort Nxx, M1 mesh, node F
9.60000 10-4
9.60005 10-4
-
Axial stress Sixx, internal skin,
9.60000 10-4 9.600013
10-4 -
net M1, node F

Dilation case 1

Moment Mxx, M1 mesh, node F
-2.38095 10-1
-2.38095 10-1
-
Axial stress Sixx, internal skin,

1.428571
1.428571
-
net M1, node F

Dilation case 2

Displacement DX of the node F
26.0000 10-6
26.0001 10-6
-
Normal effort Nxx, M1 mesh, node F
-2.00000 10-1
-1.99999 10-1
-
Axial stress Sixx, internal skin,
-2.00000 10-1 -1.99999
10-1 -
net M1, node F

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7 Modeling
C

7.1
Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of hull 3D: QUAD9
Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

not node
K NO72
L NO1
MR. NO33
NR NO39
P NO186
Q NO190

The factor of correction of shearing A_CIS is worth 5/6 (theory of hulls of Reissner).

7.2
Characteristics of the grid

A number of external nodes: 121

A number of meshs and types: 32 QUAD9 + 8 SEG3

7.3
Boundary conditions in displacement and rotation

7.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

7.3.2 Rotation

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

7.3.3 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of

nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

7.3.4 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

7.4 Functionalities tested

Orders

AFFE_MODELE AFFE MODELING
“COQUE_3D”
AFFE_CARA_ELEM HULL
THICK
A_CIS
AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
ROTATION
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM
STAT_NON_LINE COMP_INCR

Handbook of Validation

8
Results of modeling C

8.1 Values
tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 -2.32821
10-8 2.991
Displacement DY of the point NR
-2.40000 10-8 -2.32709
10-8 -3.038
Displacement DZ of the point P
5.00000 10-9 4.99919
10-9 -0.016
Displacement DZ of the point Q
5.00000 10-9 4.99911

10-9
-0.018
Rotation DRY of the point P
2.40000 10-9 2.44618
10-9
1.924
Rotation DRX of the point Q
2.40000 10-9 2.44574
10-9
1.906
Normal effort Nyy, M4 mesh, not K
8.00000 10-4 8.00157
10-4
0.020
Normal effort Nyy, M32 mesh, not NR
8.00000 10-4 8.00184
10-4 0.023
Axial stress Siyy, internal skin,

net M4, not K
8.00000 10-4 8.20512
10-4 2.564
Axial stress Siyy, internal skin,

net M32, not NR
8.00000 10-4 8.20459
10-4 2.557
Rotation centrifugal force

Displacement DX of the point L
2.91200 10-7
2.91181 10-7
-0.006
Displacement DY of the point M
2.91200 10-7
2.91073 10-7
-0.044
Normal effort Nyy, M1 mesh, not L
9.60000 10-4

9.60002 10-4
0.000
Normal effort Nyy, M29 mesh, not M
9.60000 10-4
9.60004 10-4
0.000
Axial stress Siyy, internal skin,

net M1, not L
9.84600 10-4
9.83997 10-4
-0.061
Axial stress Siyy, internal skin,

net M29, not M
9.84600 10-4 9.83961
10-4 -0.065
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1
-2.38096 10-1
0.000
Myy moment, M29 mesh, not M
-2.38095 10-1 -2.38096
10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
1.428571
1.42858
0.000
Axial stress Siyy, internal skin,

net M29, not M

1.428571
1.42858
0.000
Dilation case 2

Displacement DX of the point L
25.9946 10-6
25.9907 10-6
-0.015
Displacement DY of the point M
25.9946 10-6 25.9989
10-6
0.016
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M29 mesh, not M
-2.00000 10-1
-2.00000 10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
-1.97800 10-1
-1.97862 10-1
0.031
Axial stress Siyy, internal skin,

net M29, not M
-2.97800 10-1 -1.97864
10-1 0.032

8.2 Remarks

Satisfactory and identical results for calculations with MECA_STATIQUE and STAT_NON_LINE.

Handbook of Validation

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9 Modeling D

9.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of hull 3D: TRIA7
Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

not node
K NO72
L NO1
MR. NO33
NR NO39
P NO186

Q NO190

The factor of correction of shearing A_CIS is worth 5/6 (theory of Reissner hulls).

9.2
Characteristics of the grid

A number of external nodes: 153

A number of meshs and types: 64 TRIA7 + 8 SEG3

9.3
Boundary conditions in displacement and rotation

9.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

9.3.2 Rotation

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

9.3.3 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

9.3.4 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

9.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
"COQUE_3D"
AFFE_CARA_ELEM HULL
THICK

A_CIS

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
ROTATION
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM
STAT_NON_LINE COMP_INCR

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10 Results of modeling D

10.1 Values tested

Identification Reference
Aster %

difference
Gravity

Displacement DX of the point K
-2.40000 10-8 -2.32610
10-8 -3.079
Displacement DY of the point NR
-2.40000 10-8
-2.33110 10-8 -2.871
Displacement DZ of the point P
5.00000 10-9
4.99874 10-9 -0.025
Displacement DZ of the point Q
5.00000 10-9 4.99940
10-9
-0.012
Rotation DRY of the point P
2.40000 10-9 2.43797
10-9
1.582
Rotation DRX of the point Q
2.40000 10-9
2.43962 10-9
1.651
Normal effort Nyy, M60 mesh, not K
8.00000 10-4 7.99979
10-4
-0.003
Normal effort Nyy, M56 mesh, not NR
8.00000 10-4
8.00431 10-4 0.054
Axial stress Siyy, internal skin,

net M60, not K
8.00000 10-4
8.20178 10-4 2.522
Axial stress Siyy, internal skin,

net M56, not NR

8.00000 10-4 8.19909
10-4 2.489
Rotation centrifugal force

Displacement DX of the point L
2.91200 10-7
2.91170 10-7
-0.010
Displacement DY of the point M
2.91200 10-7
2.91091 10-7
-0.037
Normal effort Nyy, M25 mesh, not L
9.60000 10-4
9.60207 10-4
0.022
Normal effort Nyy, M53 mesh, not M
9.60000 10-4
9.59935 10-4
-0.007
Axial stress Siyy, internal skin,

net M25, not L
9.84600 10-4
9.84011 10-4
-0.060
Axial stress Siyy, internal skin,

net M53, not M
9.84600 10-4 9.84124
10-4 -0.048
Dilation case 1

Myy moment, M25 mesh, not L
-2.38095 10-1
-2.38097 10-1
0.001

Myy moment, M53 mesh, not M
-2.38095 10-1 -2.38096
10-1
0.000
Axial stress Siyy, internal skin,

net M25, not L
1.428571
1.42858
0.000
Axial stress Siyy, internal skin,

net M53 not M
1.428571
1.42858
0.000
Dilation case 2

Displacement DX of the point L
26.0000 10-6
25.9928 10-6
-0.028
Displacement DY of the point M
26.0000 10-6 25.9969
10-6
-0.012
Normal effort Nyy, M25 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M53 mesh, not M
-2.00000 10-1
-1.99999 10-1
0.000
Axial stress Siyy, internal skin,

net M25, not L

-1.97800 10-1
-1.97821 10-1
0.011
Axial stress Siyy, internal skin,

net M53, not M
-1.97800 10-1 -1.97898
10-1 0.050

10.2 Remarks

Satisfactory and identical results for calculations with MECA_STATIQUE and STAT_NON_LINE.

Handbook of Validation
V7.01 booklet: Thermomechanical linear of the axisymmetric systems
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11 Modeling
E

11.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of plate DKQ: QUAD4
Z

NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

not
node
K NO160
L NO203
MR. NO11
NR NO1
P NO226
Q NO6

11.2 Characteristics of the grid

A number of nodes: 231

A number of meshs and types: 200 QUAD4 + 80 SEG2

11.3 Boundary conditions in displacement and rotation

11.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

11.3.2 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

11.3.3 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

11.4 Functionalities tested

Orders

AFFE_MODELE AFFE MODELING
“DKT”

AFFE_CARA_ELEM HULL
THICK

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM
STAT_NON_LINE COMP_INCR

12 Results of modeling E

12.1 Values tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 -2.37341
10-8 -1.108
Displacement DY of the point NR
-2.40000 10-8
-2.37341 10-8 -1.108
Displacement DZ of the point P
5.00000 10-9
5.00883 10-9 0.177
Displacement DZ of the point Q
5.00000 10-9 5.00883
10-9
0.177
Rotation DRY of the point P
2.40000 10-9 2.36136
10-9
-1.610
Rotation DRX of the point Q
2.40000 10-9
2.36136 10-9
-1.610
Normal effort Nyy, M181 mesh, not K
8.00000 10-4 7.56157
10-4
-5.480
Normal effort Nyy, M200 mesh, not NR
8.00000 10-4
7.56157 10-4 -5.480
Axial stress Siyy, internal skin,

net M181, not K
8.00000 10-4
7.56157 10-4 -5.480
Axial stress Siyy, internal skin,

net M200, not NR
8.00000 10-4 7.56157

10-4 -5.480
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1
-2.38095 10-1
0.000
Myy moment, M20 mesh, not M
-2.38095 10-1 -2.38095
10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
1.428571
1.428571
0.000
Axial stress Siyy, internal skin,

net M20, not M
1.428571
1.428571
0.000
Dilation case 2

Displacement DX of the point L
26.0000 10-6
26.0000 10-6
0.000
Displacement DY of the point M
26.0000 10-6 26.0000
10-6
0.000
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000

Normal effort Nyy, M20 mesh, not M
-2.00000 10-1
-2.00000 10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
-2.00000 10-1
-2.00000 10-1
0.000
Axial stress Siyy, internal skin,

net M20, not M
-2.00000 10-1 -2.00000
10-1 0.000

13 Modeling
F

13.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of plate DKT: TRIA3
Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

not
node
K NO1
L NO11
MR. NO161
NR NO227
P NO6
Q NO215

13.2 Characteristics of the grid

A number of nodes: 231

A number of meshs and type: 400 TRIA3 + 80 SEG2

13.3 Boundary conditions in displacement and rotation

13.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

13.3.2 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of

nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

13.3.3 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

13.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
"DKT"
AFFE_CARA_ELEM HULL
THICK

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM
STAT_NON_LINE COMP_INCR

14 Results of modeling F

14.1 Values
tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 -2.32796
10-8 -3.002
Displacement DY of the point NR
-2.40000 10-8
-2.32796 10-8 -3.002
Displacement DZ of the point P
5.00000 10-9
5.02845 10-9 0.517
Displacement DZ of the point Q
5.00000 10-9
5.02845 10-9
0.517
Rotation DRY of the point P
2.40000 10-9 2.28975
10-9
-4.594
Rotation DRX of the point Q
2.40000 10-9
2.28975 10-9
-4.594
Normal effort Nyy, M362 mesh, not K
8.00000 10-4 7.61457
10-4
-4.818
Normal effort Nyy, M400 mesh, not NR
8.00000 10-4
7.61457 10-4 -4.818
Axial stress Siyy, internal skin,

net M362, not K
8.00000 10-4
7.61007 10-4 4.874

Axial stress Siyy, internal skin,

net M400, not NR
8.00000 10-4 7.61007
10-4 4.874
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1
-2.38095 10-1
0.000
Myy moment, M39 mesh, not M
-2.38095 10-1 -2.38095
10-1
0.000
Axial stress Sixx, internal skin,

net M1, not L
1.428571
1.428571
0.000
Axial stress Sixx, internal skin,

net M39 not M
1.428571
1.428571
0.000
Dilation case 2

Displacement DX of the point L
26.0000 10-6
25.9999 10-6
0.000
Displacement DY of the point M
26.0000 10-6 25.9999
10-6

0.000
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M39 mesh, not M
-2.00000 10-1
-1.99999 10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
-2.00000 10-1
-2.00000 10-1
0.000
Axial stress Siyy, internal skin,

net M39, not M
-2.00000 10-1 -2.00000
10-1 0.000

15 Modeling
G

15.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of plate DKT: TRIA3. Modeling uses a double-layered plate of which them characteristics of orthotropism are those of material defined in the §1.2.

Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

not
node
K NO1
L NO11
MR. NO161
NR NO227
P NO6
Q NO215

15.2 Characteristics of the grid

A number of nodes: 231

A number of meshs and types: 400 TRIA3 + 80 SEG2

15.3 Boundary conditions in displacement and rotation

15.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

15.3.2 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

15.3.3 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

15.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
“DKT”
AFFE_CARA_ELEM HULL
THICK

DEFI_MATERIAU ELAS_ORTH

DEFI_COQU_MULT
THICK

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM

---

16 Results of modeling G

16.1 Values tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 2.32796
10-8 -3.002
Displacement DY of the point NR
-2.40000 10-8 -2.32796
10-8 -3.002
Displacement DZ of the point P
5.0 10-9 5.02845
10-9 0.517
Displacement DZ of the point Q
5.0 10-9 5.02845
10-9
0.517
Rotation DRY of the point P
2.40000 10-9 2.28975
10-9
-4.594
Rotation DRX of the point Q
2.40000 10-9
2.28975 10-9
-4.594
Normal effort Nyy, M362 mesh, not K
8.00000 10-4 7.61457
10-4
-4.818
Normal effort Nyy, M400 mesh, not NR
8.00000 10-4
7.61457 10-4 -4.818
Axial stress Siyy, internal skin,

net M362, not K
8.00000 10-4
7.61007 10-4 4.874
Axial stress Siyy, internal skin,

net M400, not NR
8.00000 10-4 7.61007
10-4 4.874
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1
-2.38095 10-1
0.000
Myy moment, M39 mesh, not M
-2.38095 10-1 -2.38095
10-1
0.000
Axial stress Sixx, internal skin,

net M1, not L
1.428571
1.428571
0.000
Axial stress Sixx, external skin,

net M1, not L
-1.428571
-1.428571
0.000
Axial stress Sixx, internal skin,

net M39 not M
1.428571
1.428571
0.000
Axial stress Sixx, external skin,

net M39 not M
-1.428571
-1.428571
0.000
Dilation case 2

Displacement DX of the point L
26.0 10-6
25.9999 10-6
0.000
Displacement DY of the point M
26.0 10-6 25.9999
10-6
0.000
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M39 mesh, not M
-2.00000 10-1
-1.99999 10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
-2.00000 10-1
-2.00000 10-1
0.000
Axial stress Siyy, internal skin,

net M39, not M
-2.00000 10-1 -2.00000
10-1 0.000

HPLA100 - Thermoelastic hollow roll

Date:
01/12/03
Author (S):
P. MASSIN, F. VOLDOIRE Key
:
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17 Modeling H

17.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of plate DKQ: QUAD4. Modeling uses a double-layered plate of which them characteristics of orthotropism are those of material defined in the §1.2.

Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

Not
node
K NO160
L NO203
MR. NO11
NR NO1
P NO226
Q NO6

17.2 Characteristics of the grid

A number of external nodes: 231

A number of meshs and types: 200 QUAD4 + 80 SEG2

17.3 Boundary conditions in displacement and rotation

17.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

17.3.2 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

17.3.3 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

17.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
"DKT"
AFFE_CARA_ELEM HULL
THICK

DEFI_MATERIAU ELAS_ORTH

DEFI_COQU_MULT
THICK

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM

18 Results of modeling H

18.1 Values tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 -2.37341
10-8 -1.108
Displacement DY of the point NR
-2.40000 10-8
-2.37341 10-8 -1.108
Displacement DZ of the point P
5.00000 10-9
5.00883 10-9 0.177
Displacement DZ of the point Q
5.00000 10-9 5.00883
10-9
0.177
Rotation DRY of the point P
2.40000 10-9 2.36136

10-9
-1.610
Rotation DRX of the point Q
2.40000 10-9
2.36136 10-9
-1.610
Normal effort Nyy, M181 mesh, not K
8.00000 10-4 7.56157
10-4
-5.480
Normal effort Nyy, M200 mesh, not NR
8.00000 10-4
7.56157 10-4 -5.480
Axial stress Siyy, internal skin,

net M181, not K
8.00000 10-4
7.56157 10-4 -5.480
Axial stress Siyy, internal skin,

net M200, not NR
8.00000 10-4 7.56157
10-4 -5.480
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1
-2.38095 10-1
0.000
Myy moment, M20 mesh, not M
-2.38095 10-1 -2.38095
10-1
0.000
Axial stress Siyy, internal skin,

net M1, not L
1.428571

1.428571
0.000
Axial stress Siyy, external skin,

net M1, not L
-1.428571
-1.428571
0.000
Axial stress Siyy, internal skin,

net M20, not M
1.428571
1.428571
0.000
Axial stress Siyy, external skin,

net M20, not M
-1.428571
-1.428571
0.000
Dilation case 2

Displacement DX of the point L
26.0000 10-6
26.0000 10-6
0.000
Displacement DY of the point M
26.0000 10-6 26.0000
10-6
0.000
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M20 mesh, not M
-2.00000 10-1
-2.00000 10-1

0.000
Axial stress Siyy, internal skin,

net M1, not L
-2.00000 10-1
-2.00000 10-1
0.000
Axial stress Siyy, internal skin,

net M20, not M
-2.00000 10-1 -2.00000
10-1 0.000

19 Modeling
I

19.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of plate DKQ: QUAD4. Assignment of characteristics of homogenized plates corresponding to material of the §1.2.

Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

Not
node
K NO160
L NO203
MR. NO11
NR NO1
P NO226
Q NO6

19.2 Characteristics of the grid

A number of external nodes: 231

A number of meshs and types: 200 QUAD4 + 80 SEG2

19.3 Boundary conditions in displacement and rotation

19.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

19.3.2 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

19.3.3 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

19.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
“DKT”
AFFE_CARA_ELEM HULL
THICK

DEFI_MATERIAU ELAS_COQU

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM

---

20 Results of modeling I

20.1 Values

tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 -2.37341
10-8 -1.108
Displacement DY of the point NR
-2.40000 10-8
-2.37341 10-8 -1.108
Displacement DZ of the point P
5.00000 10-9
5.00883 10-9 0.177
Displacement DZ of the point Q
5.00000 10-9 5.00883
10-9
0.177
Rotation DRY of the point P
2.40000 10-9 2.36136
10-9
-1.610
Rotation DRX of the point Q
2.40000 10-9
2.36136 10-9
-1.610
Normal effort Nyy, M181 mesh, not K
8.00000 10-4 7.56157
10-4
-5.480
Normal effort Nyy, M200 mesh, not NR
8.00000 10-4
7.56157 10-4 -5.480
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1

-2.38095 10-1
0.000
Myy moment, M20 mesh, not M
-2.38095 10-1 -2.38095
10-1
0.000
Dilation case 2

Displacement DX of the point L
26.0000 10-6
26.0000 10-6
0.000
Displacement DY of the point M
26.0000 10-6 26.0000
10-6
0.000
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M20 mesh, not M
-2.00000 10-1
-2.00000 10-1
0.000

20.2 Remarks

The local constraints are not calculated since the characteristics material of plate are supposed to come from a calculation of homogenisation.

Handbook of Validation
V7.01 booklet: Thermomechanical linear of the axisymmetric systems
HT-66/03/008/A

Code_Aster ®
Version
6.5

Titrate:
HPLA100 - Thermoelastic hollow roll

21 Modeling J

21.1 Characteristics of modeling

Modeling of a quarter of cylinder.

Elements of plate DKT: TRIA3. Assignment of characteristics of homogenized plates corresponding to material of the §1.2.

Z
NR
K
Q
P
y
M
L
X

The discretized geometry is represented above.

not
node
K NO1
L NO11
MR. NO161
NR NO227
P NO6
Q NO215

21.2 Characteristics of the grid

A number of nodes: 231

A number of meshs and types: 400 TRIA3 + 80 SEG2

21.3 Boundary conditions in displacement and rotation

21.3.1 Gravity

Displacement DZ is blocked on the group of nodes LM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.

21.3.2 Thermal case of dilation n°1

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

21.3.3 Thermal case of dilation n°2

Displacement DZ as well as rotations around axes X and Y are blocked on the groups of nodes KNSANSKN and LMSANSLM.
Displacement DY as well as rotations around axes X and Z are blocked on the group of nodes KL.
Displacement DX as well as rotations around the axes Y and Z are blocked on the group of nodes MN.
Displacement DZ as well as rotation around the axis Y are blocked on the group of nodes KETL.
Displacement DZ as well as rotation around axis X are blocked on the group of nodes METN.

21.4 Functionalities tested

Orders

AFFE_MODELE AFFE
MODELING
"DKT"
AFFE_CARA_ELEM HULL
THICK

DEFI_MATERIAU ELAS_COQU

AFFE_CHAR_MECA GRAVITY

FORCE_ARETE
TEMP_CALCULEE
MODEL MECA_STATIQUE

CHAM_MATER
CARA_ELEM
Handbook of Validation
V7.01 booklet: Thermomechanical linear of the axisymmetric systems
HT-66/03/008/A

---

22 Results of modeling J

22.1 Values tested

Identification Reference
Aster %
difference
Gravity

Displacement DX of the point K
-2.40000 10-8 2.32796
10-8 -3.002
Displacement DY of the point NR
-2.40000 10-8 -2.32796
10-8 -3.002
Displacement DZ of the point P
5.0 10-9 5.02845
10-9 0.517
Displacement DZ of the point Q
5.0 10-9 5.02845
10-9
0.517
Rotation DRY of the point P
2.40000 10-9 2.28975

10-9
-4.594
Rotation DRX of the point Q
2.40000 10-9
2.28975 10-9
-4.594
Normal effort Nyy, M362 mesh, not K
8.00000 10-4 7.61457
10-4
-4.818
Normal effort Nyy, M400 mesh, not NR
8.00000 10-4
7.61457 10-4 -4.818
Dilation case 1

Myy moment, M1 mesh, not L
-2.38095 10-1
-2.38095 10-1
0.000
Myy moment, M39 mesh, not M
-2.38095 10-1 -2.38095
10-1
0.000
Dilation case 2

Displacement DX of the point L
26.0 10-6
25.9999 10-6
0.000
Displacement DY of the point M
26.0 10-6 25.9999
10-6
0.000
Normal effort Nyy, M1 mesh, not L
-2.00000 10-1
-2.00000 10-1
0.000
Normal effort Nyy, M39 mesh, not M
-2.00000 10-1
-1.99999 10-1

0.000

22.2 Remarks

The local constraints are not calculated since the characteristics material of plate are supposed to come from a calculation of homogenisation.

---

23 Summary of the results

The very good results obtained for modelings A and B are explained by the fact why the solutions of reference belong to the space generated by the selected finite elements. Only remain them numerical rounding errors.

Satisfactory results were obtained for modelings of plates and hulls in space C, D, E, F, G, H, I and J. For these last, a chained thermoelastic calculation was carried out. The results with modeling DKT (E, F, G, H, I and J) show that the elements quadrangle have a better behavior than the elements triangle. It is necessary to have a discretization sufficient fine with these plane elements in order to be able to model the geometry correctly circular of the cylindrical hull. Indeed, to discretize the geometry of the cylinder by plane facets or parabolic is not in conformity and induces a parasitic inflection which decreases with the smoothness of grid.

Thus a multiplication of the number of elements by two on the height of the structure makes fall the maximum error relating of 5,48% (case presented here) to 2,8%. Results with modeling COQUE_3D (C and D) are very good except for gravity with the element triangle.

Code_Aster ®
Version
5.0

Titrate:
HPLA101 - Thermoelastic hollow roll

Date:
19/10/01
Author (S):
I. DEBOST Key
:
V7.01.101-A Page:
1/6

Organization (S): EDF/MTI/MNN

Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear of the structures
axisymmetric
V7.01.101 document

HPLA101 - Thermoelastic hollow roll.
Derived compared to a variation from field

Summary

The purpose of this test is to test calculations of derived from the temperature, displacements and the constraints by
report/ratio with a variation of field (variation of the ray interns tube), under thermal dilation.

The analytical solution of reference for the thermomechanical fields is described in the document [V7.90.03]. The derivative are calculated by Mathematica. One has the results for modeling following:

.
axisymmetric 2D: isoparametric finite elements axisymmetric QUAD8.
Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear of axisymmetric structures HI-75/01/010/A

1
Problem of reference

1.1 Geometry

Z

IH
Re
Interior ray IH = 19.5 mm
External ray Re = 20.5 mm
Not F
R = 20.0 mm
Thickness
H = 1.0 mm
Height
L = 10.0 mm
R
Z
J
D
C
H
+
R
With
B
F

1.2
Properties of material

The material is homogeneous isotropic, thermoelastic linear, the initial state is virgin. Coefficients of thermoelasticity are: E =
5 NR mm2 =
=
=
= -5 °C-
2 10
0 3
1
0
10
1
.
/
.

(dilation coefficient).

1.3
Boundary conditions and loadings

Thermal dilation: T (R) - T
= 0 5
. (T + T) + 2. (T + T) (R - R)/H
ref.
E
I
E
I

with:

T = 0 5
. °C, T = -0 5
. °C, T
= 0. °C
E
I
ref.

where

1
R - R
T (R) = (T + T) +
(T - T
I
E
E
I)
2
H

These fields of temperature are calculated with THER_LINEAIRE, using a stationary calculation on the same grid, but with a plane model in order to have a solution refines in the thickness.

Vertical displacements are blocked on all the structure.

2 Reference solution

2.1 Method of calculation used for the reference solution

To refer to the document [V7.90.03].

The analytical results of reference are:

- *temperatures,*
- *displacements,*
- *axial stress.*

One deduces the derivative from it from the temperature, displacements and axial stresses by report/ ratio
with a variation of IH (with Mathematica) in the thickness of the cylinder.

Code_Aster ®
Version
5.0

Titrate:

HPLA101 - Thermoelastic hollow roll

Date:
19/10/01
Author (S):
I. DEBOST Key
:
V7.01.101-A Page:
4/6

3 Modeling
With

3.1
Characteristics of modeling

Finite elements 2D axisymmetric

D J
10
C
0
WITH F B
X
19.5
20.5

The discretized geometry is represented above:

Edge
group_no
BC BC
DA DA
LOW AB
CD HIGH

3.2
Characteristics of the grid

The grid is regular: 4 elements in the height, 8 in the thickness.

A number of nodes: 121

A number of meshs and type: 32 QUAD8

3.3 Functionalities
tested

Orders

AFFE_MODELE AFFE
MODELING
“AXIS”
AFFE_CHAR_MECA TEMP_CALCULEE

MODEL MECA_STATIQUE

CHAM_MATER
SENSITIVITY
CALC_THETA
THETA_BANDE
OPTION: “BAND”

THER_LINEAIRE SENSITIVITY

CALC_ELEM SENSITIVITY

CALC_NO OPTION
:
“DETE_NOEU_DLTE”

“DEDE_NOEU_DLDE”

“DESI_NOEU_DLSI”

Titrate:

HPLA101 - Thermoelastic hollow roll

Date:
19/10/01
Author (S):
I. DEBOST Key
:
V7.01.101-A Page:
5/6

4
Results of modeling A

4.1 Values
tested

Identification

Reference
Precision
Aster
% difference
Derived from T compared to IH in A (N120): 1
10-3 -1
1.07
10-12

F (N69):
-0.5
10-3 -0.5 1.78
10-13
Derived from DX compared to IH in a:
8.2804 10-6 10-3 8.2792
10-6 4.05
10-5

F:
1.1902 10-6 10-3 1.1903
10-6 -2.46
10-4
Derived from Siyy compared to IH out of F:
1.42491

10-3 1.42493
-2.70
10-4

4.2 Remarks

Good results.
The derivative of the constraints compared to a variation of field in the zone close to the ray intern are very sensitive to the refinement of the grid.

4.3 Parameters of execution

Version: 5.04.20

Machine: SGI 02000 claster

Obstruction memory: 64 Mo
Time CPU To use: 6.94 seconds

---

5 Summary of the results

One obtains good results for the derivative eulériennes of the temperature and displacements compared to a variation of field. For the derivative of the constraints, one needs a very fine grid

radially.

Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear of the structures
axisymmetric
V7.01.310 document

HPLA310 - Biblio_49 Fissures radial external in
a circular bar subjected to a thermal shock

Summary:

This test results from the validation independent of version 3 in breaking process.

It is about a basic static test into axisymmetric under non stationary thermal loading.
behavior of the structure is thermoelastic linear isotropic.

It includes/understands only one axisymmetric modeling.

Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

Z
B
D
R
H
has
C
R
O
With

External annular crack in a semi-infinite cylindrical bar

a/R = 0,5 and H/R 5 will be taken.

has = 1 m,
R = 2 m,
H = 10 Mr.

1.2
Properties of material

The material is thermoelastic linear isotropic.

Young modulus
E = 2E11 Pa
Poisson's ratio
= 0,3
Linear dilation coefficient
= 1E-5 C°1

Thermal conductivity
= 50 W/m.C°
Thermal diffusivity
= /Cp =0,5 m2/s
Coefficient of heat exchange
H = 250 W/m2C°

One will choose H such as Bi = hR/= 10.

1.3
Boundary conditions and loading

Boundary conditions mechanical

UX = Ur = 0 on the axis of revolution R = 0
UY = Uz = 0 on the ligament 0 R has

Null resulting thrust load at the higher edge; one will translate this boundary condition by a unit of (n-1) linear relations UY (1) = UY (2) =… = UY (N) between longitudinal displacements of N nodes of the edge higher (free axial dilation, conservation of the flatness of the cross section bar).

Conditions of unilateral contact on the lip of the crack in order to manage the closing of this one.

Boundary conditions thermal

Heat flux no one on the axis of revolution AB (by symmetry)
Heat flux no one on ligament OA (by symmetry) and on the crack AC.
T
Flow of convection
= (
H T - T at the edge R = R, T indicating the temperature of the external medium.
ext.
)
R
ext.

Thermal loading

*The temperature of the external medium undergoes an instantaneous level Text = T0*H (T) where H (T) is the function*
level-unit of Heaviside. Taking into account the boundary conditions the temperature does not vary in function of Z. One will take T0 = 100 °C in order to obtain the closing of the lip, in the vicinity of the skin
part, at the beginning of the thermal shock.

1.4 Conditions
initial

Mechanical initial conditions

Null displacements, strains and stresses in all points.

Thermal initial conditions

Null initial temperature in any point.

2
Reference solution

2.1
Method of calculation used for the reference solution

Field of temperature:
exact analytical calculation.

Thermomechanical calculation: thermoelastic stress field in the bar not fissured given by an exact analytical expression

displacement of the lips of the crack calculated starting from functions of influence determined numerically by finite elements

factor of intensity of the constraints calculated starting from the surface stresses released along the crack, by using functions weight of the solid unlimited for a distribution of pressure on the lips constant by interval along the ray.

2.2
Results of reference

T

Numbers of Fourier: Fo =
(adimensional time)
R2

hR
Numbers of Biot: Bi = (coefficient of exchange without dimension)

Expression of the temperature according to R and T:

BiJ µ/
0 (
R R

N
)
2

T = T1 2
exp
µ
0 -

.
-

2
2
N
N

=1 (
Fo
µ + Bi
µ
N
) J0 (N)
(
)
where

BiJ µ

μ
μ
0 (
=
N)
J
N 1 (N)

the eigenvalues μn are the solutions of the equation above in which J0 and J1 are them functions of Bessel of first species of order 0 and 1.

The tables below summarize the values of the temperatures (°C) for three particular rays and for three numbers of Fourier:

F0 = 0,001

Ref. (10000 terms)
Aster %
variation
R = 0
3,9968E-12
2,06844E-18
-
R = 1
2,2204E-13

8,94917E-12
-
R = 2
2,79689E+1
2,80013E+1
0,116

F0 = 0,4

Ref. (900 terms)
Aster %
variation
R = 0
1,6230E-1
1,78593E-1
10,04
R = 1
6,2391E+0
6,2555E+0
0,262
R = 2
7,7365E+1
7,73319E+1
-0,044

F0 = 1

Ref. (900 terms)
Aster %
variation
R = 0
9,8644E+1
9,8637E+1
0,006
R = 1
9,9018E+1
9,9013E+1
-0,005
R = 2
9,9835E+1
9,9834E+1
-0,001

Expression of axial stress in the bar not fissured according to R and of T:

2 AND

0

Bi

R
2Bi

2
zz = (

exp - µ Fo J µ
-

J
µ

1 -)

0

N

= 1 µ
N
2
2
N R
2 0

N
+ Bi
J
μ

μ

N

0

N

N

The table below summarizes the values of the constraints zz (Pa) for R = has (bottom of crack) and for
three numbers of Fourier:

Ref. (900 terms)
Aster %
variation
F0 = 0,001
4,584029E+6
4,58508E+6
0,017
F0 = 0,4
6,397099E+7
6,38746E+7
-0,151
F0 = 1
8,200300E+5
8,23974E+5
0,481

Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear

Factor of intensity of the constraints (adimensional) according to the number of Fourier

2.3
Uncertainty on the solution

Lower than 5%.

2.4 References
bibliographical

[1]
J.M. ZHOU, T. TAKASE and Y. IMAI: Opening and closing behavior of year external circular ace due to axisymmetrical heating. Engng.Fract.Mechs., 47, n°4, 559-568, 1994.

Code_Aster ®
Version
6.0

Titrate:
HPLA310 - Biblio_49 Fissures radial external in a circular bar

3 Modeling
With

3.1
Characteristics of modeling

Non stationary thermal calculation precedes mechanical calculation. Two calculations are done using
even grid to avoid the phenomena of smoothing.

Complete grid

Zoom on the point of crack

3.2
Characteristics of the grid

The grid consists of 8651 nodes and 2772 elements, including 2732 elements QUA8 and 40 elements TRI6.

The radial density of the grid is determined by successive tests in order to reduce to 1% the variation between the theoretical solution and the numerical solution, as well from the thermal point of view as thermomechanics, in the case of the bar not fissured.

The height of the half-model is fixed arbitrarily at 5 times ray R. One supposes a priori that the effect limitation of size of the grid in direction Z on the factor of intensity of the constraints is lower than 1%.

An indeformable block, located under the lip, was with a grid in order to manage the contact without induced friction by the closing of the lip.

3.3
Functionalities tested

Orders

MECHANICAL AFFE_MODELE AXIS ALL

AFFE_CHAR_MECA TEMP_CALCULEE

AFFE_CHAR_MECA CONTACT
NORMAL MAIT_ESCL
MECA_STATIQUE

CALC_THETA THETA_2D

CALC_G_THETA OPTION
CALC_G

4
Results of modeling A

4.1 Values tested

Identification Reference Aster % difference

G (Fo = 0,001) (J.m2)
2,3E+2 2,9449E+2*
30
KI (Fo = 0,001) (Pa.m0,5)
7,0E+6 8,0438E6 ***
14
G (Fo = 0,04) (J.m2)
1,0E+4 1,25016E+4*
19
KI (Fo = 0,04) (Pa.m0,5)
4,8E+7 5,24175E7 ***
9
G (Fo = 1) (J.m2)
1,0 1,2104864* 15
KI (Fo = 1) (Pa.m0,5)
4,8E+5 5,1579E+5 ***
7

****** *In the case of axisymmetric calculations, to obtain the total rate of refund, it is necessary to divide it rate of refund obtained with ASTER by Rfissure = has (cf Reference material [R7.02.01] - page18).***

****** Values obtained with the formula of IRWIN in plane deformations, by supposing that KII = 0, and by taking G calculated by ASTER, which does not allow the automatic calculation of KI in axisymmetric.***

4.2 Remarks

To calculate Gref, one uses the formulas of IRWIN in plane deformations:

1 - 2

G
=
K 2 + K 2

ref.
(
, K
I
II
)
E
II = 0

The raised maximum change is 30% on G (Fo = 1), of 14% on KI (Fo = 1).

The maximum relative variation on the temperature in bottom of crack, compared to the analytical solution (summoned on 900 terms), is lower A 1%.

The maximum relative variation on zz in the bar before cracking, compared to the analytical solution summoned on 900 terms, with the site of the later bottom of crack, is lower than 0,5%.

With ASTER, in axisymmetric mode, the stress field obtained is following form:

SIXX
SIYY
SIZZ
SIXY
and the associated constraints are:

SIRR SIZZ SITT SIRZ

To calculate the values of reference, we use the curve in Log/Log (page 5). Precision with reading of the values not being very good, we can estimate that the results on the rate of restitution of energy G are not too far away from the reference.

It should be noted that the rate of refund of energy G is invariable on the crowns of calculation.

5
Summary of the results

With regard to the bar not fissured, the Aster results in temperature and constraint are very close relations of the reference (less than 1% maximum for the temperature and less than 0,5% maximum for the constraints). On the other hand, for the rate of refund of energy, the Aster results are moved away from the reference since we raise a maximum change of 30% for FO = 0,001, with one precision announced of 5% on the reference solution.

Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear of the structures
axisymmetric
V7.01.311 document

HPLA311 - Murakami 11.39. Fissure circular with
center of a sphere subjected to a temperature
uniform on the lips

Summary:

This test results from the validation independent of version 3 in breaking process.

It is about a basic static test into axisymmetric under stationary thermal loading calculated by finite elements on the same grid of a limited field.

The behavior is thermoelastic linear isotropic.

It includes/understands two axisymmetric modelings for which one varies the a/b report/ratio, has being the ray of
the crack interns circular in the horizontal plane xoy and B ray of the sphere.

1
Problem of reference

1.1 Geometry

a: ray of the crack interns circular in the horizontal plane xoy
b: ray of the sphere

the rays must check the condition a/b < 0,5, with B = 2,5E-3

1.2
Properties of material

Young modulus
E = 2 1011 Pa
Poisson's ratio
v = 0,3

linear dilation coefficient = 1,2 10-5 °C-1

1.3
Boundary conditions and loadings

UX = ur = 0 on the axis of revolution X = R = 0
UY = uz = 0 in the horizontal plane Y = Z = 0, apart from the lips has R B

The lips are supposed to be free constraints (not closing partial of the crack).

Null temperature on the surface of the sphere.

Temperature of null reference (temperature to which the thermal deformations are considered null).

Uniform and negative temperature T = - Tf on the lips of the crack, melts of crack included/ understood.
stationary thermal problem (of Dirichlet type) must be solved beforehand by finite elements on the same grid as that intended for mechanical calculation. Tf = 100 °C
Handbook of Validation
V7.01 booklet: Thermomechanical stationary linear
HT-66/02/001/A

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical calculation by transform of Hankel.

2.2
Results of reference

has
= < 0 5
,
B

E Tf

has
K

I = (
·
· F
1 -)

I
F
1 0 6366
,
0 4053 2
,
2 0163 3
,
0 6773 4
,
3 8523 5
,
4 1687 6
,
3 2741 7
,
I =
-
-
+
-
-
+
+

2.3 Uncertainty on the solution

Badly definite, exact if = 0

2.4 References bibliographical

[1]

Y. MURAKAMI: Stress Intensity Factors Handbook, box 11.39, pages 1089-1090. The Society of Materials Science, Japan, Pergamon Press, 1987.

3 Modeling
With

3.1
Characteristics of modeling

Complete grid

Zoom of the point of crack

Code_Aster ®
Version
5.0

Titrate:
HPLA311 - Murakami 11.39. Fissure circular in the center of a sphere
Date:
05/11/02
Author (S):

3.1.1 Definition of the rays of the crowns

For these various cases, we define (table below) the values of the higher rays and inferiors, to specify in order CALC_THETA:

1st crown
2nd crown
3rd crown
4iéme crown
case has
rinf
1.E-6
2.5E-5
5.E-5
7.5E-5
rsup 2.5E-5
5.E-5
7.5E-5
1.E-4
case B
rinf
2.5E-5
2.75E-5 3.E-5 3.25E-5
rsup 2.75E-5
3.E-5
3.25E-5
3.5E-5

3.2
Characteristics of the grid

1756 nodes and 569 elements including 529 QUA8 and 40 TRI6

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
AXIS
ALL

AFFE_CHAR_THER
TEMP_IMPO

AFFE_MODELE
MECHANICS
AXIS
ALL

AFFE_CHAR_MECA
TEMP_CALCULEE

CALC_THETA
THETA_2D

CALC_G_THETA
OPTION
CALC_G

4
Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
G, crown n°1 (J.m2)	1,0231E+2	9,7012E+1*	-5,17
G, crown n°2 (J.m2)	1,0231E+2	1,0051E+2*	-1,75
G, crown n°3 (J.m2)	1,0231E+2	1,0055E+2*	-1,71
G, crown n°4 (J.m2)	1,0231E+2	1,0055E+2*	-1,71

4.2 Remarks

· To calculate Gref, one uses the formulas of IRWIN in plane deformations:

1 - 2

G
=
K 2 + K 2
ref.
(
, K
I
II
)
E
II = 0

· For the low values of the report/ratio a/b, the solution must asymptotically approach reference solution calculated for = 0, is FI = 1, which is then exact (see MURAKAMI 11.23, page 1069).

5 Modeling
B

5.1
Characteristics of modeling

Complete grid

Zoom

Zoom of the point of crack

5.2
Characteristics of the grid

2095 nodes and 680 elements including 640 QUA8 and 40 TRI6

5.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
AXIS
ALL

AFFE_CHAR_THER
TEMP_IMPO

AFFE_MODELE
MECHANICS
AXIS
ALL

AFFE_CHAR_MECA
TEMP_CALCULEE

CALC_THETA
THETA_2D

CALC_G_THETA
OPTION
CALC_G

6
Results of modeling B

6.1 Values tested

Identification	*Reference*	*Aster*	*% difference*
G, crown n°1 (J.m2)	*1,0505E-4**	*1,0387E-4*	*-1,129*
G, crown n°2 (J.m2)	*1,0505E-4**	*1,0388E-4*	*-1,112*
G, crown n°3 (J.m2)	*1,0505E-4**	*1,0388E-4*	*-1,111*
G, crown n°4 (J.m2)	*1,0505E-4**	*1,0387*	*-1,116*

*
In the case of axisymmetric calculations, to obtain the total rate of refund, report/ratio of

variation of energy to the variation of surface of the crack, it is necessary to divide the rate of refund obtained by radian with ASTER by Rfissure (cf Reference material [R7.02.01] - page18).

6.2 Remarks

· To calculate Gref, one uses the formulas of IRWIN in plane deformations:

1 - 2

G
=
K 2 + K 2
ref.
(
, K
I
II
)
E
II = 0

· For the low values of the report/ratio a/b, the solution must asymptotically approach reference solution calculated for = 0, is FI = 1, which is then exact (see MURAKAMI 11.23, page 1069).

· As it is awaited, the relative error on G is the double of that on K.

7
Summary of the results

· The calculation of K and G into axisymmetric in the presence of a stationary thermal loading, gives good results since the maximum change for G is 1,75% (out first crown) for
= 0,4.

· We check that the results of K and G for =0,01 are better than for = 0,4.

HPLP100 - Calculation of the rate of refund of energy of a plate fissured in thermoelasticity

Summary

It is about a test in thermoelasticity for a two-dimensional problem. A rectangular plate is considered fissured and one places oneself on the assumption of the plane deformations.

In modeling A, the rate of refund of energy is calculated in postprocessing by two methods different:

· traditional calculation by the method theta,
· calculation by the formula of IRWIN starting from the coefficients of intensity of constraints KI and KII.

These two calculations are carried out on 4 different crowns of integration. Their interest is to compare them values of G and G (IRWIN) compared to the reference solution and to test the invariance of calculations by report/ratio with the various crowns of integration.

As for modeling B, it is about a functional and data-processing test of calculation of derived from the rate from traditional restitution of energy compared to a variation of field (controlled by a function theta particular). One uses loadings which for the majority are analytical and which intervene only in post-treatment of the calculation of mechanics.
The architecture of the test makes it possible to simulate a finished difference, one can thus distinguish in term from data-processing not-regression, possible external modifications impacting the direct problem and/or its derived.
From a more anecdotic point of view, one can take as a starting point the the sequences of order CREA_CHAMP used in this modeling to build analytical fields and to relocate a grid
Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
HI-23/02/017/A

1
Problem of reference

1.1 Geometry

It is about a fissured rectangular plate (one represents only the quarter of the structure):

Y
I
v
H
U
With
O
C
X
has

Appear 1.1-a: Fissured rectangular plate

Dimensions of this plate are as follows:

Half-height of the plate:
H = 200.0 mm
Half-width of the plate:
I = 100.0 mm
Half-length of the crack: = 50.0 mm have

1.2
Properties of material

Thermal properties:
CP = 0.

= 1.0 W/m°C
Mechanical properties:
E = 200000 MPa

= 0.3

= 5.106/°C

We are on the assumption of the plane deformations

1.3
Boundary conditions and loadings

· Température imposed in X = 0. : T = - 100.0°C
· Température imposed in X = 100: T = + 100.0°C
· Déplacement for A < X < I, Y = 0. : U = 0.
· Déplacement for 0 < X < I, Y = H: U = 0.
· Point fixes for X = 0. , Y = H: U = v = 0.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution results from WILSON and YU [bib1]:

E T
K =
0 F has F
I
= 0154
.
1-

has in mm

E in NR/mm2
KI = 92 0291
.

(1- 2)
In plane deformations, the formula of IRWIN gives: G =
(K2 + K2
I
II)
E

that is to say numerically: G =
-
38535 10 1
.

2.2
Results of reference

The results of reference are those resulting from the reference solution from WILSON and YU [bib1]:

G =
-
38535 10 1
.

KI = 92 0291
.

KII = 0.

2.3 References bibliographical

[1]
The Uses of J-Integrals in thermal stress ace problems - International Newspaper of Fracture (1979) WILSON and YU.
[2]
Qualification complementary to codes INCA/MAYA in linear thermoelasticity. Note technique DRE/STRE/LMA 84/598

3 Modeling With

3.1 Characteristics of modeling

There are 4 crowns defined by order CALC_THETA:

Crown 1:
Rinf = 10.
Rsup = 40.
Crown 2:
Rinf = 15.
Rsup = 45.
Crown 3:

Rinf = 5.
Rsup = 47.
Crown 4:
Rinf = 3.
Rsup = 48.

The bottom of crack is defined by DEFI_FOND_FISS, and for each crown one carries out:

· a traditional calculation of G (option CALC_G of CALC_G_THETA_T),
· a calculation of G by the formula of IRWIN starting from the coefficients of intensity of constraints KI
and KII (option CALC_K_G of CALC_G_THETA_T).

3.2
Characteristics of the grid

A number of nodes: 853
A number of meshs and types: 359 meshs TRIA6 and 27 meshs QUAD8

3.3 Functionalities
tested

Orders

AFFE_MODELE
THERMICS
PLAN
ALL

AFFE_MODELE
MECHANICS
D_PLAN
ALL

THER_LINEAIRE

MECA_STATIQUE

CALC_THETA
THETA_2D

CALC_G_THETA_T

OPTION
CALC_G

CALC_G_THETA_T
OPTION
CALC_K_G

4
Results of modeling A

4.1 Values
tested

The values tested are those of G obtained by the traditional method and that of G_IRWIN obtained by the formula of IRWIN starting from the coefficients of intensity of constraints:

Identification Reference
Aster %
difference
Crown 1 G
3.8535 101
3.6036 101
6.62
Crown 1 G_IRWIN
3.8535 101
3.5964 101

6.67
Crown 2 G
3.8535 101
3.6014 101
6.63
Crown 2 G_IRWIN
3.8535 101
3.5958 101
6.68
Crown 3 G
3.8535 101
3.6018 101
6.65
Crown 3 G_IRWIN
3.8535 101
3.5602 101
6.68
Crown 4 G
3.8535 101
3.6021 101
6.62
Crown 4 G_IRWIN
3.8535 101
3.5962 101
6.67

4.2 Remarks

The numerical values are stable compared to the various crowns of integration and almost identical for the two methods of calculation. Nevertheless the variation with the values of reference is of the order from 6 to 7%, which seems high.

4.3 Parameters of execution

Version: 6.01.19

Machine: SGI CLASTER
System IRIX64 6.5
Obstruction memory: 8 MW

Time CPU To use: 4.22 seconds

---

5 Modeling B

5.1 Characteristics of modeling

It is about a functional and data-processing test of calculation of derived from the rate of refund of energy
traditional compared to a variation of field. This variation is controlled by a function theta
particular, noted S, generated via CALC_THETA with the key word factor THETA_BANDE.
It is pointed out that this two-dimensional function theta decrease cubiquement of the value modulates (word
key MODULATES) with the zero value, between the X-coordinates x1= -50 and x2 = -30 (key words R_INF and R_SUP) of
points delimiting its vertical support. It is null everywhere else (cf [U4.82.03] §3.10).

The crown delimiting the zone of calculation around the bottom of crack (at the point C materializing the origin
reference mark) is modelled by the function theta fissures traditional, noted F, with Rinf= 10 and Rsup= 45.

y

Field F

Field
fissure

S

sensitivity

X

x1= -50
x2= -20
X R
2 inf= 10

Rsup= 45
Appear 5.1-a: Derived from G (F) compared to a variation of field controlled by S

After having built the models Mo and moth in modeling "D_PLAN" and the field theta sensitivity S (thetas), one affects thermal loadings of temperatures type imposed on the edges right and left of the part, for then, to carry out thermal calculation itself. This last use thetas, provided via the key word SENSITIVITY, to calculate the field of temperature and its Lagrangian derivative.
Before carrying out thermoelastic calculation one affects the mechanical loadings. The activation of operator MECA_STATIQUE having been made with the key word SENSITIVITY, one enriches the result by the Lagrangian derivative of displacements.
One adds thereafter analytical loadings which intervene only in postprocessing of calculation of mechanics. They make it possible to calculate two values of G, one with a force of gravity, an internal force and a field of initial deformation (G1), the other with a stress field initial (G2). The first calculation is carried out in small deformations, the second in deformations of Green-Lagrange. The crown of calculation is defined by a call to CALC_THETA with the option THETA_2D.
These tests, purely data-processing and functional, have only little interest from a point of view

mechanics because the majority of the loadings do not check an equation with balance.

Thereafter one reiterates this series of calculations with a grid shifted according to the law S (with
S = -
10 3) which, at a point P of the area of reference makes correspond a point M,

MR. P + S S (P)

By thus simulating a finished difference, one can distinguish in data-processing term of not-regression them
possible external modifications impacting the direct problem and/or its derivative. One tests in the last
G
G

the precision of the values of G arises (F) and of
(F) (F)

obtained, before and
S
S
s=0
after the variation of field.

5.2
Characteristics of the grid

A number of nodes: 853

A number of meshs and types: 359 meshs TRIA6 and 27 meshs QUAD8

5.3 Functionalities tested

Orders

CREA_CHAMP
AFFE
ELNO_NEUT_F

ADZE
NOEU_DEPL_R

ADZE
ELNO_SIEF_R

DISC
ELNO_GEOM_R

EVAL
ELNO_NEUT_R

EXTR
NOEU_GEOM_R

EXTR
NOEU_DEPL_R

MODI_MAILLAGE
DEFORM
TRAN

AFFE_MODELE
THERMICS
PLAN
ALL

AFFE_MODELE
MECHANICS
D_PLAN
ALL

THER_LINEAIRE
SENSITIVITY

MECA_STATIQUE
SENSITIVITY

CALC_THETA
THETA_BANDE

CALC_THETA
THETA_2D

CALC_G_THETA_T
OPTION
CALC_G

CALC_G_THETA_T
OPTION
CALC_DG
CHARGE

CALC_G_THETA_T
OPTION
CALC_DG
ETAT_INIT

CALC_G_THETA_T
OPTION
CALC_DG
GREEN

6
Results of modeling B

6.1 Values tested

One tests the data-processing not-regression of the values of G (on the initial grid and that shifted) and
of its derivative (on the initial grid) compared to the V6.0.19 versions of platforms SGI and SUN.
relative tolerance is thus very severe (10 7%).

Identification
Aster Tolerance
Initial grid
G with GRAVITY,
1.748581514 102
109
FORCE_INTERNE, EPSI_INI
DG with GRAVITY,
4.422828409 101
109
FORCE_INTERNE, EPSI_INI
G with SIGMA_INI + GREEN
3.672692719 101
109
DG with SIGMA_INI + GREEN
1.102553167 102
109
Shifted grid
G with GRAVITY,
1.748585937 102
109
FORCE_INTERNE, EPSI_INI
G with SIGMA_INI + GREEN
3.672692982 101
109

6.2 Remarks

These numerical values vary if the parameters of the functions theta are modified because one uses mechanical loadings in postprocessing of thermoelastic calculation. They thus do not respect of equation to balance. By using only loadings intervening during all the process these instabilities are reduced considerably, while remaining about the percent.

6.3 Parameters of execution

Version: 6.0.19

Machine: SGI CLASTER
System IRIX64 6.5
Obstruction memory: 8 MW
Time CPU To use: 9.6 seconds

Machine: SUN CLI75AS
System SUNOS 5.6
Obstruction memory: 8 MW
Time CPU To use: 25.6 seconds

7 Summaries of the results

At the time of the first modeling, the variation with the values of reference is 6 to 7%. Validation independent of the breaking process batch should bring brief replies on the validity G in thermoelasticity.

The second modeling carrying out of the tests of functional and data-processing not-regression of calculation of derived from G compared to a variation of field, its results must be scrupulously respected, from where very severe criteria of tolerance.

Date:
11/05/04
Author (S):
X. DESROCHES Key
:
V7.02.101-B Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
Document: V7.02.101

HPLP101 - Plate fissured in thermoelasticity
(plane constraints)

Summary:

This test results from the validation independent of Code_Aster in breaking process (reference resulting from
Murakami: Mura11-17). It makes it possible to validate the operators of breaking process for a problem
two-dimensional (assumption of the plane constraints) in isotropic linear thermoelasticity.

This test includes/understands the first modeling in plane constraints in which are calculated:

·
the rate of refund of energy G (traditional calculation by the method théta),
·
coefficients of intensity of constraints KI and KII.

These two calculations are carried out on 6 different crowns of integration.

The interest of the test is to compare the values of G and KII compared to the reference solution and to test
the invariance of calculations compared to the various crowns of integration.

The second modeling makes it possible to calculate the derivative of G compared to the Young modulus and one
loading in voluminal forces and to compare them with an analytical solution.

1
Problem of reference

1.1 Geometry

Width of the plate:
W = 0.6 m
Length of the plate:
L = 0.3 m

Length of the crack:
2a = 0.3 m

1.2
Properties of material

Notation for thermoelastic properties:

S
S
0
X
11
12
X

11
= S
S
12
22
0 +
y

y
22 · (T - Re
T F)

0
0
S

66
xy
xy 0
S = 1 E
11
X

S = 1 E
22
y
S = - E = -
12
X
X
y E y

S = 1 G
66
xy
=
11
X
=
22
y

One limits oneself to isotropic material, as well from the thermal point of view as mechanical:

E = E
X
y = 2. 105 MPa
=
X
y = 0.3
=
X
y = 1.2 105 °C1
=
X
y = 54. W/m °C
Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
HPLP101 - Plate fissured in thermoelasticity (forced plane)
Date:

1.3
Boundary conditions and loading

Two models are considered:

* ***the half-model X = 0***
* ***the complete model***

Boundary conditions mechanical:

* ***half-model***

UX = 0 along the axis of symmetry X = 0
UY = 0 at the point (W/2.)

* ***complete model***

UX = 0 at the point (0, L/2.)
UY = 0 at the points (- L/2.) and (L/2.)

Boundary conditions thermal:

* ***half-model***

T = 100°C on the edge higher Y = L/2.
T = -100°C on the edge lower Y = - L/2.
null flow on the axis of symmetry, the free edge X = W/2. and on the edge of the crack

* ***complete model***

T = 100°C on the edge higher Y = L/2.

T = -100°C on the edge lower Y = - L/2.
null flow on the free edges X = ± W/2. and on the edge of the crack

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
HT-66/04/005/A

---

2 Reference solution

2.1 Method of calculation used for the reference solution

Complex potential [bib1].

2.2 Results of reference

2a
= W
L
=

W
T
W
K = 11 0 ·
· F
II
S
2
II
11

where the geometrical factor of correction FII is given according to for each material, in particular case = 0.5 on the curves below.

The isotropic material being represented by curve I

2.3
Uncertainty on the solution

Nondefinite precision.

2.4 References
bibliographical

[1]
Y. MURAKAMI: Stress Intensity Factors Handbook, box 11.17, pages 1045-1047. The Society of Materials Science, Japan, Pergamon Press, 1987.

2.5
Reference solution for the derivative of G (modeling B)

While varying the Young modulus and the Fy loading, one notes that:

2
G
G = F
with
3

310
.
5
-
=
that is to say
=
F

2

Y
Y
F
Y

G

G
G =
with
3

310
.
5
-
=
that is to say
= -
E
E

E

3 Modeling
With

3.1
Characteristics of modeling

For this modeling, the 3 topological parameters of the block crack are:

.
NS: a number of sectors on 90°
.
NC: a number of crowns
.
rt: the ray of the largest crown (with half a: length of the crack)

NS = 8
NC = 4
*rt = 0,001*a*

The values of the higher and lower rays, to specify in order CALC_THETA are:

Crown 1
Crown 2
Crown 3
Crown 4
Crown 5
Crown
6
Rinf
3,75E5
7,500E5
1,125E4 1,500E4 1,875E4 2,250E4
Rsup 7,50E5 1,125E4 1,500E4 1,875E4 2,250E4 3,000E4

3.2
Characteristics of the grid

Half-grid; grid radiating at the right end of the crack.

3831 nodes,
1516 elements,
884 TRI6,
632 QUA8.

3.3 Functionalities
tested

Orders

THERMAL AFFE_MODELE
PLAN
ALL

MECHANICAL AFFE_MODELE
C_PLAN ALL

THER_LINEAIRE

MECA_STATIQUE

CALC_THETA THETA_2D

CALC_G_THETA_T OPTION
CALC_G

CALC_G_THETA_T OPTION
CALC_K_G

4
Results of modeling A

4.1 Values tested

Identification	*Reference*	*Aster*	*% difference*
KII, crown n°1	*2,2347E+7*	*2,2814E+7*	*2,09*
KII, crown n°2	*2,2347E+7*	*2,2813E+7*	*2,08*
KII, crown n°3	*2,2347E+7*	*2,2814E+7*	*2,09*
KII, crown n°4	*2,2347E+7*	*2,2814E+7*	*2,09*
KII, crown n°5	*2,2347E+7*	*2,2817E+7*	*2,10*
KII, crown n°6	*2,2347E+7*	*2,2818E+7*	*2,11*
G, crown n°1	*2,4969E+3*	*2,5984E+3*	*4,07*
G, crown n°2	*2,4969E+3*	*2,5990E+3*	*4,09*
G, crown n°3	*2,4969E+3*	*2,5992E+3*	*4,10*
G, crown n°4	*2,4969E+3*	*2,5993E+3*	

4,10
G, crown n°5
2,4969E+3 2,6013E+3
4,18
G, crown n°6
2,4969E+3 2,5985E+3
4,07

4.2 Remarks

In the reference, the author supposes that KI = 0, but it does not check it a posteriori. With the sights of deformations resulting from ASTER, coefficient KI is different from zero, but there remains very weak by report/ratio
with KII (the crack slips more than it does not open).

With regard to the rate of refund of energy G, if we suppose that KI = 0, we draw
value of reference starting from the formula of IRWIN in plane constraints:

G

ref. = (1 E)
2
** K II*

---

5 Modeling
B

5.1
Characteristics of modeling

Same characteristics as for modeling a:

.
NS: a number of sectors on 90°
.
NC: a number of crowns
.
rt: the ray of the largest crown (with half a: length of the crack)

NS = 8
NC = 4
*rt = 0,001*a*

The values of the higher and lower rays, to specify in order CALC_THETA are:

Crown 1
Crown 2
Crown 3
Crown 4
Crown 5
Crown 6
Rinf
3,75E5
7,500E5
1,125E4 1,500E4 1,875E4 2,250E4
Rsup 7,50E5 1,125E4 1,500E4 1,875E4 2,250E4 3,000E4

5.2
Characteristics of the grid

Even grid that for modeling a:

Half-grid; grid radiating at the right end of the crack.

3831 nodes,
1516 elements,
884 TRI6,
632 QUA8.

5.3
Parameters materials and loading

For this modeling one took E=1Pa.
The loading is a voluminal force Fy=1N on all the structure. There is no loading thermics.

5.4
Functionalities tested

Orders

MECHANICAL AFFE_MODELE
C_PLAN ALL

MECA_STATIQUE

CALC_THETA THETA_2D

CALC_G_THETA_T SENSITIVITY

6
Results of modeling B

6.1 Values
tested

Identification Reference
***Aster** %*
difference
dg/dE, crown n°1
-5.3E-3
-5.299E-3
-7.6E-4
dg/dE, crown n°2
-5.3E-3

-5.301E-3
0.02
dg/dFy, crown n°1
1.06E-2
1.0599E-2
-7.6E-4
dg/dFy, crown n°2
1.06E-2
1.0602E-2
0.02

---

7 *Summary of the results*

The differences between the reference solution and the results of Code_Aster do not exceed 2% on coefficients of intensity of constraints and 4% for the rate of refund of energy. One checks the invariance of the results compared to the various crowns of integration.

The results on the derivative of G are lower than 1% (but without thermal loading).

Version
7.0

Titrate:
HPLP300 - Plate with Young modulus function of the temperature
Date:
13/10/04
Author (S):
Key ***J.M. PROIX***
:
V7.02.300-A Page:
1/6

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
Document: V7.02.300

HPLP300 - Plate with Young modulus function of the temperature

Summary:

This thermoelastic test makes it possible to compare the solution obtained by Code_Aster with an analytical solution,

when the Young modulus varies in a nonlinear way compared to the temperature.

*This test is deduced from the test 3D HPLV100 describes in [V7.03.100] (parallelepiped whose Young modulus is
function of the temperature).*

1
Problem of reference

1.1 Geometry

Y,

v

D

B

pressure Po

C1

H = 10
X,

O
C
U

B1

With

H

1.2
Material properties

Thermal conductivity: = 1

10000
Young modulus: E =
, T = temperature
8000 - T

Poisson's ratio: v = 0 3
.

1.3
Boundary conditions and loadings

1.3.1 Thermics

T (0) = 40

T
= -4 on edge X = h/2
N

T
= +4 on edge X = - h/2
N

T
= -3 on edge y = h/2
N

T
= +3 on edge y = - h/2
N

1.3.2 Mechanics

· Point O blocked (U = v = O)
· Déplacement following X blocked out of B
· Uniform Pression Po being exerted normally on contour: Po = 1.

2 Reference solution

2.1 Method of calculation used for the reference solution

· The field of temperature is given by:

T = - 4X - 3Y + 40

· The field of displacements is given by:

C
CH
2
2

U = V
- p Bxy + (X - y) + Dx +
y

2
4

B
CH
2
2

v = V
- p
(y - X) + Cxy + Dy - y

2
4

1 - v
where B = 0.003 C = 0.004 D = 0.76 p =
Po
v

· The field of deformations is given by:

=
vp By Cx D
xx = yy = -
(+ +) xy = 0.

· The stress field is given by:

E
1000
vp
v
=
0 004
.
X 0 003
.
y 0 7
. 6
p
Po
xx = yy =
= -
(
+
+
) = -
= -

1 - v
800 - T 1 - v
1 - v
Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
HT-66/04/005/A

2.2 Results of reference

Temperature at the points O, A, B, C, D, B1, C1
Displacements at the points A, B, C, D, B1, C1

2.3 Uncertainty on the solution

Analytical solution.

3 Modeling With

3.1 Characteristics of modeling

It is about a modeling in plane constraints.

y, v

B

D

C1
X, U
O

C

With
B1

Cutting: 4 X 4 elements

Limiting conditions:

· *out of O, U = v = O*
· *out of B, U = O*

3.2 Characteristics of the grid

A number of nodes: 65

A number of meshs and type: 16 QUAD8

Name of the nodes

O = N38
With = N1
B = N23
C = N16
D = N3
B1 = N9
C1 = N30

3.3 Functionalities tested

Orders

DEFI_FONCTION
“TEMP”

DEFI_MATERIAU ELAS_FO

THER
“MECHANICAL” AFFE_MODELE
“2D”
ALL

`THERMAL
"2D"
ALL
AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

PRES_REP
GROUP_MA
TEMP_CALCULEE
AFE_CHAR_THER TEMP_IMPO
GROUP_NO

FLUX_REP
GROUP_MA
POST_RELEVE "TEMP"
"EXTRACTION"

"DEPL"

4
Results of modeling A

4.1 Values tested

Localization
Type of value
Reference
Aster
% difference
Not A
T
75.
75.
0.
Not B
T
25.
25.
0.
Not C

T
20.
20.
0.
Not D
T
5.
5.
0.
Not B1
T
55.
55.
0.
Not C1
T
60.
60.
0.
Not O
T
40.
40.
0.
Not A
U
2.68975
2.64249
-1.75
v
2.55
2.55502
0.197
Not B
U
0.
1.13 10-17 1.3
10-17
v
-2.65125
-2.68625
-1.32
Not C

U
-2.695
-2.694997
-1.21 10-4
Not D
U
-2.7002
-2.74751
-1.749
v
-2.695
-2.69503
9.67 10-4
Not B1
U
0.0700
0.0699585
-0.059
v
2.59875
2.63376
1.347
Not C1
U
2.625
2.62501
4.73 10-4

4.2 Remarks

It is necessary to discretize finely the function E (T) to obtain satisfactory results. One has taken for this test 160 points of discretization, for the interval of temperatures [5. , 75.].

5 ***Summary of the results***

The results obtained with Code_Aster are in concord with the analytical solution.

Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
V7.02.310 document

HPLP310 - Biblio_35 Fissures radial intern in one
thick cylinder under pressure and loading
thermics

Summary:

This test results from the validation independent of version 3 in breaking process.

It is about a two-dimensional test in statics in which one models nonthe linearity of contact due to refermeture partial of the crack.

The behavior of the structure is thermoelastic linear isotropic.

The case test includes/understands only one plane modeling 2D for which one studies the influence of the load factor
mechanics.

1
Problem of reference

1.1 Geometry

y
r2
has
X
With
B
C
D
E
r1

Cross-section of a thick tube presenting one
internal radial crack

Report/ratio of the rays
B = r2/r1 = 2 (r1=1 mm, r2= 2 mm)

Depth of the crack
has (r2-r1) = 0,05

1.2
Properties of material

The material is thermoelastic linear isotropic standard.

Young modulus
E = 1000 MPa
Poisson's ratio
= 0,3

Linear dilation coefficient
T = 1E-6
Yield stress
0 = 1 MPa (being used to define the initial stress field created
by the process of autofrettage on the assumption of one
former behavior of elastoplastic type of Von Mises)

1.3
Boundary conditions and loadings

Boundary conditions (for a half-part in the area y 0)

Blocking UY = 0 on segment AB and the ligament OF (symmetry).

Linear relation UX (A) + UX (E) = 0 (to block the horizontal adjustment)

Loadings

Loading n° 1: radial traction rr (r2) = 0 on the external face; this produced mechanical loading
the same KI as an internal pressure acting simultaneously on the internal ray
r1 and on the lips of the crack, without taking into account of nonthe linearity of
contact.

Loading n° 2: thermal loading are equivalent to an autofrettage defined as follows:

4
2 1-

0
(
)
T = T +
·
· ln
1
3
E

R
T
1
(T - T

1
)
R
T = T -
· ln
R R
1

1

R
1
ln

R
1
T = T
R r2

In these formulas, the maximum ray of the zone indicates having undergone autofrettage, T1 the temperature with the ray r1 and T the temperature with the ray R = in the thick tube not fissured. In the application noted here, one takes = r2, which

corresponds to the autofrettage of the totality of the section of the thick tube, and one does not take into account nonthe linearity of contact. One awaits one K negative for positive temperatures (setting in compression of the tube not fissured).

*Loading n° 3: linear combination loading n° 2 + * loading n° 1, (T!) indicating the mechanical load factor; one takes here into account nonthe linearity of contact, which supposes an incremental application of the mechanical load.*

2
Reference solution

2.1
Method of calculation used for the reference solution

Calculation by finite elements with code ABAQUS. Nonthe linearity of contact is modelled with the assistance
one-way GAP elements. The factor of intensity of the constraints is calculated from the integral J.

2.2
Results of reference

Adimensional factor of intensity of the constraints according to the mechanical factor of loading, in the case of loading n° 3

Notation:
F = K/has linear factor of intensity adimensional (obtained by combination
L
IT
0
linear of the effects of autofrettage and mechanical loading, in
stopped feature)

F = K/has nonlinear factor of intensity adimensional (obtained while holding
NR
IN
0
count nonlinearity of contact, in full feature).

EJ

K 2 =

I
(
2
1 -)

5/12

Empirical formula of the factor of intensity of the constraints under external radial tension

W = r2 - r1
C
C
1
2
(
0,2 +
b)
B
has
K

ln
ln
0 0
, 1
0 8
,
1 5
,
3 0
,
0 = P
has ·

<
and
B
I
1 - 1 B
W

has 0,5
has 2
C
2 397
,
2 705
,

0 884
,
1 =
-

W +

W
has 0,5
has 2
C
0 244
,
1 447
,
0 809
,
2 = -
+

W +

W

Empirical formula of the factor of intensity of the constraints in autofrettage in full section

C
0,75
ln
1 + C2 (
b)
has
K =
0 0
, 1
0 8
,
1 5
,
3 0
,
0
has ·

2

<
and
B
Ia

1
W
1 8
, +

b4

has 0,05
has 0 1,5
has 1,5
30 221
,
- 57 714
,
29 954
,
2 444
,

W +

W -

W
C

1 =
has 0,25
1 + W

has 0,05
has 0 1,5
has 1,5
- 51522
,

+ 111 027
,
3 631
,

63 244
,
W
-

W +

W
C2 =
has 0,25
1 - W

2.3 References bibliographical

[1]
H.M. SHU, J. SMALL and G. BEZINE: Radial stress intensity factors for aces in thick walled cylinders. I. Symmetrical aces II. Combination of autofrettage and internal presses. Engng.Fract.Mechs., 49, n°4, 611-629, 1994.

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3 Modeling
With

3.1
Characteristics of modeling

The model consists of quadrangles with 8 nodes and triangles with 6 nodes.
It comprises 4877 nodes and 1598 elements.

3.2
Characteristics of the grid

Use of procedure FISS2D_V1.

The topological parameters concerning refinement around the bottom of crack are:

- *nc = 4 (a number of crowns)*
- *NS = 8 (a number of sectors)*
- *nbcour = 1 (a number of crowns of déraffinement)*

Y
X

Zoom of the fissured zone

Zoom of the zone fissured with "block of contact"

3.3
Functionalities tested

The rate of refund of energy G is calculated by the method THETA for the 4 following crowns:

· Couronne 0: Rinf = 0,0025 mm Rsup = 0,005 mm

· Couronne 1: Rinf = 0,005 mm Rsup = 0,0075 mm

· Couronne 2: Rinf = 0,0075 mm Rsup = 0,01 mm

· Couronne 3: Rinf = 0,005 mm Rsup = 0,03 mm

Orders

AFFE_CHAR_MECA CONTACT
NORMAL

STAT_NON_LINE COMP_ELAS
ELAS

NEWTON
RUBBER BAND

DEFI_FOND_FISS MELTS
GROUP_NO

NORMAL

CALC_THETA THETA_2D
GROUP_NO

CALC_G_THETA_T SYME_CHAR
SYME

OPTION
CALC_K_G

4

Results of modeling A

4.1 Values tested

Identification Reference Aster % difference
KI, loading n°1, crown 0, neglected contact
1,1482
1,12884
-1,69
KI, loading n°1, crown 1, neglected contact
1,1482
1,12883
-1,69
KI, loading n°1, crown 2, neglected contact
1,1482
1,12886
-1,69
KI, loading n°1, crown 3, neglected contact
1,1482
1,12885
-1,69

Identification Reference Aster % difference
KI, loading n°2, crown 0, neglected contact
-0,41237
-0,3847839
-6,69
KI, loading n°2, crown 1, neglected contact
-0,41237
-0,3878
-6,69
KI, loading n°2, crown 2, neglected contact
-0,41237
-0,3847897
-6,69
KI, loading n°2, crown 3, neglected contact

-0,41237
-0,384786
-6,69

Identification Reference
Aster %
difference
KI, loading n°3, contact, = 0,33, crown 0 1,2075E-3 1,2688
10-3 5,078
KI, loading n°3, contact, = 0,335, crown 0 3,0187E-3 3,0589E-3 1,332
KI, loading n°3, contact, = 0,34, crown 0 5,4336E-3 5,4177E-3 -0,293
KI, loading n°3, contact, = 0,345, crown 0 8,5865E-3 8,2570E-3 -3,837
KI, loading n°3, contact, = 0,35, crown 0 1,2075E-2 1,1620E-2 -3,767
KI, loading n°3, contact, = 0,36, crown 0 2,1757E-2 2,15976E-2 -0,73
KI, loading n°3, contact, = 0,40, crown 0 6,6478E-2 6,67511E-2 0,41
Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear
HT-66/02/001/A

Identification Reference
***Aster** %*
difference
KI, loading n°3, contact, = 0,33, crown 1 1,2075E-3 1,19085E-3 -1,19
KI, loading n°3, contact, = 0,335, crown 1 3,0187E-3 3,03577E-3 0,565
KI, loading n°3, contact, = 0,34, crown 1 5,4336E-3 5,4136E-3 0,368
KI, loading n°3, contact, = 0,345, crown 1 8,5865E-3 8,2570E-3 -3,838
KI, loading n°3, contact, = 0,35, crown 1 1,2075E-2 1,1621E-2 -3,761
KI, loading n°3, contact, = 0,36, crown 1 2,1757E-2 2,15975E-2 -0,73
KI, loading n°3, contact, = 0,40, crown 1 6,6478E-2 6,67506E-2 0,41

Identification Reference
***Aster** %*
difference
KI, loading n°3, contact, = 0,33, crown 2 1,2075E-3 1,1604E-3 -3,902
KI, loading n°3, contact, = 0,335, crown 2 3,0187E-3 3,03287E-3 0,469
KI, loading n°3, contact, = 0,34, crown 2 5,4336E-3 5,4131E-3 -0,376
KI, loading n°3, contact, = 0,345, crown 8,5865E-3 8,2572E-3 -3,635
2
KI, loading n°3, contact, = 0,35, crown 2 1,2075E-2 1,1621E-2 -3,76
KI, loading n°3, contact, = 0,36, crown 2 2,1757E-2 2,1598E-2 -0,73
KI, loading n°3, contact, = 0,40, crown 2 6,6478E-2 6,67529E-2 0,41

Identification Reference
***Aster** %*
difference
KI, loading n°3, contact, = 0,335, crown 3 3,0187E-3 2,7419E-3 -9,169

KI, loading n°3, contact, = 0,34, crown 3 5,4336E-3 5,4252E-3 -0,154
KI, loading n°3, contact, = 0,345, crown 3 8,5865E-3 8,2570E-3 -3,837
KI, loading n°3, contact, = 0,35, crown 3 1,2075E-3 1,1614E-2 -3,81
KI, loading n°3, contact, = 0,36, crown 3 2,1757E-2 2,1598E-2 0,73
KI, loading n°3, contact, = 0,40, crown 3 6,6478E-2 6,67525E-2 0,41

Identification Reference
***Aster** %*
difference
0
0,3410 0,3410
0

4.2 Remarks

The tables below give the rate of refund of energy G for two values of the coefficient
who correspond to nonthe separation of the lip of the crack. (There is separation of the lip for
> 0,32).

Identification
Reference
G ASTER
G, loading n°3, contact, = 0,30, crown 0

0
-8,7941 10-16
G, loading n°3, contact, = 0,30, crown 1
0
4,4308 10-15
G, loading n°3, contact, = 0,30, crown 2
0
3,3312 10-15
G, loading n°3, contact, = 0,30, crown 3
0
4,4794 10-13

Identification
Reference
G ASTER
G, loading n°3, contact, = 0,32, crown 0
0
-1,17E-14
G, loading n°3, contact, = 0,32, crown 1
0
-3,26E-16
G, loading n°3, contact, = 0,32, crown 2
0
-1,02E-15
G, loading n°3, contact, = 0,32, crown 3
0 4,23E-13

4.3 Parameters of execution

Version: 6.03

Machine: CRAY C90

Obstruction memory: 16 MW
Time CPU To use: 136 seconds

Handbook of Validation

V7.02 booklet: Thermomechanical stationary linear
HT-66/02/001/A

Code_Aster ®
Version
6.3

Titrate:
HPLP310 - Biblio_35 Fissures radial intern in a thick cylinder
Date:
22/11/02
Author (S):
S. GRANET, I. CORMEAU, B. KURTH Key
:
V7.02.310-A Page:
12/12

5
Summary of the results

The calculation of G is correct in all the cases, including for a completely closed crack.

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear
HT-66/02/001/A

Code_Aster ®
Version
5.0

Titrate:
HPLP311 - Murakami 11.17 Fissures in the center of a thin section
Date:
19/09/02
Author (S):
S. GRANET, E. SCREWS, I. CORMEAU, E. LECLERE Clé
:
V7.02.311-A Page:
1/14

Organization (S): EDF/AMA, UTO, CS IF, IPSN

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear of the plane systems
V7.02.311 document

HPLP311 - Murakami 11.17 Fissures in the center of one rectangular thin section making obstacle with one uniform heat flow in isotropic medium

Summary:

It is about an isotropic linear thermoelastic calculation static.

It is a basic test in plane 2D for a stationary thermal loading calculated by finite elements on even grid with an isotropic material in mode II.

Objective:

· basic test in plane 2D, for a stationary thermal loading calculated by finite elements on even grid, with isotropic material, in mode II,
· validation of the calculation of KII,
· variability of G according to the topology (sectors, crowns) of the radiant grid. Checking invariance of the results in breaking process, at an end of crack, compared to grid of the other end of the same crack.

Calculation is tested on a complete grid and a half-grid. Parameters L/W and 2A/W being fixed.

One measures a relative variation on KII, the precision is nevertheless badly defined.

1
Problem of reference

1.1 Geometry

Width of the plate:
W = 0,6 m
Length of the plate:
L = 0,3 m
Length of the crack:
2a = 0,3 m

1.2
Properties of material

Notation for thermoelastic properties:

11
12
0

X
S
S
X

11

y = S
S
12
22
0

y +

22 (
T - ref.
T
)

0
0

xy
S

66
xy 0
S11 = 1 Ex
S22 = 1 Ey
S12 = - X Ex = - y Ey

S66 = 1 Gxy
11 = X
22 = y

One limits oneself to isotropic material, as well from the thermal point of view as mechanical:

Ex = Ey = 2.105 MPa
X = y = 0,3
X = y = 1,2 10-5 °C-1

X = y = 54 W/m °C

1.3
Boundary conditions and loading

Two models are considered:

- *the half-model X 0*
- *the complete model*

Boundary conditions mechanical:

- *half-model*

UX = 0 along the axis of symmetry X = 0
UY = 0 at the point (W/2,0)

- *complete model*

UX = 0 at the point (0, L/2)
UY = 0 at the points (L/2,0) and (L/2,0)

Boundary conditions thermal:

- *half-model*

T = 100°C on the edge higher Y = L/2

T = 100°C on the edge lower Y = L/2
null flow on the axis of symmetry, the free edge X = W/2 and on the edge of the crack

· complete model

T = 100°C on the edge higher Y = L/2
T = 100°C on the edge lower Y = L/2
null flow on the free edges X = ± W/2 and on the edge of the crack

---

2
Reference solution

2.1
Method of calculation used for the reference solution

Complex potential.

2.2
Results of reference

2a
= W

L
=

W
T
W
K = 11 0 ·
· F
II
S
2
II
11

where the geometrical factor of correction FII is given according to for each material, in particular case = 0,5 on the curves below.

The isotropic material being represented by curve I

2.3
Uncertainty on the solution

Nondefinite precision.

2.4 References
bibliographical

[1]
Y. MURAKAMI: Stress Intensity Factors Handbook, box 11.17, pages 1045-1047. The Society of Materials Science, Japan, Pergamon Press, 1987.

3
Modelings A, B, C, D, E and F

3.1
Characteristics of modeling

These 6 modelings correspond to 6 grids where one varies 3 topological parameters.
table below summarizes the various studied cases:

NS = 8, NC = 4
NS = 4, NC = 3
*rt = 0,001*a*
With
B
*rt = 0,01*a*
C
D
*rt = 0,1*a*
E
F

The topological parameters which vary are:

NS:
a number of sectors on 90°
NC:
a number of crowns
rt:
the ray of the largest crown (with half a: length of the crack)

3.1.1 Modelings A and B

Half grid - Modeling A

Zoom of the point of crack - Modeling A

Half grid - Modeling B

Zoom of the point of crack - Modeling B

3.1.2 Modelings C and D

Complete grid - Modeling C

Complete grid - Modeling D

Handbook of Validation
V7.02 booklet: Thermomechanical stationary linear
HT-66/02/001/A

3.1.3 Modelings E and F

Complete grid - Modeling E

Complete grid - Modeling F

3.1.4 Definition of the rays of the crowns

For these various cases, we define the values of the higher and lower rays, to specify in order CALC_THETA:

Modeling A

1st crown
2nd crown
3rd crown
4th crown
rinf (m)
3,75E5
7,500E5 1,125E4
1,500E4
rsup (m)
7,50E5
1,125E4 1,500E4
1,875E4

Modeling B

1st crown
2nd crown
3rd crown
rinf (m)
5,00E5
1,00E4
1,50E4
rsup (m)
1,00E4
1,50E4
2,00E4

Modeling C

1st crown
2nd crown
3rd crown
4th crown
rinf (m)
3,75E4

7,500E4 1,125E3
1,500E3
rsup (m)
7,50E4
1,125E3 1,500E3
1,875E3

Modeling D

1st crown
2nd crown
3rd crown
rinf (m)
5,00E4
1,00E3
1,50E3
rsup (m)
1,00E3
1,50E3
2,00E3

Modeling E

1st crown
2nd crown
3rd crown
4th crown
rinf (m)
3,75E3
7,500E3 1,125E2
1,500E2
rsup (m)
7,50E3
1,125E2 1,500E2
1,875E2

Modeling F

1st crown

2nd crown
3rd crown
rinf (m)
5,00E3
1,00E2
1,50E2
rsup (m)
1,00E2
1,50E2
2,00E2

3.2
Characteristics of the grid

Half-grid; grid radiating at the right end of the crack.

The table below gives the constitution of the studied grids:

NS = 8, NC = 4
NS = 4, NC = 3

3831 nodes,
3507 nodes,
*rt = 0,001*a*
1516 elements,

1388 elements,
884 TRI6,
820 TRI6,
632 QUA8.
568 QUA8.

1179 nodes,
855 nodes,
*rt = 0,01*a*
400 elements,
272 elements,
104 TRI6,
40 TRI6,
296 QUA8.
232 QUA8.

659 nodes,
335 nodes,
*rt = 0,1*a*
240 elements,
112 elements,
104 TRI6,
40 TRI6,
136 QUA8.
72 QUA8.

3.3 Functionalities tested

Variation of the result according to the topological and geometrical parameters of the radiant grid (a many crowns, number sectors, diameter of the largest crown)

4
Results of modelings A, B, C, D, E and F

4.1 Values
tested

Identification Reference
Aster %
difference
*Diameter crowns external = 0,001*a*

Radiant grid
NS= 8
NC= 4
Modeling A
KII, crown n°1
2,2347E+7
2,2814E7
2,09
KII, crown n°2
2,2347E+7
2,2813E7
2,08
KII, crown n°3
2,2347E+7
2,2814E7
2,09
KII, crown n°4
2,2347E+7
2,2814E7
2,09
Radiant grid
NS= 4
NC= 3
Modeling B

KII, crown n°1
2,2347E+7
2,282E7
2,10
KII, crown n°2
2,2347E+7
2,282E7
2,10
KII, crown n°3
2,2347E+7
2,281E7
2,09
Diameter crowns external = 0,01*a

Radiant grid
NS= 8
NC= 4
Modeling C
KII, crown n°1
2,2347E+7
2,166 107 3,058
KII, crown n°2
2,2347E+7
2,214 107 0,919
KII, crown n°3
2,2347E+7
2,214 107 0,919
KII, crown n°4
2,2347E+7
2,214 107 0,919
Radiant grid
NS= 4
NC= 3
Modeling D
KII, crown n°1
2,2347E+7
2,214 107 0,919
KII, crown n°2
2,2347E+7
2,214 107 0,919
KII, crown n°3
2,2347E+7

2,214 107 0,919
*Diameter crowns external = 0,1*a*

Radiant grid
NS= 8
NC= 4
Modeling E
KII, crown n°1
2,2347E+7
2,2632 107 1,276
KII, crown n°2
2,2347E+7
2,2572 107 1,009
KII, crown n°3
2,2347E+7
2,2572 107 1,008
KII, crown n°4
2,2347E+7
2,2564 107 0,972
Radiant grid
NS= 4
NC= 3
Modeling F
KII, crown n°1
2,2347E+7
2,255E7
0,932
KII, crown n°2
2,2347E+7
2,2568E7
0,988
KII, crown n°3
2,2347E+7
2,2568E7
0,987

Identification Reference
Aster %
difference
*Diameter crowns external = 0,001*a*

Radiant grid
NS= 8
NC= 4
Modeling A
G, crown n°1
2,4969E+3
2,5984E+3
4,07
G, crown n°2
2,4969E+3
2,5990E+3
4,09
G, crown n°3
2,4969E+3
2,5992E+3
4,10
G, crown n°4
2,4969E+3
2,5993E+3
4,10
Radiant grid
NS= 4
NC= 3
Modeling B
G, crown n°1
2,4969E+3

2,600 103 4,134
G, crown n°2
2,4969E+3
2,5996 103 4,114
G, crown n°3
2,4969E+3
2,5996 103 4,111
Diameter crowns external = 0,01*a

Radiant grid
NS= 8
NC= 4
Modeling C
G, crown n°1
2,4969E+3
2,451 103 1,842
G, crown n°2
2,4969E+3
2,475 103 0,858
G, crown n°3
2,4969E+3
2,475 103 0,858
G, crown n°4
2,4969E+3
2,475 103 0,858
Radiant grid
NS= 4
NC= 3
Modeling D
G, crown n°1
2,4969E+3
2,475 103 0,858
G, crown n°2
2,4969E+3
2,475 103 0,858
G, crown n°3
2,4969E+3
2,475 103 0,858
Diameter crowns external = 0,1*a

Radiant grid
NS= 8
NC= 4
Modeling E
G, crown n°1
2,4969E+3
2,5624E3
2,627
G, crown n°2
2,4969E+3
2,5503E3
2,139
G, crown n°3
2,4969E+3
2,5499E3
2,124
G, crown n°4
2,4969E+3
2,5489 E3
2,084
Radiant grid
NS= 4
NC= 3
Modeling F
G, crown n°1
2,4969E+3
2,5470 E3
2,006
G, crown n°2
2,4969E+3
2,5497 E3
2,117
G, crown n°3
2,4969E+3
2,5491 E3
2,094

4.2 Remarks

In the reference, the author supposes that KI = 0, but it does not check it a posteriori.

With regard to the rate of refund of energy G, if we suppose that KI = 0, we draw value of reference starting from the formula of IRWIN in plane constraints:

*Gref = (1/E) * KII2*

5 Modeling
G

5.1
Characteristics of modeling

For this modeling, we use the complete model with the best parameters NS, NC and rt calculated in preceding modelings. We thus used the following values:

· NS = 8,
· NC = 4,
*· rt = 0,01*a.*

Complete grid

5.2
Characteristics of the grid

Complete model, with grid radiating only at the right end of the crack and grid regular, not refined, at the left end.

The grid consists of 1718 nodes and 568 elements, including 464 elements QUA8 and 104 elements

TRI6.

5.3 Functionalities tested

Independence of KII at the end of right-hand side compared to the grid of the end of left.

6
Results of modeling G

6.1 Values tested

Identification Reference
Aster %
difference
*Diameter crowns external = 0,01*a*

Radiant grid
NS= 8
NC= 4

KII, crown n°1

2,2347E+7
2,2640E7
1,31
KII, crown n°2
2,2347E+7
2,2640E7
1,31
KII, crown n°3
2,2347E+7
2,2640E7
1,31
KII, crown n°4
2,2347E+7
2,2641E7
1,31

Identification Reference
Aster %
difference
*Diameter crowns external = 0,01*a*

Radiant grid
NS= 8
NC= 4

G, crown n°1
2,4969E+3
2,5620E3
2,610
G, crown n°2
2,4969E+3
2,5626E3
2,631
G, crown n°3
2,4969E+3
2,5627E3
2,635
G, crown n°4
2,4969E+3
2,5628E3
2,640

7
Summary of the results

The differences between the reference solution and the results of Code_Aster do not exceed 3% on coefficients of intensity of constraints and 4% for the rate of refund of energy. Invariance is checked results compared to the various crowns of integration.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
Document: V7.03.100

HPLV100 - Parallelepiped of which the Young modulus is a function of the temperature

Summary

This thermoelastic calculation compares the solution provided by Code_Aster with an analytical solution when it
Young modulus varies in a nonlinear way compared to the temperature.
Modeling does not have anything physics and is described in [V7.90.01].

Version
3
Titrate:
HPLV100 - Parallelepiped whose Young modulus is a function
Date:
21/05/96
Author (S):
P. MIALON
Key:
V7.03.100-C Page:
2/6

1
Problem of reference

1.1 Geometry

y
I
p
B
D
H
C
O
With
X
Z
H
I = 20. H = 10. O = (0. 0. 0.) With = (20. 0. 0.) D = (20. 5. 5.)

1.2
Material properties

Thermal conductivity: = 1.
1000.
Young modulus: E =
(T being the températur) E
800.T
Poisson's ratio: = 0.3

1.3
Boundary conditions and loadings

· Thermique
T
T ()
To = 0. ,
= - 2.
X =

N

for
I
= + 2. for X = 0
= - 3. for y = H/2.
= + 3. for y = - H/2.
= - 4 for Z = H/2.
= + 4. for Z = - H/2.
N being the outgoing normal.
· Mécanique
:
ux (O) = uy (O) = uz (O) = 0.
ux (B) = ux (C) = uz (B) = 0.
· Pression
:
p = 1.
Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HI-75/96/032/A

Code_Aster ®
Version
3
Titrate:
HPLV100 - Parallelepiped whose Young modulus is a function
Date:
21/05/96
Author (S):
P. MIALON
Key:
V7.03.100-C Page:
3/6
2
Reference solution
2.1
Method of calculation used for the reference solution
T = 2x 3y 4z + 40
1000
One thus has: E =
Emin = .138 Emax = 120
2x + 3y + 4z + 760
With

Ah
2
2
2

ux (X, y, Z) = p

2 [X + (y + Z)] + B xy + C xz + Dx v
(y + Z)

4

B
x2
Ah
C H
2
2

uy (X, y, Z) = Pa xy + y Z +
+ C yz + Dy
X
Z

2

4
4

C
x2
C H
Ah
2
2

uz (X, y, Z) = Pa xz + B yz + Z y +
+ Dz +
y
X

2

4
4

With:
To = 0 002
.
, B = 0 003
.
, C = 0 004
.
, D = 0 7
. 6
2.2
Result of reference
Temperature at the point O and point D.
Displacement of point A.
2.3 Reference
bibliographical
[1]
S. ANDRIEUX "an analytical solution to a linear problem of elasticity isotropic 3D with Young modulus function of the variables of space [V4.90.01].
Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HI-75/96/032/A

---

3 Modeling
With

3.1
Characteristics of modeling

3D

3.2
Characteristics of the grid

A number of nodes: 141
A number of meshs and types: 16 HEXA20

3.3 Functionalities
tested

Orders
Keys
DEFI_FONCTION
[U4.21.02]
DEFI_MATERIAU
ELAS_FO
[U4.23.01]

3.4 Remarks

It is necessary to envisage a great number of points of discretization of the curve E (T) for to obtain the desired precision. Here one took 250 points (E, T
I
I).

---

4 Results of modeling A

4.1 Values tested

Identification	**Reference**	***Aster***	**% difference**
0 T	+40.	+40.00	0
D T	-35.	35.00	0
With ux	+15.6	+15.60	0
uy	0.57	0.5701	0.02
uz	0.77	0.7700	0
D ux	+16.3	+16.30	0
uy	1.785	1.785	

0
uz
2.0075
2.0075
0

4.2 Parameters
of execution

Version: 3.05.13
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
12 seconds

5
Summary of the results

This problem requires a very fine discretization of the function *E* (*T*) to obtain the solution of reference.

Handbook of Validation

V7.03 booklet: Thermomechanical stationary linear of the voluminal systems

V7.03.101 document

HPLV101 - Homogenisation of a material homogeneous

Summary:

This test tests, in a commonplace situation where the material is homogeneous, the thermal resolution of the problems
and mechanics stationary, with loadings corresponding to a variation in temperature and to one
imposed deformation, close to those corresponding to the elementary problems of the method
of periodic homogenisation.

---

1 Problem of reference

1.1 Geometry

Z
N4
N5
N6

N3
X y Z

N7
N4
0 0 16.410
N2
y
N8
N8 1. 1. 16.410
N3 0.5 0 16.410
0
N1
C
16.410
1
X
With
B
1

1.2
Material properties

E = 1.0 MPa
= 0.3
K = 1.0 W (m.°C)
CP = 0 J (°C.m3)

1.3
Boundary conditions and loadings

· Mécanique 3D:
Plan Z = 0:
dz = 0
for the membrane loading;
dx = 0, Dy = 0
for the loading of inflection
Plans y = 0, y = 1:
Dy = 0
Plans X = 0, X = 1:
dx = 0
Node: O
dz = 0
(for the only loading of inflection)
1 0

0

membrane deformation:
E = 0
0

0

Loading:
0 0

0
Z 0

0

imposed uniform inflection:
E = 0 0

0

0 0 0
· Mécanique 2D, constraints plane:
Center: X = 0
dx = 0
(these conditions do not correspond to the application of
Node: O
Dy = 0
method of homogenisation).
1 0

0

Loading: deformation E = 0
0

0 uniform imposed

0 0 0
· Thermique 3D and 2D:
Plan X = 0
temp = 0

(this condition does not correspond to the application of
method of homogenisation).
Loading: gradient **G** = (,
1 ,
0)
0 imposed uniform.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

· In thermics: the stationary thermal problem is solved:

-
1

T.K. =
.
G K., V, with **G**

=

0

0

Note:
The boundary conditions chosen here are not those necessary to the method

of homogenisation: one would find T indeed = 0 *everywhere.*
The solution is then (checking the conditions defined in [§1.3]): T (*X*, *y*, *Z*) = X
1
1
The potential energy is then with balance: W *HT* =
T
. **K**.*T*
=
here
2
-

2
· In mechanics: one solves the problem of elastostatic:
(**U**). **A.** (**v**) = E.A. (**v**), **v**

W
,

for the cases:
loading 3D
loading 3D
loading 2D
membrane
of inflection
plane constraints
1 0

0
Z 0

0
1 0

0

E = 0
0

0
E = 0 0

0
E = 0
0

0

0 0 0

0 0 0

0 0 0
The solutions are:

Z
· in 3D, **membrane** loading: **U** (*X*, *y*, *Z*) =,
0 ,
0 -

(
;
1-)
the potential energy with balance is:
1
2

W *pot* =
(**U**). **A.** (**U**) =
-
.
(2μ)
2

1 -

+
2

+ *z2*

· in 3D, loading of **inflection**: **U** (*X*, *y*, *Z*) =,
0 ,
0
;

2 (1-)

2
h3

W *pot* =
-
.
(2µ)

.
1 -
+
2
3
· in 2D, plane loading: **U** (*X*, *y*) = (*X*,)
0 ;
-
W *pot* = 2 (1 2)
Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HI-75/96/032/A

---

3 Modeling
With

3.1
Characteristics of modeling

y
N6
C
B
GRNM14
O
With
X

Boundary conditions and loading:
Thermics:
GROUP_NO: GRNM14: TEMP: 0.0
GRAD_TEMP_INIT: FLUX_X: 1.0
Mechanics:
GROUP_NO: GRNM14: DX: 0.0
(plane constraints)
NODE: O DY: 0.0
EPSI_INIT: EPXX: 1.0

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 QUAD8

3.3 Functionalities
tested

Orders
Keys
AFFE_CHAR_THER
GRAD_TEMP_INIT
ALL
“YES”
[U4.25.02]
FLUX_X
AFFE_CHAR_MECA
EPSI_INIT
ALL
“YES”
[U4.25.01]
EPXX

POST_ELEM
ENER_POT
ALL
“YES”
[U4.61.04]
Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HI-75/96/032/A

4
Results of modeling A
4.1 Values
tested
Not
Size
Reference
Aster
% difference
Tolerance %
CMP
With
TEMP
1.0000
1.00000
0.000
106
With
DX
1.0000
1.00000
0.000

106
N6
DX
0.5000
0.50000
0.000
106
Net
Energy
Reference
Aster
% difference
potential
with balance
M1
Thermics
0.500000000
0.500000
108
M1
Mechanics
0.549450550
+0.549451
108

4.2 Remarks

Code_Aster provides the value of the deformation energy, equal contrary to the potential energy to balance (elastic case).

4.3 Parameters
of execution

Version: 3.02.18
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
16 megawords
Time CPU To use:
3.7 seconds

5 Modeling

B

5.1

Characteristics of modeling

Z
N4
N6
N3
N2
N8
O
C
y
With
B
X
Name of the meshs of the faces:
ZEGAL0
YEGAL0
YEGAL1
XEGAL0
XEGAL1
Summits:
B C O WITH
O With N2 N4 B C N6 N8
C O N4 N6 A B N8 N2
Boundary conditions:
ZERO: DEFI_CONSTANTE (VALE: 0.0);
FCT1: DEFI_FONCTION (Nom_para: “Z”, VALE: (0.0 0.0.1.0.1.0));
Thermics:
GROUP_NO: XEGAL0: TEMP: 0.0
GRAD_TEMP_INIT: FLUX_X: -1.0
Mechanics:

GROUP_NO: YEGALO: DY = 0.0
XEGAL1: DX = 0.0
YEGAL1: DY = 0.0
XEGALO: DZ = 0.0
Membrane case:
GROUP_NO: ZEGALO: DZ = 0.0
EPSI_INIT: EPXX: -1.0
Case inflection:
GROUP_NO: ZEGALO: DX = ZERO, DY = ZERO
NODE: 0 DZ = ZERO
EPSI_INIT: EPXX: FCT1

5.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 1 HEXA20

5.3 Functionalities
tested
Orders
Keys

AFFE_CHAR_THER
GRAD_TEMP_INIT
ALL
[U4.25.02]
FLUX_X
AFFE_CHAR_MECA
EPSI_INIT
EPXX
[U4.25.01]
AFFE_CHAR_MECA_F
EPSI_INIT
EPXX
[U4.25.01]
POST_ELEM
ENER_POT
ALL
“YES”
[U4.61.04]

6
Results of modeling B
6.1 Values
tested

Case	**Size**	**Not**	**Reference**	***Aster***	**% difference**
Thermics	temp	N8	1.000000	1.000000	1010
	temp	N3	0.500000	0.5000000	1010
Mechanics	dz	N4	7.03285714	7.03285714	1010
membrane	dz	N8	7.03285714	7.03285714	1010

Mechanics
dz
N4
57.70459285
57.70459285
1010
inflection
dz
N8
57.70459285
57.70459285
1010
Net
Energy
Reference
Aster
% difference
potential
with balance
M1
Thermics
8.20500
8.20500
107
M1
Mechanics
Membrane
2.0287088
2.02871
107
Inflection
1.8210238 102
1.82102 102
107

6.2 Parameters
of execution

Version: 3.05.30
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
16 megawords
Time CPU To use:

16.51 seconds

Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HI-75/96/032/A

---

7 Summary of the results

The results are exact with errors rounding close, since the sought solutions belong to the space of the finite elements selected for modeling.

Organization (S): EDF/IMA/MNN

Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
V7.03.102 document

HPLV102 - Thermoelastic calculation of G in medium infinite for a circular crack

Summary

It is about a test of breaking process into thermomechanical for an axisymmetric problem. One consider a circular crack plunged in a presumedly infinite medium. One imposes a uniform temperature on
lips of the crack. This test makes it possible to calculate the rate of refund of energy G.

The interest of the test is the stability of G according to various crowns and the comparison with an analytical solution.
This test contains a modeling into axisymmetric.
The variations of the calculation of G on various crowns compared to the reference solution do not exceed
1,5%.
Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HI-75/96/032/A

1
Problem of reference
1.1 Geometry
AB: grnm2
OC: grnm1
Y
A: N3
OA: grn03
BC: grn05
C
X
O
With
B
It is about a circular crack of ray OA = 5.
The presumedly infinite medium is modelled by a sphére ray OB = 600.
1.2
Material properties
Thermal conductivity:
= 1.
Thermal dilation coefficient:

= 10-6/°C
Young modulus:
E = 2.105 MPa
Poisson's ratio:
= 0.3

1.3
Boundary conditions and loadings

· Mécanique: Imposed Déplacment
(GROUP_NO: grnm1 DX: 0.)
(GROUP_NO: grnm2 DY: 0.)
· Thermique
:
TEMP_IMPO
(GROUP_NO: grno3 TEMP: 0.)
(GROUP_NO: grno5 TEMP: -1.)
(NODE: N3 TEMP: -1.)

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution results from OLESIAK and SNEDDON [bib1]:
Z
T0 = constant = -- 1
Y
O
has
X

The expression of the rate of refund of energy is as follows:
(1- 2)
E
G =
K 2 with *K*
1
1 =
T has
E
(1 -) 0
(1- 2)
that is to say: *G* =
2
2
(

1-)
E T has
2
0

2.2
Result of reference

The result of reference is thus: G = 5.9115 10-7 J/m2

2.3 Reference
bibliographical

[1]
Uniform Temperature one has Penny-Shaped Crack (OLESIAK and SNEDDON (1959)), begun again in Handbook of stress-intensity, factors of G.C. SIH.

4/6

3 Modeling
With
3.1
Characteristics of modeling

It is about a modeling into axisymmetric:

3.2
Characteristics of the grid

A number of nodes: 832
A number of meshs and types: 323 TRIA6, 42 QUAD8, 59 SEG3
Crown 1:
Rinf=1.
Rsup=4.
Crown 2:
Rinf=0.5
Rsup=4.5
Crown 3:
Rinf=1.5
Rsup=3.5
Crown 4:
Rinf=1.
Rsup=4.5

3.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
THERMICS
AXIS
[U4.22.01]
AFFE_MODELE
MECHANICS
AXIS
[U4.22.01]
THER_LINEAIRE
[U4.33.02]
MECA_STATIQUE
[U4.31.01]
CALC_THETA
THETA_2D
[U4.63.02]
CALC_G_THETA
OPTION

---

4 Results of modeling A

4.1 Values tested

The values tested are those of the rate of refund of energy G on the various crowns of integration:

Identification	**Reference**	***Aster***	**% difference**	**% Tolerance**
Crown 1 G	1.4778 10-6	1.4586 10-6	1.30	1.50
Crown 2 G	1.4778 10-6	1.4574 10-6	1.38	1.50
Crown 3 G	1.4778 10-6	1.4583 10-6	1.32	

1.50
Crown 4 G
1.4778 10-6
1.4573 10-6
1.38
1.50

4.2 Notice

The value of reference is G = 5.945 10-7 J/m2
It is given per unit of area of extension of the crack, therefore for A = 5 and taking into account
has
symmetry of the grid, it is necessary to compare the result of *Aster* with: *G*
= *G*
Aster
réf ×
= 1.4778 10-6, because G
2
in *Aster* to a surface of extension of 1 radian corresponds.

4.3 Parameters
of execution

Version: 3.1
Machine: CRAY C98
System:
UNICOS
Obstruction memory:
8 MW
Time CPU To use:
6 seconds

5
Summary of the results
Invariance of the result compared to the crowns. Correct thermal term.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
V7.03.103 document

HPLV103 - Calculation of KI and G thermoelastic 3D
for a circular crack

Summary

It is about a test of breaking process into thermomechanical for a three-dimensional problem. One consider a circular crack plunged in a thermoelastic medium. A uniform temperature is imposed on the lips of the crack. This test makes it possible to calculate the total rate of refund of energy G and the factor of intensity of the constraints room KI in various points of the bottom of crack.

The interest of the test is the invariance of G and KI according to various crowns and the comparison with a solution analytical.

This test contains two modelings 3D.

Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HT-62/06/005/A

1
Problem of reference

1.1 Geometry

One considers a circular crack plunged in a thermoelastic medium. Taking into account symmetries of the problem, only a eighth of the structure is represented:

Z
E
H
F
G
D
O
R
y
P
Q
B
C
X

Dimensions of the crack are as follows:

COP = GOLD = 1.0

The medium is modelled by a parallelepiped of dimensions:

OB = OD = OC = 30.0

1.2
Material properties

Thermal conductivity:
= 1.
Thermal dilation coefficient:
= 10-6/°C

Young modulus:
E = 2.10+5 MPa
Poisson's ratio:
= 0.3

1.3
Boundary conditions and loadings

.
Mechanics: displacements imposed (DDL_IMPO) on the following groups of meshs:

DX = 0 on ODHE;
DY = 0 on OEFB;
DZ = 0 on PBCDRQ (i.e lower face of the parallelepiped, without the lip of the crack).

.

Thermics: temperature imposed (TEMP_IMPO) on the following groups of meshs:
TEMP = 0 on BCGH, CDHG and EFGH (outsides of the parallelepiped);
TEMP = -1 on OPQR.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution results from the collection of MURAKAMI [bib1]:

Z
T0 = constant = - 1
Y
O
has
X

The expression of the rate of refund of energy is as follows:

(1 2
-)
E
2
G =
K avecK =
T
F has, with = a/b and,
1
1
E
(1-)
( )
0

F () = 1 -.
0

6366 - .
0

4053 2 + .
2

0163 3 - .
0

6773 4 - .
3

8523 5 + .
4

1687 6 + .
3

2741 7 .

Note:

For = 0 (infinite medium), the solution is exact. For a medium finished, uncertainty on the solution is unknown. In this test, = 1/30.

2.2 Result of reference

The result of reference is thus: KI = 157.73 103 Pa m1/2 and G = 1.132 10-1 J/m2

2.3 References bibliographical

[1]
Stress intensity factors Handbook (Y. MURAKAMI), box 11.39, pp. 1089-1090, the Society of Material Science, Japan, Pergamon Press, 1987.

Handbook of Validation
V7.03 booklet: Thermomechanical stationary linear of the voluminal systems
HT-62/06/005/A

---

3 Modeling With

3.1 Characteristics of modeling

It is about a three-dimensional modeling. The grid was carried out using procedure GIBI of block fissured 3D [bib1]. One represented only the eighth of the structure (and thus a quarter of the face of the crack), the quarter of this face being discretized in 16 sectors.

3.2 Characteristics of the grid

The grid is composed of quadratic elements

A number of meshs and types: 624 PENTA 15, 5600 HEXA 20

3.3 Functionalities tested

Orders

THER_LINEAIRE

MECA_STATIQUE

CALC_THETA THETA_3D

CALC_G_THETA_T

CALC_G_LOCAL_T CALC_G

4
Results of modeling A

4.1 Values
tested

The values tested are those of the rate of refund of energy G total and the rate of refund of energy room at points A and B starting from the various crowns of integration and the two methods of definition of the fields:

Identification Reference
Aster *%*
difference
G total

Crown 1 G
8.8910-8 8.66
10-8
2.53
Crown 2 G
8.8910-8 8.68
10-8
2.31
Crown 3 G
8.8910-8 8.69
10-8
2.17
Crown 4 G
8.8910-8 8.68
10-8
2.31
G local Lagrange Legendre (degree 7)

G local 1 in A
5.66 10-8
6.13 10-8
8.31
G local 2 in A
5.66 10-8
6.19 10-8
9.37
G local 3 in A
5.66 10-8
6.42 10-8
13.46
G local Lagrange Legendre (degree 7)

G local 1 out of B
5.66 10-8 5.50
10-8
2.75
G local 2 out of B
5.66 10-8 5.51
10-8

2.62
G local 3 out of B
5.66 10-8 5.50
10-8
2.84
G local Legendre Legendre (degree 7)

G local 1 in A
5.66 10-8
5.54 10-8
2.07
G local 2 in A
5.66 10-8
5.58 10-8
1.39
G local 3 in A
5.66 10-8
5.71 10-8
1.01
G local Legendre Legendre (degree 7)

G local 1 out of B
5.66 10-8 5.51
10-8
2.62
G local 2 out of B
5.66 10-8 5.52
10-8
2.46
G local 3 out of B
5.66 10-8 5.52
10-8
2.52

Crown 1:
Rinf=0.07
Rsup=0.2
Crown 2:
Rinf=0.2
Rsup=0.4
Crown 3:
Rinf=0.4.

Rsup=0.6.
Crown 4:
Rinf=0.07
Rsup=0.6

The supports of the local field correspond to the first three crowns of the total field.

4.2 Remarks

.
The value of reference is the value of the rate of refund of energy room: Gréf = 5.66 10-8 J/m2. The total rate of refund of energy provided by Code_Aster is:

2 A
G
= G
Aster
réf ×
, since by reason of symmetry one models only one quarter of the plan of
8
fissure and only one lip.

.
The results of G local are not given that for the points A and B respectively located on one symmetry plane and face of crack. Results concerning the point B (medium of face) reveal a variation from approximately 3% compared to the result of reference. Results concerning point A are worse (the variation ranges between 3% and 13.5%), which is a report usual for the estimate of G local for the points located on a symmetry plane.

---

5 Modeling B

5.1 Characteristics of modeling and the grid

It is about a three-dimensional modeling. To calculate the local KI it is necessary to pass by order DEFI_FISS_XFEM.

A grid made up of quadratic elements, identical to that of modeling A, is used for thermal calculation:

A number of meshs and types: 624 PENTA 15, 5600 HEXA 20

After thermal calculation the quadratic meshs are converted into linear meshs (operator CREA_MAILLAGE, key word QUAD_LINE). The conversion of the grid is necessary because the operator DEFI_FISS_XFEM functions for the moment only with linear elements.

A number of meshs and types: 624 PENTA 6, 5600 HEXA 8

5.2 Functionalities tested

Orders

THER_LINEAIRE

CREA_MAILLAGE QUAD_LINE

MECA_STATIQUE

CALC_THETA THETA_3D

CALC_G_THETA_T

DEFI_FISS_XFEM

CALC_G_LOCAL_T CALC_K_G

6
Results of modeling B

6.1 Values tested

The values tested are those of the total rate of refund of energy G and of the factor of intensity of constraints room KI at points A and B starting from the various crowns of integration:

Identification Reference
Aster %
difference
G total

Crown 1 G
1.7781 10-1 1.686
10-1
-5.2
Crown 2 G
1.7781 10-1 1.695
10-1
-4.7
Crown 3 G
1.7781 10-1 1.696
10-1
-4.6
Local KI Lagrange - Lagrange

Local KI 1 in A
157.73 103
158.8 103
0.7
Local KI 2 in A
157.73 103
161.0 103
2.1
Local KI 3 in A
157.73 103
161.9 103
2.7
Local KI 1 out of B
157.73 103
159.7 103
1.2
Local KI 2 out of B
157.73 103
162.1 103
2.7
Local KI 3 out of B
157.73 103
163.1 103
3.3

Crown 1:
Rinf=0.04

Rsup=0.2
Crown 2:
Rinf=0.08
Rsup=0.28
Crown 3:
Rinf=0.08
Rsup=0.36

In this modeling, the use of key word SYME_CHAR makes it possible to multiply it automatically result by two to take into account symmetry compared to the lips of the crack.

The results of local KI are not given that for the points A and B respectively located on a plan of symmetry and in the middle of the face of crack. Results concerning point A and the point B (medium of face) are also satisfactory, with a variation from approximately 3% compared to the result of reference.

7
Summary of the results

.
The passage of a quadratic grid to a linear grid for mechanical calculation decreases precision of the result: G total have a variation of 4.8% on average with the reference for linear grid against 2.2% for the quadratic grid.
.

The smoothing LEGENDRE-LEGENDRE led, on this case test, to the most precise results for local values of G. For the calculation of K local, smoothing LAGRANGE-LAGRANGE is advised.

.

The precision on the calculation of local KI is satisfactory, the average deviation being limited to 2.3%.

HSLS01 - Thin square plate subjected to one heat gradient in the thickness

Summary

The purpose of this test is to validate thermal dilation in the elements of plate, where the temperature is variable in the thickness.

Two modelings make it possible to test modelings DKT, DST, Q4G on meshs TRIA3 and QUAD4 and COQUE_3D on meshs TRIA7 and QUAD9.
Handbook of Validation
V7.11 booklet: Thermomechanical linear statics of the plates and hulls
HT-66/02/001/A

1
Problem of reference

1.1 Geometry

= 1.2 m have
C
B = 1.3 m
E = 0.01 m
E is the thickness of the plate

B
D
B
y
has
= 53.1301°
Z
X
With

1.2
Properties of materials

Young modulus: E = 2.1011 Pa
Poisson's ratio: = 0.3
Dilation coefficient: = 1.105 °C1

1.3
Boundary conditions and loadings

Sides AB, BC, CD and DA are embedded. The temperature is constant on the higher face and to Ts = 100°C is equal.
The temperature is constant on the lower face and is equal to Ti = 0°C; the variation in temperature is supposed to be linear in the thickness.

3/8

2 Reference solution

2.1 Method of calculation used for the reference solution

The solution is analytical.
C
B
D
M
With

The thermal loading is equivalent to a loading defined by a uniform distribution of moments on the edges such as it appears on the figure.
T - T
E × e3
S
I
× (1+)
The value of these moments per unit of length is equal to: M =
×
.
E
(
12 1 - 2)
E × e2
That is to say: M = (T - T
S
I) ×
. This led to a uniform distribution of M in the plate
12(1-)
.

2.2 Results of reference

There are thus M = 2380.95238 NR; the plate being turned of an angle = 53°.1301, one has components whose absolute value is: M X cos = 1428.5715 NR and M X sin = 1904.76184 NR.

The reactions are defined by a distribution of moments equal to the preceding one in absolute value *and of contrary sign.*

The meshs are squares of which the length is equal to 0.05 m, therefore the moments in each node to M1 = M X must be equal cos X 0.05 = 71.42857 N.m
and m2 = M X sin X 0.05 = 95.2381 N.m
that is to say M =
M2
2
1 + m2 = 119.0476 N.m

2.3
Uncertainty on the solution

Uncertainty is null.

2.4 References
bibliographical

[1]
TIMOSHENKO: Theory of punts and shells chapter 2, article 14.
Handbook of Validation
V7.11 booklet: Thermomechanical linear statics of the plates and hulls
HT-66/02/001/A

---

3 Modeling
With

3.1
Characteristics of modeling

The model consists of:

· 936 elements,
· 675 nodes,

of which:
-
114 elements Q4G,
-
84 elements DSQ,
-
84 elements DKQ,
-
312 DST elements,
-
312 elements DKT.

The elements are squares of which the length is equal to 0.05 Mr.

Edges AB, BC, CD and DA are embedded.

The plate is subjected to a variation in temperature of 100°C in the thickness. This gradient is uniform on the plate.

3.2 Functionalities tested

Order

CREA_CHAMP
NOM_CMP
TEMP
TEMP_INF
TEMP_SUP
AFFE_CHAR_MECA
TEMP_CALCULEE
EPSI_INIT
MECA_STATIQUE
OPTION
SIEF_ELGA_DEPL
CALC_NO
FORC_NODA
Handbook of Validation
V7.11 booklet: Thermomechanical linear statics of the plates and hulls

---

4
Results of modeling A

4.1 Values
tested

R
X-ray reaction according to O X
R
Ry reaction according to O y

Identification Reference
Aster %
difference
N104 (on edge AD in the part with a grid DRx = 71.4286
DRx = 71.4286
0
in DKT)
DRy = 95.2381
DRy = 95.2381
0

N260 (on edge AD in the part with a grid DRx = 71.4286
DRx = 71.4286
0

in DSQ)
DRy = 95.2381
DRy = 95.2381
0

N270 (on edge AD in the part with a grid DRx = 71.4286
DRx = 71.4286
0
in Q4G)
DRy = 95.2381
DRy = 95.2381
0

N8 (on edge AB in the part with a grid in DRx = 95.2381
DRx = 95.2381
0
DKT)
DRy = 71.4286
DRy = 71.4286
0

N21 (on edge AB in the part with a grid DRx = 95.2381
DRx = 95.2381
0
in DST)
DRy = 71.4286
DRy = 71.4286
0

N102 (on edge BC in the part with a grid DRx = 71.4286
DRx = 71.4286
0
in DST)
DRy = 95.2381

DRy = 95.2381
0

NR 466 (on edge BC in the part with a grid DRx = 71.4286
DRx = 71.4286
0
in DKQ)
DRy = 95.2381
DRy = 95.2381
0

NR 544 (on edge BC in the part with a grid DRx = 71.4286
DRx = 71.4286
0
in Q4G)
DRy = 95.2381
DRy = 95.2381
0

4.2 Remarks

The nodes tested are about placed as follows:

N544
N466
4G
Q
DKQ
N102
DSQ
DST
N270
N260
N21
DKT
N104
N8

5 Modeling B

5.1 Characteristics of modeling

Modeling is COQUE_3D.

The model consists of:

· 662 elements,
· 2267 nodes,

of which:
- *462 triangles with 7 nodes,*
- *200 quadrilaterals with 9 nodes.*

Edges AB, BC, CD and DA are embedded.

The plate is subjected to a variation in temperature of 100°C in the thickness. This gradient is uniform on the plate.

5.2 Functionalities tested

Order

CREA_CHAMP
NOM_CMP
TEMP
TEMP_INF
TEMP_SUP
AFFE_CHAR_MECA
TEMP_CALCULEE
EPSI_INIT
MECA_STATIQUE
OPTION
SIEF_ELGA_DEPL
CALC_NO
FORC_NODA
STAT_NON_LINE
CALC_ELEM
OPTION EFGE_ELNO_DEPL
OPTION SIEF_ELNO_ELGA

6
Results of modeling B

6.1 Values tested

One tests moments MXX and MYY. These values are given in the local reference mark to the plate,

chosen
parallel at the sides.

One thus has: MXX = MYY = M = 2,38095 103 NR as the moment is uniform in the plate, it is enough to test the values maximum and minimum of the moments and to check that they are both equal to M:

Identification
Reference
***Aster** %*
diff
Efforts obtained by EFGE_ELNO_DEPL:
MXX Maximum
-2,38095 103 -2,38095
103 0

MXX Minimum
-2,38095 103 -2,38095
103 0

Maximum MYY
-2,38095 103 -2,38095
103 0

Minimum MYY
-2,38095 103 -2,38095
103 0

Efforts obtained by SIEF_ELNO_ELGA:
MXX Maximum
-2,38095 103 -2,38095
103 0

MXX Minimum
-2,38095 103 -2,38095
103 0

Maximum MYY
-2,38095 103 -2,38095
103 0

Minimum MYY
-2,38095 103 -2,38095
103 0

---

7 *Summary of the results*

The perfect adequacy of the results with the analytical reference shows the good taking into account of variation in the temperature.

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.12 booklet: -
Document: V7.12.303

HSLA303 - Roll under pressure and dilation thermics

Summary:

Calculation is carried out into axisymmetric. The goal of the test is to validate the initial deformations (key word EPSI_INIT).

The cylinder is subjected to a homogeneous thermal dilation (T constant).

The followed procedure is as follows:

.

that is to say 1 the field of deformations resulting from one the 1st calculation, the cylinder being subjected to a dilation *homogeneous thermics T (**U1 the** field of resulting displacements),*
.

*in the second calculation, the cylinder is subjected to an internal pressure, with like deformations initial the field of deformations 1 (either **U2 the** resulting field of displacements),*
.
*one then compares the results with the field **U**, obtained with cylinder under pressure, but without initial deformations. One must have the relation: **U2** = **U** + **U1**.*

1
Problem of reference

1.1 Geometry

O
Z

H

With
D

B
C

L

R

Length:
L
= 1 m
Thickness:
H
= 0.0025 m
External ray:
Re = 0.05 m

1.2
Material properties

E = 2.1 X 1011 Pa

v = 0.3

= 0.12 X 10-4/°C

1.3
Boundary conditions and loadings

·
Section AB in support (direction Z),
·
Thermal dilation in the thickness (calculation 1): T = 100°C
·
Internal pressure (calculation 2): p = 2 X 108 N/m2
·
Taking into account of the basic effect.

1.4 Conditions
initial

2
Reference solution

2.1
Method of calculation used for the reference solution

.
The deformation due to direct compression is given by:

(1 - 2v) (2R - H)

E
=
p = 3.714 X 10-3, Re = external ray
zz
4Eh

.
Axial displacement due to the pressure is given by:

Uz = Z zz

.
The deformations due to the thermal loading are worth:

= = = T
= 1.2 X 10-3
rr

Z Z

.
Radial displacement due to the thermal loading is worth:

U = R = 1.2 X 10-3 R
R
rr

2.2
Results of reference

.
Deformation and radial and axial displacement at the points A, B, C, D due to the thermal loading.
.
Deformation and axial displacement at the points A, B, C, D due to the pressure.

2.3
Uncertainty on the solution

Analytical solution.

4/6

3 Modeling
With

3.1
Characteristics of modeling

AXIS, mesh Q 8

Cutting:
10 elements according to the length

1 element in the thickness

Limiting conditions:

in A, B
DDL_IMPO = (GROUP_NO = "A", DY = 0.)

DDL_IMPO = (GROUP_NO = "B", DY = 0.)

Pressure + basic effect: field U

PRES_REP:
(GROUP_MA = cont_pr, CLOSE = 2.E8)
FORCE_CONTOUR: (GROUP_MA = effond, FY = 1.95E9)

Thermal dilation: U1 field

char_no:

CREA_CHAMP
(AFFE = (ALL = "YES", NOM_CMP = "TEMP", VALE = 100.))

char_th:

AFFE_CHAR_MECA
(TEMP_CALCULEE = char_no)

Initial deformations: U2 field

EPSI_INIT:
(ALL = "YES", EPXX = 1.2E-3, EPYY = 1.2E-3,

EPZZ = 1.2E-3, EPXY = 0.)

Names of the nodes:

With = N1
B = N2
C = N3
D = N4

3.2
Characteristics of the grid

A number of nodes: 53

A number of meshs and types: 10 QUAD8, 22 SEG3

3.3 Functionalities
tested

Orders

“MECHANICAL” AFFE_MODELE
“AXIS”
ALL

AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

TEMP_CALCULEE

PRES_REP
GROUP_MA
CREA_CHAMP AFFE

CALC_CHAM_ELEM OPTION
“EPSI_ELNO_DEPL”

AFFE_CHAR_MECA EPSI_INIT

Handbook of Validation
V7.12 booklet: - HT-66/05/005/A

Code_Aster ®
Version
7.4

Titrate:
HSLA303 - Roll under pressure and thermal dilation

Date:
25/11/05
Author (S):
X. DESROCHES Key
:
V7.12.303-A Page:
5/6

4
Results of modeling A

4.1 Values
tested

Results concerning the fields U1, U2, U

Field Localization Variables Reference Aster
% Reference
Field
In Ur (DX)
5.7 X 10-5
5.7 X 10-5
-6.42 X 10-11
U1 thermics
B
Ur
(DX)
6 X 10-5
6 X 10-5
-7.14 X 10-11

C
Ur (DX)
6 X 10-5
6 X 10-5
8.29 X 10-12
DY
1.2 X 10-3
1.2 X 10-3
3.9 X 10-10
D
Ur (DX)
5.7 X 10-5
5.7 X 10-5
1.19 X 10-11
U (DY)
1.2 X 10-3
1.2 X 10-3
3.9 X 10-10

With, M1 mesh
rr
1.2 X 10-3
1.2 X 10-3
-1.91 X 10-10

1.2 X 10-3
1.2 X 10-3
5.54 X 10-10

zz
1.2 X 10-3
1.2 X 10-3
-1.12 X 10-10

B, M1 mesh
rr
1.2 X 10-3
1.2 X 10-3
-1.89 X 10-10

1.2 X 10-3
1.2 X 10-3
5.57 X 10-10

zz
1.2 X 10-3
1.2 X 10-3
-1.16 X 10-10

C, M10 mesh
rr
1.2 X 10-3
1.2 X 10-3
-3.74 X 10-11

1.2 X 10-3
1.2 X 10-3
1.08 X 10-10

zz
1.2 X 10-3
1.2 X 10-3
-4.74 X 10-12

D, M10 mesh
rr
1.2 X 10-3
1.2 X 10-3
-3.98 X 10-11

1.2 X 10-3
1.2 X 10-3
1.12 X 10-10

zz
1.2 X 10-3
1.2 X 10-3 -2.93
x10-12

Field of
C
U (DY)
3.714 X 10-3
3.997 X 10-3
7.614
pressure U
D
U (DY)
3.714 X 10-3
3.997 X 10-3
7.614

C, M10 mesh

3.714 X 10-3
3.996 X 10-3
7.602

D, M10 mesh

3.714 X 10-3
3.996 X 10-3
7.602
U2 field
C
U
4.914 X 10-3
5.197 X 10-3
5.754
D
U
4.914 X 10-3
5.197 X 10-3
5.754
C,
net

4.914 X 10-3
5.196 X 10-3
5.746
D,
net

4.914 X 10-3
5.196 X 10-3
5.746

4.2 Remarks

.
The goal of the test is not to obtain a high degree of accuracy on the level of the results, but simply to check the relation: U2 = U + U1; so calculation was carried out only with one grid coarse.

.
It is noted that the required relation is well checked at the loose lead of the cylinder.

.
It is checked in addition that the field of deformation resulting from thermal dilation is uniformly equal to 1.2 X 10-3.

5
Summary of the results

Option EPSI_INIT (initial deformations into constant) provides completely satisfactory results.

V7.12 booklet: - HT-66/05/005/A

Code_Aster ®
Version
6.3

Titrate:
EPICU01 - Validation of order POST_K_BETA

Date:
07/01/04
Author (S):
A. Key DAHL, A. BOYER
:
V7.14.100-A Page:
1/10

Organization (S): EDF-R & D /MMC, CS

Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems
Document: V7.14.100

EPICU01 - Validation of the order
POST_K_BETA

Summary:

This test validates the operation of the order POST_K_BETA which calculates the factors of intensity of
constraints with the two points of defects, using the constraints with the nodes resulting from the mechanical resolution.
This test breaks up into two type of modeling:

· EPICU01a: axisymmetric modeling,
· EPICU01b: modeling 3D.
Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems
HT-26/03/023/A

Code_Aster ®
Version
6.3

Titrate:
EPICU01 - Validation of order POST_K_BETA

Date:
07/01/04
Author (S):
A. *Key* **DAHL,** *A. BOYER*
:
V7.14.100-A Page:
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1 *Problem of reference*

1.1 Geometry

The studied geometry is that of a section of tank bimetal, limited to 45° in azimuth.

Base metal
Coating

erz

200 mm
200 mm

er

45°

Center
er

R
7.5 mm
the tank

1994 mm

1.1.1 Defect considered

In the method K, the defect is not modelled in the grid. The grid makes it possible to calculate constraints with the nodes. A postprocessing is then applied to calculate the factor of intensity constraints by the method starting from the constraints with the nodes (the method is detailed in [R7.02.10]).
For this test, the defect considered is elliptic and of longitudinal orientation. Its dimensions are them following (see figure which follows):

· depth: prof_def = 6mm
· width: 2b = 60mm
· shift in the coating: decaf = 0,2mm

3/10

Initial defect
Defect considered
in calculation
2b
2a
- decaf
prof_def
Coating
Base metal
ray_int
ep_rev
ep_mdb
Center tank

1.2
Material properties

For calculation in thermics:

Two properties are indicated, it acts of:

· LAMBDA: thermal conductivity isotropic function of the temperature, expressed in W.m
1.K-1,
· BETA: voluminal enthalpy according to the temperature, expressed in J.m3.

For the coating:

Temperature (°C)
Lambda
0 14.7
20 14.7
50 15.2
100 15.8
150 16.7
200 17.2
250 18
300 18.6
350 19.3

Temperature (°C)
BETA

0 0.000000.E+00
50 1.102100.E+08
100 3.013300.E+08
150 5.014300.E+08
200 7.081300.E+08
250 9.188800.E+08
300 1.132910.E+09
350 1.348980.E+09

For the base metal:

Temperature (°C)	***Lambda***
0	*37.7*
20	*37.7*
50	*38.6*
100	*39.9*
150	*40.5*
200	*40.5*
250	*40.2*
300	*39.5*
350	*38.7*

Temperature (°C)	***BETA***

0 0.000000.E+00
50 1.061900.E+08
100 2.903300.E+08
150 4.829100.E+08
200 6.832800.E+08
250 8.921600.E+08
300 1.109440.E+09
350 1.335060.E+09

For calculation in mechanics:

Four parameters are indicated, it acts of:

· E:
modulus Young, expressed out of Pa,
· naked = 0.3
Poisson's ratio,
· ALPHA:
isotropic thermal dilation coefficient, expressed in °C,
· TEMP_DEF_ALPHA = 20: value of the temperature to which values of the coefficient of thermal dilation ALPHA were determined, expressed in °C.

For the coating:

Temperature (°C)
E
0 1.985E+11
20 1.97E+11
50 1.95E+11
100 1.915E+11
150 1.875E+11
200 1.84E+11
250.1.8E+11
300 1.765E+11
350 1.72E+11

Modeling has

Modeling B
Temperature (°C)
ALPHA

Temperature (°C)

ALPHA
0 1.756E-05

20 1.764E-05

20 1.64E-05
50 1.7787E-05

50 1.654E-05
100 1.8019E-05

100 1.68E-05
150 1.8225E-05

150 1.704E-05
200 1.8575E-05

200 1.72E-05
250 1.8568E-05

250 1.75E-05
300 1.8768E-05

300 1.777E-05

For the base metal:

Temperature (°C)
E
0 2.05E+11
20 2.04E+11
50 2.03E+11
100 2E+11
150 1.97E+11
200 1.93E+11
250 1.89E+11
300 1.85E+11
350.1.8E+11

Modeling has

Modeling B
Temperature (°C)
ALPHA

Temperature (°C)
ALPHA
0 1.2878E-05

20 1.3002E-05

20 1.122E-05
50 1.3198E-05

50 1.145E-05
100 1.3521E-05

100 1.179E-05
150 1.382E-05

150 1.214E-05
200 1.4102E-05

200 1.247E-05
250 1.4382E-05

250 1.278E-05
300 1.4682E-05

300 1.308E-05

1.3 Boundary conditions and loadings

The boundary conditions imposed are those of an axisymmetric system.

Two types of loadings are applied:

· heat exchange in internal skin,
· fluid pressure in internal skin.

2 Reference solution

2.1 Results of reference

The results of reference are those resulting from a similar calculation carried out starting from code CUVE1D.

2.2 Uncertainty on the solution

2%

---

3 Modeling
With

3.1
Characteristics of modeling

2D, axisymetic (SEG3, QUAD8)
5 mm

3.2
Characteristics of the grid

A number of nodes: 63
A number of elements: 12

3.3 Functionalities
tested

Orders

MECA_STATIQUE

INTE_MAIL_2D DEFI_SEGMENT
POST_K_BETA FISSURES
DEPTH

WIDTH

ORIENTATION

K1D
TABL_MECA_REV
TABL_MECA_MDB
TABL_THER

4
Results of modeling A

4.1 Values tested

Below, the comparison of the Aster results compared to the results of reference resulting from the code of calculation CUVE1D:

Type of value
Moment
Reference Aster
% difference
K1_REV
0
1.5298E+07
1.5198E+07
0
KCP_REV 0
1.8239E+07
1.8239E+0.7 0
TEMPPF_REV
0
287
287
0
K1_MDB
0

1.53234E+07
1.5234E+07
0
KCP_MDB 0
2.03147E+07
2.03147E+07 0
TEMPFF_MDB
0
287
287
0
K1_REV
3871
9.4963E+06
9.4963E+06
0
KCP_REV 3871
2.70057E+07
2.70057E+07 0
TEMPPF_REV
3871
84.93
84.93
0
K1_MDB
3871
4.3231E+06
4.3231E+06
0
KCP_MDB 3871
2.9587E+06
2.9587E+06 0
TEMPFF_MDB
3871
86.09
86.09
0

5 Modeling B

5.1 Characteristics of modeling

3D (SEG3, QUAD8, HEXA20)

5.2 Characteristics of the grid

A number of nodes: 480
A number of elements: 2559

5.3 Functionalities tested

Orders

MECA_STATIQUE

INTE_MAIL_3D DEFI_SEGMENT
POST_K_BETA FISSURES
DEPTH

WIDTH

ORIENTATION

K1D
TABL_MECA_REV
TABL_MECA_MDB
TABL_THER

6
Results of modeling B

6.1 Values
tested

Below, the comparison of the Aster results compared to the results of reference resulting from the code of calculation CUVE1D:

Type of value
Moment
Reference Aster
% difference
K1_REV
3871
9.419E+06

9.517E+06
1.04
KCP_REV 3871
25.563E+06
25.503E+06 0.23
TEMPPF_REV
3871
84.84
84.92
0.10
K1_MDB
3871
3.578E+06
3.604E+06
0.74
KCP_MDB 3871
26.363E+06
26.197E+06 0.63
TEMPFF_MDB
3871
86.02
86.08
0.07

7
Summary of the results

This case test validates order POST_K_BETA for the two types of modeling.
Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems
HT-26/03/023/A

Code_Aster ®
Version
7.1

Titrate:
HSLV304 - Roll under thermal loading

Date:
06/11/03
Author (S):
X. DESROCHES *Key*
:
V7.14.304-A Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems
V7.14.304 document

HSLV304 - Roll under thermal loading

Summary:

The goal of the test is to validate a decomposable thermal loading in 2 harmonics, applied to one axisymmetric structure (cylinder in fact).

The harmonies considered are harmonies 1 and 2.
The comparison is carried out compared to a model hull, with a software finite elements.

In modeling B, one imposes a field of initial deformations O defined by AFFE_CHAR_MECA, corresponding to the field of deformations resulting from model A. the goal is to compare the results compared to
those obtained for model A.
Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems
HT-66/03/008/A

---

1 Problem of reference

1.1 Geometry

Length
:
L
= 4 m
Position of the points E, F, G
Thickness:
H
=
0.1
m
.
E, F, G
remote Ro of the axis
Average radius:
Ro = 1 m
.
G
with middle height

1.2 Material properties

E = 2.1 X 1011 Pa
= 0.3
= 0.12 X 104/°C

1.3 Boundary conditions and loadings

.
Sections AB and CD embedded
.
Field of temperature T = cos + sin 2

1.4 Conditions initial

Without object for the static analysis.

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V7.14 booklet: Thermomechanical linear statics of the voluminal systems
HT-66/03/008/A

---

2 Reference solution

2.1
Method of calculation used for the reference solution

Comparison of the results compared to the software finite elements CA.ST.OR-SD of CETIM.

The element of CA.ST.OR used is an isoparametric element of hull with 8 nodes, based on formulation of Ahmad. It is about a degenerated three-dimensional element, of which the applicability is that of the thick hulls.

2.2
Results of reference

.
Displacement and constraints at the points E, F, G for each harmonic.
.
Displacement and constraints at the points E, F, G for the total loading.

2.3
Uncertainty on the solution

Comparison of software.
Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems
HT-66/03/008/A

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling AXIS_FOURIER, meshs QUAD8

F
D
C
G
Z
R
WITH E B

Loading
Uniform field of temperatures T0 = 1.

Cutting:
80 elements according to the length

2 elements according to the ray

Name of the nodes:

WITH = NR 1
B = N2
C = NR 3
D = NR 4
E = NR 9
F = NR 171
G = NR 371

3.2
Characteristics of the grid

A number of nodes: 645
A number of meshs and types: 160 QUAD8
Handbook of Validation
V7.14 booklet: Thermomechanical linear statics of the voluminal systems

3.3 Functionalities tested

"MECHANICAL" AFFE_MODELE "AXIS_FOURIER"
ALL
AFFE_CHAR_MECA DDL_IMPO

CREA_CHAM AFFE
"NOEUD_TEMP_R"

TEMP
AFFE_CHAR_MECA TEMP_CALCULEE

CALC_CHAM_ELEM OPTION
"SIGM_ELNO_DEPL"
MODE_FOURIER
COMB_CHAM_NO
COMB_FOURIER

COMB_CHAM_ELEM
COMB_FOURIER
MACRO_ELAS_MULT CHAR_MECA_GLOBAL

CAS_CHARGE

MODE_FOURIER

TYPE_MODE
“SYME”
CHAR_MECA
“ANTI”

4
Results of modeling A

4.1 Values
tested

Localisatio
Type of value
Reference
Aster *%*
N
(Beaver)
différenc
E
Charge in cos
Not G
ur (m)
0.96 X 105
0.963057 10-5
1.22 10-5
U (m)
0.15 X 105
0.152412 10-5
2.13 10-5
Charge in sin 2
Not G
ur (m)
0.544426 X 105 0.54442614
105
2.58 10-5
Total load
Not G
ur (m)
1.50748 10-5

1.5074832 10-5
2.16 10-4
U (m)
1.52412 10-5
1.5241197 10-5
2.13 10-5

4.2 Notice

Model EF of reference: 640 elements of hull with 8 nodes (10 elements according to the length 64 elements according to the circumference.

---

5 Modeling
B

5.1
Characteristics of modeling

Modeling AXIS_FOURIER, meshs QUAD8

F
D

C
G
Z
R
WITH E B

Loading
Field of initial deformations O constant = T0, T0 = 1.
(rr = zz = = 0.12 X 104)

Cutting:
80 elements according to the length

2 elements according to the ray

Name of the nodes:

WITH = NR 1
B = N2
C = NR 3
D = NR 4
E = NR 9
F = NR 171
G = NR 371

5.2
Characteristics of the grid

A number of nodes: 645
A number of meshs and types: 160 QUAD8

5.3 Functionalities
tested

"MECHANICAL" AFFE_MODELE "AXIS_FOURIER"
ALL
AFFE_CHAR_MECA DDL_IMPO
GROUP_NO

AFFE_CHAM_NO AFFE
GROUP_NO

NOM_CMP
AFFE_CHAR_MECA TEMP_CALCULEE

CALC_CHAM_ELEM OPTION
"SIGM_ELNO_DEPL"
MODE_FOURIER
COMB_CHAM_NO
COMB_FOURIER

COMB_CHAM_ELEM
COMB_FOURIER
MACRO_ELAS_MULT CHAR_MECA_GLOBAL

CAS_CHARGE
MODE_FOURIER
TYPE_MODE
CHAR_MECA

6
Results of modeling B

6.1 Values
tested

Localisatio
Type of value
Reference
Aster *%*
N
(Beaver)
différenc
E
Charge in cos
Not G
ur (m)
0.96 X 105
0.963057 10-5
1.22 10-5
U (m)
0.15 X 105
0.152412 10-5
2.13 10-5
Charge in sin 2
Not G
ur (m)
0.544426 X 105 0.54442614
105
2.58 10-5
Total load
Not G
ur (m)
1.50748 10-5
1.5074832 10-5
2.16 10-4
U (m)
1.52412 10-5
1.5241197 10-5
2.13 10-5

7
Summary of the results

Results obtained for the modeling B in which one imposes like initial deformations the deformations resulting from modeling A, are identical to those of modeling A.

***Code_Aster** ®*
Version
6.4

Titrate:
FORMA01 - TP of the basic training to the use of Code_Aster
Date:
16/05/03
Author (S):
***J.M. PROIX**, I. BAKER, E. BOYERE*
Key: V7.15.100-B
Page:
1/28

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.15 booklet: Thermomechanical linear statics of the voluminal systems
(formation)
V7.15.100 document

FORMA01 - Work practise formation of base with the use of Code_Aster

Summary:

This test corresponds to practical work of the basic training to the use of Code_Aster. It is about one bent piping, made up of a linear elastic material, subjected to various loadings: force applied with the end, internal pressure, thermal transient.

Modelings used are as follows:

· modeling a: beams (POU_D_T), which corresponds to the TP1,
· modeling b: hulls DKT, grid GIBI,
· modeling F: hulls DKT, grid GMSH, identical (with the grid near) to modeling B,
· modeling C: solid elements 3D, grid GIBI,
· modeling D: beams (POU_D_T), dynamic calculation,
· modeling E: elements PIPE.
· Modélisation G: solid elements 3D, (linear grid GMSH),
· Modélisation H: solid elements 3D, (quadratic grid GMSH).

The chapter 1 "Problem of reference" presents the problem to be treated and the data common to all modelings; the statements of Practical Work of the formation are included in it document:

· TP1: "beams" to see modeling A,
· TP2: "hulls" to see modeling F,
· TP3: "thermoelastic 3D" to see modeling H,

· TP4: “dynamic” to see modeling D.

1
Problem of reference

1.1 Geometry

The study relates to a piping including/understanding two right pipes and an elbow [Figure 1.1-a].

The geometrical data of the problem are as follows:

· length LG of the two right pipes is 3 m,
· the Rc ray of the elbow is 0.6 m,
· the angle of the elbow is 90 degrees,
· the thickness of the right pipes and the elbow is 0.02 m,
· and the ray external Re of the right pipes and the elbow is of 0.2 Mr.

LG

D
B
section D
section B
RC
C
O
section C

Z
Y
E
L
Z
G
X
Re
X
With
section A

Appear 1.1-a
Note:

The geometry of the problem has a symmetry compared to the plan (A, X, Y).

1.2
Material properties

For all modelings:
Isotropic linear elastic material. the properties of material are those of A42 steel:
· the Young modulus E = 204.000. 10+6 N/m2,
· the Poisson's ratio = 0.3,

· For thermoelastic calculation (modelings C, G H)
-
the thermal dilation coefficient =10.92 106/°C,
-
thermal conduction = 54.6 W/m °C,
-
voluminal heat CP = 3.71 106 J/m3 °C,

· For dynamic calculation (modeling D)
-
The Young modulus is worth 210.000. 10+6 N/m2
-
density = 7800 kg/m3,
- the damping of the clean modes will be taken to 2% for the first 2 modes, 3% for 3rd, 4% for the fourth and 5% for the fifth.

1.3
Boundary conditions and loadings

The boundary conditions for all modelings are as follows:

· for the mechanical loadings, there is an embedding on the level of section A,
· for the thermomechanical loading, there is embedding on the level of section A and of section B.

With regard to static calculations (modeling A, B, C, E, F, G, H), the loadings applied are of three types:

· constant force FY = 100.000. NR directed according to the axis Y and applied to the section B,
· pressure interns P = 15. E+6 N/m2, (modelings B, C, E, F, G, H)
· thermomechanical loading with a transient of temperature imposed on the face intern of piping (gone up 20°C with 70°C in 10 seconds) and a condition of exchange no one on the external face of piping (heat insulator) (modeling C only).

With regard to dynamic calculation (modeling D), the loading applied is a force transient (in Newton):

*FY (T) = 1 00.000. * cos (2 ** Freq1 *t)*

directed according to the axis Y and applied to the section B,

Freq1 such as = 2 *Freq1 = 121 rad/s.*

(formation)
HT-66/03/008/A

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is obtained numerically, it thus acts only of the tests of not regression. However below the results of various modelings are compared.

2.2
Results of various modelings:

2.2.1 Static calculation, Force FY

For the loading of force constant FY applied to the section B, one compares displacement with not B for various modelings (or at the point of co-ordinates (Lg+Rc, Lg+Rc, Re) for modelings hull and 3D):

Loading forces constant FY
Modeling DX
DY
DRZ
A1: beam flexibility = 1
2.657E02 6.702E
2.097E02
02
A2: beam flexibility RCCM
2.983E02 1.156E
3.530E02
01

B: Hull (grid GIBI, 1260 QUAD4) 2.90E02
1.06E01
3.27E02
F: Hull (grid GMSH, 2240 TRIA3, 700 QUAD4)
2.89E02
1.053E
3.24E02
01
C: 3D (grid GIBI, 800 HEXA20)
2.914E02 1.065E
-
01
G: 3D (grid GMSH, 7260 TETRA4, 1240 PENTA6)
2.65E02
0.731E
-
01
H: 3D (grid GMSH, 7260 TETRA10, 1240 PENTA15) 2.94E02
1.056E
-
01
E: pipe
2.935E02 1.083E
3.326E02
01
Maximum relative variation (without taking account of A1 nor G)
3%
9%
8%

For the loading of pressure, one compares displacement with the point B for the different ones modelings:
Loading
pressure
Modeling DX
DY
DRZ
B: Hull (grid GIBI, 1260 QUAD4) 2.903E01 4.687E01
1.305E01
F: Hull (grid GMSH, 2240 TRIA3, 700 QUAD4)
2.890E01 4.654E01 1.296E01
C: 3D (grid GIBI, 800 HEXA20)
2.766E01 4.473E01

-
G: 3D (grid GMSH, 7260 TETRA4, 1240 PENTA6)
2.622E01 3.967E01
-
H: 3D (grid GMSH, 7260 TETRA10, 1240 PENTA15)
2.734E01
4.41E01
-
E: pipe
2.763E01 4.505E01 1.257E01
Maximum relative variation
9%
17%
4%

Note:

So that the results of modeling beam are comparable with the different one
modelings, it is necessary to take into account the coefficients of flexibility of the elbows
(AFFE_CARA_ELEM):
65
.
1
er
C
with
courb
=
(value recommended by the RCCM, current regulation).
flex =

2
Rmoy

With regard to dynamics, one tests the constraints obtained after restitution in base physique of transitory calculation by modal recombination (on the basis of clean mode the first 5) piping subjected to force FY (T), the moment 0.2s, point b:

Component SIXX
SIYY
Constraints at the point B, urgent 0.2s
5.29775E+05
9.40503E+05

2.3
Uncertainty on the solution

The difference between the various solutions lies between 3% and 17%. This is due on the one hand to
modelings themselves (corrective terms for flexibility in the beams, and coefficient on pressure in the hulls), and in addition with the grids used, which are not very fine (so that it time of resolution is not an embarrassment for the TP of the formation.

Note:

The results 3D are much more precise with a quadratic grid.

For modeling hull, the pressure is applied to the average surface of Rmoy ray.
One thus took into account a corrective factor on the value of the pressure to be applied:
P*=P.Rint/Rmoy

---

3 Modeling
With

3.1
Characteristics of modeling

3.1.1 Grid
GMSH

The telegraphic grid could be built inter-actively using GMSH (or GIBI). It is enough to define the points A, B, C D, then the two lines AC and dB, item 0 and rings it BC. Size of the elements could be defined like parameter. In GMSH, one will be able to declare "physical" the points A and B, then lines AC and data base, then circle BC. Once grid carried out, to save it (format msh).

The elbow will be modelled initially by at least four elements of right beams (to provide for GMSH a density lower than 0.25).

With regard to the right pipes, the discretization does not have an influence on the result, because them
elements of right beam of Timoshenko (POU_D_T) of Code_Aster provide results correct with the nodes of the grid, even for a discretization with very little element, in LINEAR STATICS only [R3.08.01].

3.2
To drive orders Aster

· Lecture of grid (PRE_GMSH) and generation of grid (LIRE_MAILLAGE).

· Définition of the finite elements used (AFFE_MODELE). One will affect initially to group meshs composing the elbow, as on the right parts, modeling POU_D_T.

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU).

The mechanical characteristics are identical on all the structure.

· Affectation of the characteristics of the elements beams (AFFE_CARA_ELEM).
The section of all the pipes is circular.

· Définition of the boundary conditions and loading (AFFE_CHAR_MECA).
Piping is embedded in its base, on the level of point A.

The loading is a specific force FY applied to the point B.

· Résolution of the elastic problem (MECA_STATIQUE).
Calculation of the field of efforts generalized by element with the nodes, the field of calculated displacement (option "EFGE_ELNO_DEPL").

· Impression of results (IMPR_RESU).
One will print in form listing displacement at the point B and the maximum values of efforts.

One will also print the field of displacement to format GMSH, for one visualization of the results with GMSH. (to use DEFUFI to define the output file).

Optional calculation: curved beams and coefficient of flexibility

One will be able to check the impact of a coefficient of flexibility of the elbow on displacements with not B. This coefficient of flexibility is defined in the level of order AFFE_CARA_ELEM (key word DEFI_ARC).

It will then be necessary to assign to the group of meshs composing the elbow modeling POU_C_T.

4
Results of modeling A

4.1 Values
tested

The results obtained with 2 elements in each right part and 4 elements in the elbow are:

Without coefficient of flexibility:

Loading Value
tested
Reference
Aster %
difference
Force concentrated Fy out of B Displacement out of B Dx
2.657E02 2.657E02
0

Displacement out of B Dy
6.702E02 6.702E02
0

Rotation out of B DRZ
2.097E02 2.097E02
0

With coefficient of flexibility:

Loading Value
tested
Reference
Aster %
difference
Force concentrated Fy out of B Displacement out of B Dx
2.983E02 2.983E02
0

Displacement out of B Dy
1.156E01 1.156E01
0

Rotation out of B DRZ
3.530E02 3.530E02
0

---

5 Modeling B

5.1 Characteristics of modeling

In the case of modeling in elements hulls, the grid consists of the discretization of surface average piping. Geometry being symmetrical compared to the plan (A, X, Y), one net that a half-surface.

5.2 Characteristics of the grid

The grid is created using GIBI. It comprises 1260 meshs QUAD4, and 1356 nodes

5.3 Orders Aster

The principal stages of calculation with Aster will be:

· Lecture of grid (PRE_GIBI) and generation of grid (LIRE_MAILLAGE).

· Définition of the finite elements used (AFFE_MODELE). The right pipes and the elbow will be modelled by elements of hull (DKT).

· Réorientations of the normals to the elements: one will use MODI_MAILLAGE to direct all elements in the same way, with a normal turned towards the interior of the pipe (being data the convention of sign on the pressure) in order to give a positive value to pressure.

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU). mechanical characteristics are identical on all the structure.

· Affectation of the characteristics of the elements hulls (AFFE_CARA_ELEM): thickness

· Définition of the boundary conditions and loadings (AFFE_CHAR_MECA).

· Piping is embedded in its base, on all the nodes located in the Y=0 plan. piping presents a symmetry plane Z=0.

· One calculates two loading cases:

- an effort distributed F directed according to the axis Y and applied to the section B, (the effort distributed is such*
that the resultant 2Pi Rmoy F* = FY, FY being the total force which one wishes to apply).*
To apply the effort to the section B, FORCE_ARETE will be used,
-
a pressure interns P.

Note:

The value of the pressure P is positive according to the contrary direction of the normal with the element. To direct this normal MODI_MAILLAGE should be used/ ORIEN_NORM_COQUE: to define in A1 a vector giving the direction of the normal (opposed to the pressure).

· Résolution of the elastic problem for each loading case (2 calls to MECA_STATIQUE).

· Impression of results (IMPR_RESU).

· One will print in form listing displacement for each result on the section B. One will also print with format GMSH, displacements.

One will be able in the second Aster calculation to evaluate the constraints with the nodes:

· One adds in the characteristics hulls (AFFE_CARA_ELEM) the vector V defining it locate examination (key word ANGL_REP). One can take for example V=Oz.

· Calcul of the stress field by elements to the nodes for each loading case (option "SIGM_ELNO_DEPL"). The constraints are calculated in the definite local reference mark for each element using the vector V (preceding key word ANG_REP). To use NIVE_COUCHE for to define the level of calculation in the thickness.

6
Results of modeling B

6.1 Values
tested

Loading Value
tested
Reference
Aster %
difference
Force concentrated Fy out of B Displacement out of B Dx
2.901E02 2.901E02
0

Displacement out of B Dy
1.060E01 1.060E01
0

Rotation out of B DRZ
3.274E02 3.274E02
0

Internal pressure
Displacement out of B Dx
2.903E01 2.903E01
0

Displacement out of B Dy
4.687E-01 4.687E-01
0

Rotation out of B DRZ
1.305E-01 1.305E-01
0

---

7 Modeling
C

7.1
Characteristics of modeling

The right pipes and the elbow are modelled by isoparametric solid elements quadratic. Piping presents a symmetry plane Z=0. Only one half volume is netted.

Y
X
With
d2 A
With D A
e2
i2
i1
1
e1
d2
L
With
2
With
i1
P
L
With
i2
P
L
i1
2
With
i1
1
e2
e1
P
L
e1
1
D
P
1
e1
Z

7.2
Characteristics of the grid

4240 meshs HEXA20, 5913 nodes

7.3 Orders
Aster

In the case of load thermal, the study requires the first transitory thermal calculation followed of one mechanical calculation.

In order to use the possibilities of recovery of a calculation, one will make two successive and coupled executions
with Aster. In the first execution, one will make the resolution of the various loading cases, in second of postprocessings on the thermomechanical loading case.

The principal stages of the first execution with Aster will be:

Reading of grid (PRE_GIBI) and generation of grid (LIRE_MAILLAGE) in elements quadratic.

· Définition of the finite elements used (AFFE_MODELE). One will define a model for calculation thermics and a mechanical model.

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU).
thermal characteristics and mechanics are identical on all the structure.

· Définition of the boundary conditions thermal (DEFI_FONCTION and AFFE_CHAR_THER_F): There is a transient of temperature imposed on the interior surface of piping (assembled of 20°C with 70°C in 10s). It is considered that piping is insulated and thus one applies a condition of null exchange on external surface.

· Résolution of the thermal problem (THER_LINEAIRE). The calculation of the field of temperature be carried out for the two moments of the transient (5. and 10. S).

· Définition of the three mechanical loading cases: boundary conditions and loading mechanics or thermics (AFFE_CHAR_MECA):

- an effort FY directed according to the axis Y and applied to the section B, (to use FORCE_FACE. value of the surface effort of Fy resultant can be calculated in Aster using DEFI_VALEUR),
-
an internal pressure,
-
the thermal transient previously calculated,
- piping is embedded in its base (Ae1, Ai1, Ae2, Ai2), on all the nodes located in the plan of Y=0 equation. In the case of load thermal, the section B of piping is also embedded.

· Résolution for the various loading cases from the mechanical problem and calculation of the field of constraints with the nodes by element (3 calls to MECA_STATIQUE)

· Using CALC_ELEM, calculation of the constraints by elements extrapolated with the nodes (SIEF_ELNO_ELGA) and of the equivalent constraints of Von Mises (EQUI_ELNO_SIGM).

· Impression of results (IMPR_RESU).

- One will print in form listing on the one hand displacement on the section B, and of other leaves the maximum values the tensor of constraints, in the case of load mechanics.
- One will print for thermomechanical calculation, displacements, and the component VMIS on field EQUI_ELNO_SIGM with format CASTEM.
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Version
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Titrate:

The principal stages of the second execution with Aster will be:

· Création of a table per extraction of values on a way (INTE_MAIL_3D and POST_RELEVE_T).

· One will extract from the values of temperature and displacement for an azimuth on the level from the entry of elbow in the case of load thermomechanical. The azimuth is defined by the way ends (0. 3. 0.1) and (0. 3. 0.2).

· Impression of curves (IMPR_COURBE).

· One will print with format AGRAF the change of the temperature and the component following Y field of displacement, along the preceding azimuth. One will be able to then visualize these curves by means of AGRAF.

8 Results of modeling C

8.1 Values tested

Loading	Value tested	Reference	Aster	% difference
Force concentrated Fy out of B	Displacement out of B Dx	2.907E02	2.907E02	0
	Displacement out of B Dy	1.065E01	1.065E01	0

Internal pressure
Displacement out of B Dx
2.763E01 2.763E01 0

Displacement out of B Dy
4.472E01 4.472E01 0

Temperature at the moment 10s Temperature in AI1
70 70 0

Constraint of Von
1.2383 108 1.2383
108 0
Settings maximum

9 Modeling
D

9.1

Characteristics of modeling

The geometry is identical to that of modeling A. the grid must be enough fine to obtain a correct solution in dynamics, in particular to describe the clean modes correctly: bend and the right pipes will be modelled chacuns by at least 5 elements of right beams of Timoshenko POU_D_T.

One first of all wishes to know the first clean modes.

Then one will make a transitory analysis of the response of the pipe to the sinusoidal force between 0.0 and 2.0 S.
The structure is initially at rest. One will be able initially to make the analysis on basis modal. One will be able to compare the results of the analysis on modal basis with a direct analysis on base physical.

9.2
Characteristics of the grid

9.2.1 Grid
GMSH

The grid will be obtained with GMSH, as for modeling A. Attention not being forgotten in the command file ASTER to create the groups of "physical" meshs and, then, in command file ASTER to create the groups of nodes corresponding to the groups of meshs thanks to order DEFI_GROUP.

9.2.2 Alternative grid: with GIBI

For those which prefer GIBI, one will be able to create the grid using this maillor, in the following way:
one will create with the editor a data file which will include/understand the list of the instructions that one will subject
with GIBI. The various stages of modeling with GIBI will be:

· Définition of the options of grid by the procedure OPTION.
The co-ordinates of the points will be introduced in dimension 3.
The elements will be of type SEG2.

· Définition of the points A, B, C, D, O.
The points will be named Pa, PB, PC, PD, PO.

· Maillage of piping
For the grid of piping, one will use the operators RIGHT-HAND SIDE, CIRCLE and AND.
Cutting will be of only one element for the right pipes and the elbow.

· Visualisation of the final grid.
Visualization is made by the procedure TRACE, for which one must specify a point, which indicate the position of the eye which looks at the object.

· Sauvegarde of the grid for its use in Aster.
To be able to read again the grid by Aster it should be safeguarded in a formatted file, this safeguard is made by the procedure SAVE with the key word FORMAT. The file which will be creates the same name will have as the data file GIBI, but will have as an extension ".mgib".

· Arrêt of the execution of GIBI.
To leave GIBI it should be indicated by the directive END.

Note:

Any instruction GIBI ends in the symbol "; ".
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9.3 Orders *Aster*

The principal stages of calculation with *Aster* will be:

9.3.1 Preparation of the data and analyzes modal

· Maillage (not to forget the PRE_GMSH or the PRE_GIBI).

· Définition of the finite elements used (AFFE_MODELE).

· One will use the groups of meshs envisaged in GMSH (or GIBI).

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU).

· The mechanical characteristics are identical on all the structure.

· Affectation of the characteristics of the elements beams (AFFE_CARA_ELEM).

· The section of all the pipes is circular, of ray 0.2 m and thickness 0.02 Mr.

· The elbow constitutes of an arc of circle of center the point O and ray 0.6 Mr. to define the curved element, one will use key word DEFI_ARC.

· Définition of the boundary conditions and loading (AFFE_CHAR_MECA). Point A is embedded.

· Définition of the matrices of the elastic problem (MACRO_MATR_ASSE).

· Calcul of the first 5 clean modes (MODE_ITER_SIMULT).

· Impression of the clean modes (IMPR_RESU): one will print the grid and the modes with the format GMSH for a visualization in GMSH (or with format CASTEM, for a visualization of results with GIBI). In the case of GMSH, not to forget to open the logical unit of the file of postprocessing by a DEFUFI!

9.3.2 Analyze transient

Construction of the specific force

· Définition of the load forces at the point B (AFFE_CHAR_MECA FORCE_NODALE).
· Calcul of the elementary vectors forces (CALC_VECT_ELEM).
· Assemblage of the vector forces (ASSE_VECTEUR).
· Définition of the function evolution of time (FORMULA).

Transient on modal basis
· Projection of the problem assembled on the basis of clean mode (MACRO_PROJ_BASE).
· Transitory Calcul by modal recombination (DYNA_TRAN_MODAL).
· Récupération of displacements, speed in there of B, C, D (RECU_FONCTION).
· Impression of these functions to the format listing and AGRAF (IMPR_COURBE).
· One will be able to possibly determine the constraints MIN and MAX due to the efforts generalized during the transient while passing by a restitution on the physical basis (REST_BASE_PHYS), a calculation of constraints (CALC_ELEM), a skilful postprocessing for to calculate the maximum in the course of time (CREA_CHAMP) and a writing in the file result (IMPR_RESU).

Direct calculation on physical basis: transient on physical basis
· Direct transitory Calcul by Newmark (DYNA_LINE_TRAN).
· Récupération of displacements, speed in there of B, C, D (RECU_FONCTION).
· Impression of these functions to the format listing and AGRAF (IMPR_COURBE).
· Calcul of the MAX (space and temporal) of the constraints due to the generalized efforts.

9.3.3 Postprocessings

One will visualize with GMSH or GIBI the grid and the first five clean modes of the structure.
One will also trace using AGRAF the evolution of displacements according to time at the points B, C and D.
Lastly, one will be able to determine the maximum (and minimum) space and temporal of the constraints due to
generalized efforts, in order to consider the requests maximum which the pipe during this test undergoes.

9.3.3.1 Helps for postprocessing with GMSH

Postprocessing in GMSH is rather intuitive. However some points are to be known:

· One must put GMSH in *Post-Processing* mode.
· In *Tools/Options*, the Aspect mitre makes it possible to specify *Displacement* like *Vector display*, i.e to observe the modes like a structural deformation. One will be able to also specify
the amplitude of the deformation thanks to the box *Vector size*.
· The *Step* button of the *General* mitre makes it possible, as for him, to make ravel the various modes
(which is seen in GMSH like "steps of time").

9.3.3.2 Helps for postprocessing with GIBI (possibly)

One will provide a command file GIBI allowing to carry out graphic postprocessings.
Principal orders GIBI used are:

*** Second reading of the file result to format "CASTEM" coming from *Aster*:**
OPTI REST FORMAT "nom_de_fichier.cast";
REST FORMAT;
*** Recovery of the number of moments calculated in the object "resu" resulting**
of *Aster*
ninst = DIME resu;
*** One can post it:**
LIST ninst;
i=0;
*** Buckle over every filed moment:**

to repeat ninst boucl1:
I = i+1;

Ti = resu. I. inst;
*** Recovery of the fields of displacements in the result:**
C = resu. I. depl;
*** visualization of the deformation**
defo1 = defo red email C 100.;
defo0 = defo email green C 0.;
titrate “deformed Piping urgent” Ti;
trac oe (defo1 and defo0);
end boucl1;

9.3.3.3 Helps for postprocessing with AGRAF

Visualization of curves of results printed with format AGRAF. In the continuation, one will replace
<résultat> by the name of the file result of the type AGRAF produced by order IMPR_COURBE in
the command file.

The various stages of the visualization of the results with AGRAF are:

· launching of AGRAF: to type “agraf” in a window Unix,
· opening of a file Directives: small Directives (cf Table 1),
· to select To open, give a name of directive by the BSF (for example <résultat>.digr),

to click in the BSF on Opening Directive, and confirming the creation of a new file of directives,
· reading of the results resulting from Aster: small Data (cf Table 1),
· to select the file <résultat>.dogr thanks to the BSF,
· definition of the graph to be traced: small Graphs,
· to select To specify/a window entitled Spécification of the curves of a graph opens,
· a Titre zone makes it possible to give a title to the graph, to replace Nouveau graph by titrate your graph (ex: Displacement of the pipe) - in lower parts, actionable with wish by a toggle-short prop, appear of the lines of definition of the curves to trace,

· zone Abscisses one defines the n° table and the n° of the column constituting the data in to put in X-coordinates of the curve (1 1 for the L era curves),
· zone Ordonnées one defines No of the table and No of the column constituting the data in to put in ordinates of the curve (1 2 for the first curve),
· zone Marqueur one defines the shape of the marker, the periodicity of layout of this marker (all N points of the curve), (10),
· Légende zone makes it possible to give a text of legend following the curve curve (DY-B),
· to click on Safeguarding to record the definition of the graph,
· Sauvegarde and actualization of the graph to be traced: small Graphs,
-
button To safeguard,
-
button To trace,
· Impression POSTSCRIPT of the graph: fenestrate Tracé,
· button To print the Layout,

---

10 Results of modeling D

10.1 Values
tested

This test is a test of nonregression. The values of reference are the results obtained with version 6.4 of *Code_Aster*.

Loading
Value tested
Reference
***Aster* %**
difference
Force concentrated
Constraint out of B due to the effort
-6.20356 104 -6.20356
104
0
Fy out of B
normal SN

In addition to this result of nonregression, one can observe displacement according to Y of the point D:

One observes that the modes of the structure are excited during the first second transient, it who explains the chahutée shape of the curve of displacement. Then movements of the modes clean are deadened and there remains only the stationary movement regulated on the frequency of sinusoidal force at the point B.

---

11 Modeling E

11.1 Characteristics of modeling

Modeling PIPE. The elbow is modelled by 20 elements of the segment type to 3 nodes.
The right pipes are modelled by 20 elements of the segment type to 3 nodes.
The first two loadings (specific force FY and pressure intern) are treated.

11.2 Characteristics of the grid

60 meshs SEG3, 126 nodes

11.3 Functionalities tested

Orders

AFFE_CHAR_MECA FORCE_TUYAU NEAR

MECA_STATIQUE

CALC_ELEM OPTION SIGM_ELNO_DEPL

AFFE_CHAR_MECA FORCE_NODALE FY

12 Results of modeling E

12.1 Values tested

Loading Value

tested
Reference
***Aster* %**
difference
Force concentrated Fy out of B Displacement out of B Dx
2.935E02 2.935E02 0

Displacement out of B Dy
1.083E01 1.083E01 0
(Reference pipe)
Rotation out of B DRZ
3.326E02 3.326E02 0

Internal pressure
Displacement out of B Dx
2.7624E01 2.7624E
0
01

Displacement out of B Dy
4.505E01 4.505E01 0

Rotation out of B DRZ
1.257E01 1.257E01 0

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13 Modeling
F

13.1 Characteristics of modeling

This modeling in elements hulls, is in all points identical to modeling B, except grid, generated using GMSH.

13.2 Characteristics of the grid

700 meshs QUAD4, 2240 meshs TRIA3, 1344 nodes

Grid GMSH built in quadrilaterals and triangles is available in the base of the tests: geometrical data file names forma01f.datg. (to change the extension into ".geo"). It the numbers of the entities "physical corresponds to the geometry above (to find" which correspond to the groups of meshs, to use Tools/Visibility/Physical). The groups correspond with:

GM30 <=> surface of the PIPE
GM28 <=> section B (effort)

GM31 <=> not A1 (- R, 0, 0)
GM27 <=> section A (embedding)
GM29 <=> SYMMETRY

13.3 Orders
Aster

· Lecture of grid (PRE_GMSH) and generation of grid (LIRE_MAILLAGE). One can to use DEFI_GROUP to re-elect the groups of meshs according to the correspondence:

 # GM30 <=> PIPE
 # GM28 <=> EFOND
 # GM31 <=> A1
 # GM27 <=> ENCAST
 # GM29 <=> SYMMETRY

· Définition of the finite elements used (AFFE_MODELE). The right pipes and the elbow will be modelled by elements of hull (DKT).

· Réorientations of the normals to the elements: one will use MODI_MAILLAGE to direct all elements in the same way, with a normal turned towards the interior of the pipe (being data the convention of sign on the pressure) in order to give a positive value to pressure.

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU). mechanical characteristics are identical on all the structure.

· Affectation of the characteristics of the elements hulls (AFFE_CARA_ELEM): thickness

· Définition of the boundary conditions and loadings (AFFE_CHAR_MECA).

· Piping is embedded in its base, on all the nodes located in the Y=0 plan. piping presents a symmetry plane Z=0.

· One calculates two loading cases:

· An effort distributed F* directed according to the axis Y and applied to the section B, (the effort distributed is such as the resultant 2Pi* Rmoy F* = FY, FY being the total force which one wishes to apply). For to apply the effort to the section B, one will use FORCE_ARETE.

· A pressure interns P. Remarque: The value of the pressure p is positive according to the direction opposite of the normal to the element. To direct this normal it is necessary to use

MODI_MAILLAGE/ORIEN_NORM_COQUE: to define in A1 a vector giving the direction of normal (opposed to the pressure).

· Résolution of the elastic problem for each loading case (2 calls to MECA_STATIQUE).

· Impression of results (IMPR_RESU).

· One will print in form listing displacement for each result on the section B. One will also print with format GMSH, displacements.

One will be able in the second *Aster* calculation to evaluate the constraints with the nodes:

· One adds in the characteristics hulls (AFFE_CARA_ELEM) the vector V defining it locate examination (key word ANGL_REP). One can take for example V=Oz.

· Calcul of the stress field by elements to the nodes for each loading case (option "SIGM_ELNO_DEPL"). The constraints are calculated in the definite local reference mark for each element using the vector V (preceding key word ANG_REP). To use NIVE_COUCHE for to define the level of calculation in the thickness.

14 Results of modeling F

14.1 Values tested

Loading Value
tested
Reference
***Aster* %**
difference
Force concentrated Fy out of B Displacement out of B Dx
2.89E02 2.89E02
0

Displacement out of B Dy
1.053E01 1.053E01
0

Rotation out of B
3.24E02 3.24E02
0
DRZ

Internal pressure
Displacement out of B Dx
2.890E01 2.890E01
0

Displacement out of B Dy
4.654E01 4.654E01
0

Rotation out of B
1.296E01 1.296E01
0
DRZ

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15 Modeling
G

15.1 Characteristics of modeling

Modeling in voluminal elements, grid being obtained using GMSH. Modeling is in all points identical to modeling C. the results obtained differ because the elements are linear.

15.2 Characteristics of the grid

A number of nodes:
6633
A number of meshs and types: 7260 TETRA4

1539 PENTA6
4319 QUAD4
7003 TRIA3

15.3 Orders
Aster

In the case of load thermal, the study requires the first transitory thermal calculation followed of one
mechanical calculation.

In order to use the possibilities of recovery of a calculation, one will make two successive and coupled executions
with *Aster*. In the first execution, one will make the resolution of the various loading cases, in second of postprocessings on the thermomechanical loading case.

The principal stages of the first execution with *Aster* will be:

· Lecture of grid (PRE_GMSH) and generation of grid (LIRE_MAILLAGE) in elements linear. One can use DEFI_GROUP to re-elect the groups of meshs according to correspondence:

PIPE <=> GM10000
EFOND <=> GM10005
ENCAST <=> GM10001
SYMMETRY <=> GM10002
SURFINT <=> GM10004
SURFEXT <=> GM10003

· Définition of the finite elements used (AFFE_MODELE). One will define a model for calculation thermics and a mechanical model.

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU). thermal characteristics and mechanics are identical on all the structure.

· Définition of the boundary conditions thermal (DEFI_FONCTION and AFFE_CHAR_THER_F):
There is a transient of temperature imposed on the interior surface of piping (assembled of 20°C with 70°C in 10s). It is considered that piping is insulated and thus one applies a condition of null exchange on external surface.

· Résolution of the thermal problem (THER_LINEAIRE). The calculation of the field of temperature
be carried out for the two moments of the transient (5. and 10. S).

· Définition of the three mechanical loading cases: boundary conditions and loading mechanics or thermics (AFFE_CHAR_MECA):

- an effort FY directed according to the axis Y and applied to the section B, (to use FORCE_FACE.
value of the surface effort of Fy resultant can be calculated in Aster using DEFI_VALEUR),
-
an internal pressure,
-
the thermal transient previously calculated,
- piping is embedded in its base (Ae1, Ai1, Ae2, Ai2), on all the nodes located in the plan of Y=0 equation. In the case of load thermal, the section B of piping is also embedded.

· Résolution for the various loading cases from the mechanical problem and calculation of the field of constraints with the nodes by element (3 calls to MECA_STATIQUE)

· Using CALC_ELEM, calculation of the constraints by elements extrapolated with the nodes (SIEF_ELNO_ELGA) and of the equivalent constraints of Von Mises (EQUI_ELNO_SIGM).

· Impression of results (IMPR_RESU).

- One will print in form listing on the one hand displacement on the section B, and of other leaves the maximum values the tensor of constraints, in the case of load mechanics.
- One will print for thermomechanical calculation, displacements, and the component VMIS on field EQUI_ELNO_SIGM with format GMSH.

The principal stages of the **second** execution with *Aster* will be:

· Création of a table per extraction of values on a way (INTE_MAIL_3D and POST_RELEVE_T).

· One will extract from the values of temperature and displacement for an azimuth on the level from the entry of elbow in the case of load thermomechanical. The azimuth is defined by the way ends (0. 3. 0.1) and (0. 3. 0.2).

· Impression of curves (IMPR_COURBE).

· One will print with format AGRAF the change of the temperature and the component following Y field of displacement, along the preceding azimuth. One will be able to then visualize these curves by means of AGRAF.

16 Results of modeling G

16.1 Values tested

Loading
Value tested
Reference
***Aster* %**
difference
Force concentrated Fy out of B
Displacement out of B Dx
2.65E02 2.65E02 0

Displacement out of B Dy
0.731E01 0.731E01
0
Internal pressure
Displacement out of B Dx
2.622E01 2.622E01 0

Displacement out of B Dy
3.967E01 3.967E01
0
Temperature at the moment 10s Temperature in AI1
70 70 0

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17 Modeling
H

17.1 Characteristics of modeling

Modeling in voluminal elements, grid being obtained using GMSH. Modeling is in all points identical to modeling G. the linear meshs generated by GMSH are transforms in quadratic meshs by macro-order PRE_GMSH.

17.2 Characteristics of the grid

A number of nodes:
5029
A number of meshs and types: 188 HEXA20
658 PENTA15
1136 QUAD8
28 TRIA6

17.3 Functionalities tested

In the case of load thermal, the study requires the first transitory thermal calculation followed of one
mechanical calculation.

In order to use the possibilities of recovery of a calculation, one will make two successive and coupled executions
with *Aster*. In the first execution, one will make the resolution of the various loading cases, in second of postprocessings on the thermomechanical loading case.

The principal stages of the **first** execution with *Aster* will be:

· Lecture of grid (PRE_GMSH) and generation of the grid in quadratic elements (word key MODI_QUAD). Call to LIRE_MAILLAGE to read this quadratic grid. One can use DEFI_GROUP to re-elect the groups of meshs according to the correspondence:

PIPE <=> GM10000
EFOND <=> GM10005
ENCAST <=> GM10001
SYMMETRY <=> GM10002
SURFINT <=> GM10004
SURFEXT <=> GM10003

· Définition of the finite elements used (AFFE_MODELE). One will define a model for calculation thermics and a mechanical model.

· Définition and assignment of material (DEFI_MATERIAU and AFFE_MATERIAU). thermal characteristics and mechanics are identical on all the structure.

· Définition of the boundary conditions thermal (DEFI_FONCTION and AFFE_CHAR_THER_F): There is a transient of temperature imposed on the interior surface of piping (assembled of 20°C with 70°C in 10s). It is considered that piping is insulated and thus one applies a condition of null exchange on external surface.

· Résolution of the thermal problem (THER_LINEAIRE). The calculation of the field of temperature be carried out for the two moments of the transient (5. and 10. S).

· Définition of the three mechanical loading cases: boundary conditions and loading mechanics or thermics (AFFE_CHAR_MECA):

- an effort FY directed according to the axis Y and applied to the section B, (to use FORCE_FACE. value of the surface effort of Fy resultant can be calculated in Aster using DEFI_VALEUR),
-
an internal pressure,

-
the thermal transient previously calculated,
- Piping is embedded in its base (Ae1, Ai1, Ae2, Ai2), on all the nodes located
in the plan of Y=0 equation. In the case of load thermal, the section B of
piping is also embedded.

· Résolution for the various loading cases from the mechanical problem and calculation of the field of constraints with the nodes by element (3 calls to MECA_STATIQUE)

· Using CALC_ELEM, calculation of the constraints by elements extrapolated with the nodes (SIEF_ELNO_ELGA) and of the equivalent constraints of Von Mises (EQUI_ELNO_SIGM).

· Impression of results (IMPR_RESU).

- One will print in form listing on the one hand displacement on the section B, and of other
leaves the maximum values the tensor of constraints, in the case of load
mechanics.
- One will print for thermomechanical calculation, displacements, and the component
VMIS on field EQUI_ELNO_SIGM with format GMSH.

The principal stages of the **second** execution with *Aster* will be:

· Création of a table per extraction of values on a way (INTE_MAIL_3D and POST_RELEVE_T).

· One will extract from the values of temperature and displacement for an azimuth on the level from the entry of elbow in the case of load thermomechanical. The azimuth is defined by the way ends (0. 3. 0.1) and (0. 3. 0.2).

· Impression of curves (IMPR_COURBE).

· One will print with format AGRAF the change of the temperature and the component following Y field of displacement, along the preceding azimuth. One will be able to then visualize these curves by means of AGRAF.

18 Results of modeling H

18.1 Values tested

Loading
Value tested
Reference (3D
***Aster* %**
MOD. C)
difference
Force concentrated Fy out of B
Displacement out of B Dx
2.94E02 2.94E02 0

Displacement out of B Dy
1.056E01 1.056E01 0
Internal pressure
Displacement out of B Dx
2.734E01 2.734E01 0

Displacement out of B Dy
4.41E01 4.410E01
0
Temperature at the moment 10s Temperature in AI1
70 70 0

---

19 Summary of the results

The purpose of this test is not to validate functionalities, but is used for the formation. However, it is interesting to compare certain modelings of the same problem. It is noted that the variations remain relatively weak (5% of variation to the maximum between 3D (quadratic elements), hull and pipe).

Titrate:
FORMA08 - Work practise of Post Traitement 3D with Code_Aster Date:
24/10/02
Author (S):
NR. SELLALI, J.M. PROIX Key
:
V7.15.101-A Page:
1/6

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.15 booklet: Thermomechanical linear statics of the voluminal systems (formations)
V7.15.101 document

FORMA08 - Work practise Postprocessing 3D

Summary:

This test corresponds to the TP 3D of the formation to the post treatment using Code_Aster (postprocessing of one calculation of piping bent in 3D).

This TP is the continuation of the TP of the basic training Aster included in the case test forma01c describes in documentation of validation [V7.15.100].

It is about a bent piping made up of a linear elastic material. One considers only one case of loading (force applied at the end of the elbow).

In this T.P, one is interested in the operators of post following treatment:

· Opérateurs allowing to define groups of entities of the type grid (DEFI_GROUP for definition and the handling of groups of nodes and meshs, MODI_MAILLAGE for reorientation of the elements of face subjected to a pressure).
· Total Opérateurs allowing to enrich the concepts results (CALC_ELEM for calculation of fields with the elements, CALC_NO for the calculation of the fields to the nodes).
· Impressions (IMPR_RESU for the impression of the results to the formats RESULT, IDEAS, GIBI)
· Localised Dépouillements (POST_RELEVE_T for the statement of values on lines or groups nodes and calculation of derived quantities).
· Tracé of curve (IMPR_COURBE for the visualization of the evolution of a size according to time or of space).

Handbook of Validation

V7.15 booklet: Thermomechanical linear statics of the voluminal systems (formation)
HT-66/02/001/A

1
Facts of the case

1.1 Geometry

The study relates to a bent piping modelled in 3D.

LG

D
B

section D
section B

R

C
C

O
section C

Z

Y
E

L
Z
G
X

Re
X

With
section A

Y

X
With
d2 A
With D A
e2
i2
i1
1
e1

d2

L
With
2

With
i1

P
L
With
i2
P
L
i1
2
With
i1
1
e2
e1

P
L

e1
1
D
P
1
e1

Z

· length LG of the two right pipes is 3 m,
· the Rc ray of the elbow is 0.6 m,
· the angle of the elbow is 90 degrees,
· the thickness of the right pipes and the elbow is 0.02 m,
· and the ray external Re of the right pipes and the elbow is of 0.2 Mr.

1.2
Material properties

Isotropic linear elastic material. the properties of material are those of A42 steel:

· the Young modulus E = 204.000. 10+6 N/m2,
· the Poisson's ratio = 0.3,
· the thermal dilation coefficient =10.92 106/°C.

1.3
Boundary conditions and loadings

A condition of embedding is applied to section A,

The loading applied is a constant force FY = 100.000 NR directed according to the axis Y and applied to
the section B.

1.4
Reference solution

The reference solution is obtained numerically, it thus acts of a test of nonregression.

---

2 Modeling
With

2.1
Characteristics of modeling

The right pipes and the elbow are modelled by isoparametric solid elements quadratic. Piping presents a symmetry plane Z=0. Only one half volume is netted.

Y
X
With
d2 A
With D A
e2
i2
i1
1
e1
d2
L

With
2
With
i1
P
L
With
i2
P
L
i1
2
With
i1
1
e2
e1
P
L
e1
1
D
P
1
e1
Z

One considers the loading case according to:

· An effort FY directed according to the axis Y, applied to the section B,

Piping is embedded in its base (Ae1, Ai1, Ae2, Ai2), on all the nodes located in the plan of Y=0 equation.

2.2
Characteristics of the grid

A number of nodes: 5900
A number of meshs and type: 2500 HEXA20

2.3 Functionalities
tested

Orders

AFFE_CHAR_MECA
FORCE_FACE
Fy
MECA_STATIQUE
POST_RELEVE_T
OPERATION
AVERAGE

3
Results of modeling A

3.1 Values
tested

Value tested
Aster
Displacement out of B (Dx)
2.907E02
Displacement out of B (Dy)
1.065E01

---

4 Modeling B

Modeling B corresponds to corrected TP 3D.

4.1 Characteristics of modeling

The right pipes and the elbow are modelled by isoparametric solid elements
quadratic. Piping presents a symmetry plane Z=0. Only one half volume is netted.

4.2 Characteristics of the grid

A number of nodes: 5900
A number of meshs and type: 2500 HEXA20

4.3 Functionalities tested

Orders

DEFI_GROUP
CREA_GROUP_MA
CREA_GROUP_NO
AFFE_CHAR_MECA
FORCE_FACE
Fy
MECA_STATIQUE

CALC_ELEM
OPTION
EQUI_ELNO_SIGM
POST_RELEVE_T
OPERATION
AVERAGE
CALC_ELEM
SIGM_ELNO_DEPL
EQUI_ELNO_SIGM
ERRE_ELGA_NORE
ERRE_ELNO_ELGA
CALC_NO
FORC_NODA
REAC_NODA
IMPR_RESU
FORMAT
RESULT
CASTEM
POST_RELEVE_T
OPERATION
EXTRACTION
IMPR_COURBE
INTE_MAIL_3D
DEFI_SEGMENT
IMPR_TABLE

4.4 Values tested

Value tested
Aster
Displacement out of B (Dx)
2.907E02
Displacement out of B (Dy)
1.065E01

5 Synthesis

This case test, redundant as regards calculation with modeling C of the case test FORMA01, has for objective to ensure that the command files of the TP of the formation "post treatment" follow them evolutions of syntax of the code.
Handbook of Validation

Code_Aster ®
Version
6.4

Titrate:
HSNA100 - Drying of a concrete enclosing wall

Date:
23/06/03
Author (S):
G. DEBRUYNE Key
:
V7.20.100-C Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.20 booklet: Thermomechanical nonlinear statics of the structures
axisymmetric
V7.20.100 document

HSNA100 - Drying of a concrete enclosing wall

Summary:

This case test is intended to not validate the calculation of the drying of the concrete, developed in the operator of thermics
linear of Code_Aster. The studied case corresponds to the simulated drying of the enclosure of Flamanville. Data
geometrical and the characteristics materials result from the thesis of Laurent Granger "Behavior
differed from the concrete in the enclosures of nuclear thermal power stations " published by the Central Laboratory of the Bridges and
Roadways (1996, pages 185 to 204).

Drying is carried out by exchange with outside, on the walls internal and external of the wall, in modeling
axisymmetric 2D. It is carried out over one 54 years duration.

The coefficient of diffusion of drying depend on the temperature, the analysis is made up of the chaining of one
thermal calculation and of a calculation of drying. One carries out then a mechanical calculation of withdrawal in elasticity
linear and in plasticity Von Misès with an isotropic work hardening.

1
Problem of reference

1.1 Geometry

The enclosure is modelled on a Lint height = Lext = 1 m
Ray external of the enclosure: Rext = 23,4 m
Interior ray of the enclosure: Rint = 22,5 m

Y
L_int
L_ext
Rint
Rext
X (R)

1.2
Material properties

For thermal calculation:

Thermal coefficient of diffusion process: = 8000 W/m/°C
Voluminal heat: C
2 4.106 J m3
.
/
/C
p =
°

For the calculation of drying:

In the equation of drying:

cd. - Di [v (cd., T) GradC] = 0
dt

the coefficient of diffusion D will be form recommended by Granger [bib1], [bib2]:

T
Q 1
1
D (C, T) = Aexp (BC
S
)
exp-
-

T
R
0
T T0

With =,
3 8 ×
-13
10
m2/S
B =,
0 05

T0 = 273 K
°
Qs = 4700K-1
R
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1.3
Boundary conditions and loadings

For thermal calculation:

The temperatures are imposed on the walls interior and external of the enclosing wall (groups meshs l_ int and l_ ext.).
During the first five years, the imposed temperature is of 15°C on each wall:
T
T
= °
15 C
int = ext.

From the fifth year, the temperature in internal wall passes to 35°C:
T
= °
35 C and T
= °
15 C
int
ext.

In practice, the scales of time of drying being much higher than that of thermics, one can to consider that thermal balance is quasi immediate. Calculation is carried out in linear thermics.

For the calculation of drying:

The boundary conditions are expressed in term of normal flow of moisture on the walls internal and external of the enclosure (groups of meshs l_ int and l_ ext.). One uses option FLUX_NL of the operator AFFE_CHAR_THER_F. Normal flow is expressed generally, in a calculation of drying, in function of the initial concentration C0 and the external concentration Ceq, in the form:

C
,
0
5
W = - D (C, T)
=
C - 2 C - C
C - C

N
(C
2
0 - C
) [

(eq)](eq)
eq
with = 3.41557.108

The data retained in the case of the enclosure of Flamanville are as follows:
C = 105 7
, L/m3
0
(initial concentration)

On the interior face:

from 0 to 5 years,
C
L m
eq = 69 1
3
,
/

from 5 to 54 years,
C
L m
eq = 51 6
3
,
/

On the outside:
C
L m
eq = 69 1
3
,
/

The expression of flow is interpolated by Code_Aster, according to the current price of water concentration, (variable of calculation). One uses an interpreted function, to define sound expression, according to the formulation above (operator FORMULATES), and operator CALC_FONC_INTERP to define the corresponding tabulée function.

The calculation of drying is carried out in nonlinear thermics, by chaining with thermal calculation linear.

1.4 Conditions initial

The initial conditions are consisted the initial temperature, which one takes with 15°C, and initial water concentration, which is worth C = 105 7
, L/m3
0
.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The reference solution is consisted the calculation carried out with a similar modeling by L. Granger, within the framework of its thesis [bib1]. The case test relates to the calculation carried out with the data experimental corresponding to the enclosure of Flamanville. The implementation and the results are there described pages 185 to 204.

Drying is carried out over 54 years, by taking account of the change of boundary conditions at the time of the fifth year.

2.2 Results of reference

Water concentration in the middle of the enclosure, at the end of 5, 15, and 54 years.

2.3 Uncertainty on the solution

One does not have that water concentrations calculated within the framework the thesis of Laurent Granger, without numerical data on uncertainty of the solution, with regard to the enclosure of Flamanville.

2.4 References bibliographical

[1]
L. GRANGER: "Behavior differed from the concrete in the enclosures of nuclear thermal power stations" published by the Central Laboratory of the Highways Departments (1996).
[2]
G. DEBRUYNE, B. CIREE: "Modeling of thermohydration, drying and the withdrawal concrete", handbook of Code_Aster Reference, [R7.01.12] (2001).

---

3 Modeling
With

3.1
Characteristics of modeling

It is about an axisymmetric modeling.

Cutting in 10 elements of variable size on the thickness, 2 elements on the height.

10 subdivisions in
Y (Z)
R
With
X (R)

3.2
Characteristics of the grid

A number of nodes: 85
A number of meshs and type: 20 QUAD8

3.3
Characteristics of the temporal discretization

Thermal calculation (years)
Calculation of drying (years)
0.1
0.001
1
0.1
5
1
5.1
4.9

6
5
10
5.001
54
5.1
6
10
50
54

3.4 Functionalities tested

Orders Options

"THERMAL" AFFE_MODELE
"AXIS" "ALL"

AFFE_CHAR_THER_F "FLUX_NL"
"GROUP_MA"

DEFI_MATERIAU "SECH_GRANGER"

THER_NON_LINE "COMP_THER_NL"
"SECH_GRANGER"

"EVOL_THER_SECH"

4
Results of modeling A

4.1 Values
tested

Water concentration at point a:

Identification Reference Aster %
difference
concentration at 5 years
104.
104.818
0.951
concentration at 15 years
95.
96.161
1.540
concentration at 54 years
78.
78.276
0.568
Radial displacement with 54
-0.2759 -0.2758 0.011
years (elasticity)
Radial displacement with 54
-0.1840 -0.1840 0.005
years (plasticity)

5 Modeling B

5.1 Characteristics of modeling

It is about a modeling 3D

Z
GM73 (behind)
GM70 (surface external of roll)
y
GM69 (interior surface)
GM72 (in front of)
N7
GM71 (bases)
Rint
N6
X
Rext

5.2 Characteristics of the grid

The grid is carried out with the graphic tool gmsh.
A number of nodes: 456.
The voluminal meshs are tetrahedral meshs tetra4.

A number of meshs and types: 929 TETRA4, 410 TRIA3, 8 SEG2, 2 POI1.

5.3
Functionalities tested

Orders Options

DEFI_MATERIAU "SECH_GRANGER"

"THERMAL" AFFE_MODELE
"3D"
"ALL"
AFFE_CHAR_THER_F "FLUX_NL"
"GROUP_MA"

DEFI_MATERIAU "SECH_GRANGER"

THER_NON_LINE "COMP_THER_NL"
"SECH_GRANGER"

STAT_NON_LINE "COMP_INCR" "GRANGER_FP"

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6
Results of modeling B

6.1 Values tested

Reference AUTRE_ASTER corresponds to the results of modeling A.

Water concentration with the N6 node:

Identification	***Reference***	***Aster***	*%* ***difference***
Water concentration	***AUTRE_ASTER***		
at 5 years	*104.818*	*107.094*	*2.171*
at 15 years	*96.161*	*98.459*	*2.390*
at 54 years	*78.276*	*79.693*	*1.810*

Water concentration with the N6 node:

Identification	***Reference***	***Aster***	*%* ***difference***
Water concentration	***AUTRE_ASTER***		
at 10 years	*100.071*	*102.345*	*2.273*

at 20 years
92.787 95.056
2.445
at 30 years
87.224 89.290
2.368
at 40 years
82.893 84.673
2.147
at 50 years
79.460 80.970
1.901

Water concentration with the N7 node:

Identification
Reference
***Aster** %*
difference
Concentration
NON_REGRESSION
at 5 years
104.818
105.773
0.912
at 15 years
96.161
97.597
1.494
at 54 years
78.276
79.558
1.638

Water concentration with the N7 node:

Identification
Reference
***Aster** %*
difference
Water concentration
NON_REGRESSION
at 10 years
100.071

101.571 1.499
at 20 years
92.787 94.185
1.507
at 30 years
87.224 88.571
1.543
at 40 years
82.893 84.202
1.579
at 50 years
79.460 80.746
1.619

Dx displacement with the node elastoplastic N6 calculation:

Identification
Reference
***Aster** %*
difference
Dx displacement
AUTRE_ASTER
at 54 years
-0.184
-0.184 0.126

Dx displacement with the node elastoplastic N7 calculation:

Identification
Reference
***Aster** %*
difference
Dx displacement
NON_REGRESSION
at 54 years
-0.181
-0.184 -1.592

Titrate:
HSNA100 - Drying of a concrete enclosing wall

Date:
23/06/03
Author (S):
***G. DEBRUYNE** Key*
:
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Dx displacement with the node N6 elastic design:

Identification	***Reference***	***Aster***	***% difference***
Dx displacement ***AUTRE_ASTER*** *at 54 years*	*-0.275*	*-0.275*	*-0.073*

Dx displacement with the node N7 elastic design:

Identification	***Reference***	***Aster***	***% difference***
Dx displacement ***NON_REGRESSION*** *at 54 years*	*-0.271*	*-0.275*	*-1.626*

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Titrate:
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7 Modeling C

7.1 Characteristics of modeling

It is a question here of comparing the mechanical fields resulting from orders MECA_STATIQUE and STAT_NON_LINE. Those must be identical provided that the initial water concentration is null. Indeed, the withdrawal of dessication is equal to (T) = (C (T) - C)
0 for incremental calculation
(STAT_NON_LINE) and (T) = C (T) in MECA_STATIQUE since calculation does not take account of history of material. One then affects a water preconcentration equal to C0 by the operator CREA_CHAMP and one replace the running water concentration C (T) by C (T) - C0 using operator COMB_CHAM_NO.

One uses same axisymmetric modeling as A, with the same space discretization and temporal. Only the mechanical loading is modified, one removes the mechanical pressures exerted on the enclosure as well as thermal dilation (by cancelling the dilation coefficient) so to isolate the withdrawal from with drying.

7.2 Functionalities tested

The functionalities tested are those of other modelings plus the following ones:

Orders Options

CREA_CHAMP "AFFE"
"NOEU_TEMP_R"

CREA_CHAMP "EXTR"
"NOEU_TEMP_R"

COMB_CHAM_NO

CREA_RESU "EVOL_THER"

8 Results of modeling C

8.1 Values tested

Displacement at the A2 point:

Identification	**Reference**	**Stat_Non_Line Aster**	**Aster Méca_Statique**	*%* **difference**
DX (N47)	*8.7688E-4*	*8.9645E-4*	*8.7688E-4*	*2.2*

The value of reference selected is that obtained by operator MECA_STATIQUE.

9 Summary of the results

For modeling A, the precision of the results reaches approximately 1.5% for the water concentration compared to the reference solution which one does not know the proper precision.

The test was also carried out on a grid much coarser (4 elements in the direction radial), and the results are also good in the center of the concrete structure.

For modeling B, the difference reaches 2.5% on the concentrations because of a grid 3D relatively coarse.

This test makes it possible of more than check nonthe regression of the code for the calculation of drying in
the nonlinear operator of mechanics. The law of behavior chosen, as well as the field of moisture resultant do not make it possible to know simple analytical solution. Convergence in thermics nonlinear is delicate with the first step of time, to find the first state of balance, because of the important scale of the steps of time. Modeling C makes it possible to take account of a concentration out of nonnull initial water in a calculation carried out with operator MECA_STATIQUE.

V7.20.101 document

FORMA09 - TP of the formation thermoplasticity

Summary:

This test in quasi-static axisymmetric 2D makes it possible to illustrate on a simple case the questions relative to
thermoelastoplastic modelings:

.
for thermal calculation, it highlights the effects of going beyond of maximum, of instability of diagram clarifies and shows the contribution of the diagonalisation of the thermal matrix of mass,
.
For mechanical calculation, it highlights the constraints due to the incompatibility of the deformations thermics, even if the cylinder is free, then incrémentaux aspects of calculation with STAT_NON_LINE. One shows also the influence of the temperature of reference and the temperature of definition of the thermal dilation coefficient.

1
Problem of reference

1.1 Geometry

The studied structure is a section of cylinder, modelled into axisymmetric, (cf HPLA100)

Z
IH
Re
Interior ray IH = 19.5 mm
External ray Re = 20.5 mm
Not F
R = 20.0 mm
Thickness
H = 1.0 mm
Height
L = 10.0 mm
R
Z
J
D
C
H
+
R
With
B
F

1.2
Properties of materials

The material is homogeneous isotropic, thermoelastic linear. The mechanical coefficients are

The dilation coefficient is a function of the temperature:

The temperature of reference is worth 0°C. The thermal coefficients are worth:

1.3

Boundary conditions and loadings of thermal calculation

The cylinder is subjected on its internal edge to an exchange with a fluid which passes brutally from 100°C with 0°C:
·
null flow on edges AB, BC, CD
·
on the edge AD, condition of convectif exchange, with:
H = 100 W/mm ²/°C
Text = 100°C with T = 0s, then 0°C with T = 0.01s, and then maintained constant.
Handbook of Validation
V7.20 booklet: Thermodynamic nonlinear statics of the axisymmetric structures
HT-66/03/008/A

1.4
Boundary conditions and loadings of mechanical calculation

Conditions of symmetry
Case not attached: null displacement following OY along side AB.
Attached case: null displacement following OY along sides AB and CD.
Loading: thermal dilation.

2
Reference solution

2.1 Solution
thermoelastic

The reference solution is numerical. It is obtained with Code_Aster for a fine grid (20 elements in the thickness). The TP is carried out with a very coarse grid (3 elements in the thickness), one thus should not be astonished to obtain results rather far away from the solution from reference.

Indeed, the goal of the TP is to show:

·
for thermal calculation, the effects of going beyond of maximum, instability of the diagram explicit and the contribution of the diagonalisation of the thermal matrix of mass,
·
for mechanical calculation, the constraints due to the incompatibility of the deformations thermics, even if the cylinder is free, then incrémentaux aspects of calculation with STAT_NON_LINE.

The values tested are:

Moment (S) Temperature max
A number of nodes Temperature min a Number of nodes
(Tmax) in °C
reached by Tmax
(Tmin) in °C
and numbers of
nodes
0 100 63
nodes 100 63
0,1
100
1 node: N26
69,5309
1 node: N62
4
100
1 node: N1
8,5 182
1 node: N62
10
100
1 node: N2
5,56755
1 node: N62
100

95,1712
1 node: N3
1,81091
1 node: N62

The values maximum and minimum of constraints SIYY at the moments t=0s and t=11s

Case not attached

Moment (S)
Constraint
A number of meshs
Constraint
A number of meshs
maximum
attacks by
minimal
attacks by
SIYY max
SIYY max and
SIYY min
SIYY min and
number of the meshs
number of the meshs
11
364,875
1 mesh: M21
-320,094
1 mesh: M2

Case attached with MECA_STATIQUE and STAT_NON_LINE with TREF=0 (and an initial state T=0°C),

Moment (S)
Constraint
A number of meshs
Constraint
A number of meshs
maximum
attacks by
minimal
attacks by
SIYY max

SIYY max and
SIYY min
SIYY min and
number of the meshs
number of the meshs
0
-200
1 mesh: M40
-200
1 mesh: M1
11
-61,5003
1 mesh: M1
-702,563
1 mesh: M22

Case attached with MECA_STATIQUE and STAT_NON_LINE with TREF=100°C (and an initial state T=100°C),

Moment (S)
Constraint
A number of meshs
Constraint
A number of meshs

maximum
attacks by
minimal
attacks by
SIYY max
SIYY max and
SIYY min
SIYY min and
number of the meshs
number of the meshs
11
138,5
1 mesh: M21
-502,563
1 mesh: M2

2.2 Reference bibliographical

Documentation of validation [V7.01.100].
Handbook of Validation
V7.20 booklet: Thermodynamic nonlinear statics of the axisymmetric structures
HT-66/03/008/A

---

3 Modeling With

3.1
Characteristics of modeling

Modeling A corresponds to the statement of the TP. It comprises only the first thermal calculation (without diagonalisation of the thermal mass). The grid comprises 3 meshs QUAD4 in the thickness (grid GIBI).

3.2
Characteristics of the grid

6 meshs

The useful edges for the boundary conditions are defined by the groups of meshs:

- *EXCHANGE (left edge)*
- *HIGH (higher edge)*
- *LOW (lower edge)*

3.3 Functionalities tested

Orders

STAT_NON_LINE COMP_INCR RELATION = ELAS
DEFI_MATERIAU THER

ELAS_FO

THER_LINEAIRE

MECA_STATIQUE

Handbook of Validation

4
Results of modeling A

4.1 Values tested

Temperature moment Identification Reference
Aster %
diff
maximum
4 temp
max
126.314
126.314 0

Note:

This modeling comprises only one test of nonregression. It is the starting point of TP, intended to improve modeling (cf modeling B). On the change of the temperature in the middle of the cylinder according to time, and the distribution of temperature to t=4s. One note (see curved reds, with square marker on the following figure), that one exceeds the temperature of 100°C, which is not physical. This characterizes nona respect of principle of the maximum.

---

5 Modeling B

5.1 Characteristics of modeling

This modeling corresponds to corrected TP. It implements all calculations suggested, in commenting on the results obtained.

Appear 5.1-a

Appear 5.1-b

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Code_Aster ®
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Titrate:
FORMA09 - TP formation thermoplasticity

5.1.1 Calculation
thermics

To improve the results of modeling A, therefore to mitigate these goings beyond of the temperature maximum (cf [R3.06.07]), several solutions are possible:

·
one can increase the step of time, which is not always compatible with the maid apprehension of the speed of the transient (as in this case),
·
or to refine the grid, which is a good solution, but expensive in time calculation,
·
one can finally use the diagonalisation of the thermal matrices of mass, i.e. here modeling AXIS_DIAG. One then obtains the curves marked of circles on the figures [Figure 5.1-a] and [Figure 5.1-b] Ci above. The temperature remains always lower than 100°C. It is the simplest solution.

If one seeks to use an explicit diagram (THETA = 0), one sees appearing a clear instability for great steps of time (curve with marker cross on the figure [Figure 5.1-a] above).

In conclusion, for thermal calculation, it is necessary to use THETA equal to or higher than 0.5, to have one
stable diagram some is the step of time. Moreover it is necessary to use a step of sufficiently small time
to apprehend the transient, but not too small to avoid the oscillations. If they appear,
either the grid should be refined, or to use modeling AXIS_DIAG, (or PLAN_DIAG, or 3D_DIAG).

5.1.2 Thermoelastic calculation in free dilation

One carries out calculation with MECA_STATIQUE, using for only loading thermal dilation. With the boundary conditions of the case not attached: null displacement following OY along side AB.

For mechanical calculation, it will be enough to calculate at the moment T = 0s, and T = 11s for example.

The constraints at the moment t=0s are null, because the field of temperature is uniform (T = 200°C) and
remain compatible. On the other hand the deformations obtained are not null since the temperature of
reference is equal to 200°C.

With T = 11s, or any other positive mechanical moment, one sees appearing constraints known as of compatibility thermics. Indeed, the field of temperature is not uniform any more but varies according to R.
This produced of the incompatible deformations, which thus generate constraints, even for one
roll not attached. This situation occurs even for a linear field of temperature by report/ratio
with the ray. On the other hand (cf exposed) a linear field of temperature compared to the co-ordinates
total does not produce constraint for a not attached structure.

5.1.3 Thermoelastic calculation with fastening

Calculation with MECA_STATIQUE of the attached case shows the contribution of fastening on constraints (SIYY in
private individual): at the moment T = 0s, the temperature of reference being equal to 0°C, the uniform field of
temperature causes a uniform state of stress SIYY of 200MPa, and with T = 11s, the state of constraints is different from the case not attached.

This modeling is correct, but is limited to the linear behaviors.

5.1.4 Thermoplastic calculation with fastening

One seeks to carry out same calculation as previously, but this time with STAT_NON_LINE, with COMP_INCR=_F (RELATION=' ELAS'), not to complicate the problem (another behavior would lead to the same observations). The list of moments provided to STAT_NON_LINE is: t=0s, and t=11s.

Since an incremental calculation is made, moment 0 is regarded as initial moment. It is not thus not calculated, and at the next moment (t=11s), one calculates the solution due to the increase in load (thermics here) between 0s and 11s. It is noted whereas the solution obtained (displacements, constraints) is different from calculation with MECA_STATIQUE. It is logical and coherent with the definition of calculation incremental, but it is a trap for the use. To retain: implicitly, STAT_NON_LINE in incremental supposes that at the initial moment, the structure is not forced, not deformed. This implies that the field of temperature must be uniform and equal to the temperature of reference.

It is not the case here: with t=0s, TREF=0°C, and T=200°C. By not calculating this thermal dilation, it is supposed here that with t=0s, there is no deformation, and no constraint.

5.1.5 Thermoplastic calculation with fastening and addition of initial conditions

One modifies the list of moments: one adds one preliminary moment t=1s for example. In this moment, one a field of uniform temperature, equal to the temperature of reference defines. One uses for this purpose them orders CREA_CHAMP, then CREA_RESU to enrich the structure of data thermics results with this uniform field. One carries out then mechanical calculation, by providing the list of moments:
t=1s, t=0s, and t=11s
It is noted whereas the moment t=0s is well calculated, and that the constraints are identical to the case calculated with MECA_STATIQUE.

5.2
Characteristics of the grid

Even grid that for modeling A.

5.3 Functionalities
tested

Orders

STAT_NON_LINE COMP_INCR
RELATION
=
ELAS
DEFI_MATERIAU THER

ELAS_FO

PROJ_CHAMP

THER_LINEAIRE

MECA_STATIQUE

6
Results of modeling B

6.1 Values
tested

Modeling AXIS_DIAG

Temperature moment Identification Reference
Aster %
diff
maximum
4 temp
max 100 100
0
Handbook of Validation
V7.20 booklet: Thermodynamic nonlinear statics of the axisymmetric structures
HT-66/03/008/A

7
Summary of the results

This test relates to the formation thermoplasticity. It shows the utility of the choice of modeling DIAG (thermal matrix of diagonalized mass) for thermal calculations, and illustrates in incremental thermomechanics (order STAT_NON_LINE) how to take into account correctly the initial state.

Organization (S): EDF-R & D /AMA, EDF-R & D /MMC

Handbook of Validation
V7.20 booklet: Thermomechanical nonlinear statics of the structures
axisymmetric
V7.20.102 document

HSNA102 - Validation of the laws of drying on one cylindrical concrete test-tube

Summary:

This case test is intended to not validate the calculation of the drying of the concrete, developed in the operator of thermics
linear of Code_Aster. One tests here the various laws of diffusion available in Code_Aster, namely SECH_GRANGER, SECH_MENSI, SECH_BAZANT and SECH_NAPPE. Possible dependence at the temperature of
models is however not tested.
It is about an axisymmetric case test where the water concentration is applied directly to the external wall.
The results are compared with a numerical resolution of the equations using Scilab.
Handbook of Validation
V7.20 booklet: Thermomechanical nonlinear statics of the axisymmetric structures
HT-66/04/005/A

1
Problem of reference

1.1 Geometry

One models a cylindrical section of test-tube of diameter 160mm.
1 cm
FI
FE
8 cm

1.2
Material properties

Each modeling makes it possible to validate a coefficient of diffusion D, namely:

· modeling a: law of Mensi D (C) = Aexp (BC)
T
Q
S
1
1
· modeling b: law of Granger D (C, T) = Aexp (BC)
exp-

-

0
T

R T
0
T
· *modeling C: definition of D in the form of tablecloth*

1-

· *modeling D: law of Bazant D (H) = D1 +*

1 - H () N
C

1+

1 - 75
.
0

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HT-66/04/005/A

Code_Aster ®
Version
7.4

Titrate:
HSNA102 Validation of the laws of drying

Date:
16/11/04
Author (S):
S. MICHEL-PONNELLE, Y. the Key POPE

The coefficients used are those recommended by Granger in its thesis [bib1]:

SECH_MENSI:
With = 0.74 10-13 m2/s
B = 0.05

SECH_GRANGER
With = 0.74 10-13 m2/s
B = 0.05
T0 = 293 °K
Qs/R = 4700 K-1

SECH_NAPPE
One returns in the form of tablecloth the law of Mensi
Coefficient of diffusion
6th-11
4th-11
S)
2/
m
(
D 2nd-11
0
0
20
40
60
80
100
120
140
C (l/m3)

SECH_BAZANT
D1 = 3.0 10-10 m2/s
= 0.04
N = 6
2
C C

- 0
H = 1 - 5
.
0

with C =128.8 l/m3 and C = 58.8 l/m3
C
C

0
eq
0 - eq

1.3
Boundary conditions and loadings

The calculation of drying is carried out over one 5 years duration

· the temperature remains uniform and is worth 20 °C
· one applies to FE Ceq = 58.8 l/m3

1.4 Conditions
initial

The initial conditions are consisted the initial temperature, which one takes with 20°C, and initial water concentration, which is worth
3
C0 =
8
.
128 L/Mr.

2
Reference solution

2.1
Method of calculation used for the reference solution

The 2 reference solutions are obtained by resolution of the equation of drying by differences finished using Scilab. The command file is given in appendix to possibly be able to test new models.
The space discretization is the same one as for Aster with knowing of the meshs of 1 Misters the discretization temporal is 3600 seconds for the equation of Mensi, and 60 seconds for the equation of Bazant.

2.2
Results of reference

One is interested in the water concentration in the test-tube after 1h, 3j, 28j, 1.25 year, 3 years and 5 years.
The evolution of the profiles obtained with Scilab for the law of Mensi and the law of Bazant is visible on [Figure 2.2-a] and [Figure 2.2-b].

Note:

The comparison between the solutions Scilab and Aster is visible in [§Annexe 2]: they are shown concentrations obtained in the test-tube after 1h and 5 years. The maid thus is checked correlation excluded for the solution obtained with Aster for the law of Mensi at the end of one hour when one observes an oscillation which makes much think of a violation of the principle of maximum observed in thermics (cf [bib2]). It would be thus interesting to be able to use them lumpés elements when one solves the equation of drying even if the phenomenon is accentuated here because of the boundary conditions, since one directly imposes the water concentration on place to impose a flow [bib3].
Evolution of the water concentration in

the test-tube in the course of time
Law of Mensi
138,8
128,8
3)
L
/
m 118,8
(
1 hour
108,8
water
3 days
in
28 days
N
98,8
I
O
1.25 year
88,8
T
R
At
3 years
cen
78,8
5 years
N
Co
68,8
58,8
0
0,02
0,04
0,06
0,08
position X (m)

Appear 2.2-a: Scilab solution - law of Mensi
Handbook of Validation
V7.20 booklet: Thermomechanical nonlinear statics of the axisymmetric structures
HT-66/04/005/A

Evolution of the water concentration in
the test-tube in the course of time
Law of Mensi
138,8
128,8
3)
L
/
m 118,8
(
1 hour
108,8
water
3 days
in
28 days
N
98,8
I
O
1.25 year
88,8
T
R
At
3 years
cen

78,8
5 years
N
Co
68,8
58,8
0
0,02
0,04
0,06
0,08
position X (m)

Appear 1.2-b: Scilab solution - law of Bazant

The TEST_RESU are carried out for the 6 characteristic moments with the X-coordinates X = 0mm, x= 40 mm
and x=60 Misters.

2.3 References
bibliographical

[1]
L. GRANGER: "Behavior differed from the concrete in the enclosures of nuclear thermal power stations"
published by the Central Laboratory of the Highways Departments (1996).
[2]
S. MICHEL-PONNNELLE, A. RAZAKANAIVO: "I7-01-08 Project: Quality of the Studies in Mechanics of the Solids Stage n°4
: study of the finite elements
", Note EDF
:
HT-64/02/007/A, June 2002
[3]
G. DEBRUYNE, B. CIREE: "Modeling of thermohydration, drying and the withdrawal concrete", handbook of Code_Aster Reference, [R7.01.12] (2001).

Version
7.4

Titrate:
HSNA102 Validation of the laws of drying

Date:
16/11/04
Author (S):
S. MICHEL-PONNELLE, Y. the Key POPE
:
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3 Modeling
With

3.1
Characteristics of modeling

One uses the law of diffusion of Mensi.

3.2
Characteristics of the grid

The test-tube is with a grid using 80 QUAD4 regularly distributed. There is only one element in height.

A number of nodes: 162
A number of meshs and type: 80 QUAD4

3.3
Characteristics of the temporal discretization

Initial moment (S)
Final moment (S)
Numbers of steps of time
0 3600
10
3600 259
200

10
259 200
2 419 200
10
2 419 200
39 420 000
10
39 420 000
94 608 000
10
94 608 000
1 57 680 000
10

3.4
Functionalities tested

Orders Options

“THERMAL” AFFE_MODELE
“AXIS” “ALL”

DEFI_MATERIAU “SECH_MENSI”

THER_NON_LINE COMP_THER_NL “SECH_MENSI”

EVOL_THER_SECH

4
Results of modeling A

4.1 Values
tested

Water concentration at the point x=0.0:

Identification	*Reference*	*Aster*	*% difference*
after 1 a.m.	*128.80*	*128.80*	*2.21 10-14*
after 3 days	*128.80*	*128.80*	*-2.21 10-14*
after 28 days	*128.80*	*128.80*	*-3.67 10-5*
after 1.25 year	*117.49*	*117.76*	*0.231*
after 3 years	*105.06*	*105.38*	*0.307*
after 5 years	*96.77*	*97.09*	*0.332*

Water concentration at the point x=0.04:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
1.31 10-13
after 3 days
128.80
128.80
-1.77 10-13
after 28 days
128.61
128.66
0.038
after 1.25 year
117.74
112.35
0.543
after 3 years
99.43
100.06
0.634
after 5 years
91.39
91.99
0.661

Water concentration at the point x=0.06:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
2.53 10-11
after 3 days
128.80
128.80
0.002
after 28 days
124.98

125.67
0.552
after 1.25 year
101.32
102.42
1.089
after 3 years
89.60
90.64
1.158
after 5 years
82.33
83.27
1.140

4.2 Comments

It is checked here that the made error is weak since lower than 1.5%, which is completely correct being given the relatively coarse temporal discretization used, in particular at the end of the calculation.

---

5 Modeling B

5.1

Characteristics of modeling

One uses the law of diffusion of Granger

5.2
Characteristics of the grid

The test-tube is with a grid using 80 QUAD4 regularly distributed. There is only one element in height.

A number of nodes: 162
A number of meshs and type: 80 QUAD4

5.3
Characteristics of the temporal discretization

Initial moment (S)
Final moment (S)
Numbers of steps of time
0 3600
10
3600 259
200
10
259 200
2 419 200
10
2 419 200
39 420 000
10
39 420 000
94 608 000
10
94 608 000
1 57 680 000
10

5.4
Functionalities tested

Orders Options

"THERMAL" AFFE_MODELE
"AXIS" "ALL"

DEFI_MATERIAU "SECH_GRANGER"

THER_NON_LINE COMP_THER_NL "SECH_GRANGER"

EVOL_THER_SECH

6
Results of modeling B

6.1 Values tested

Water concentration at the point x=0.0:

Identification Reference Aster %

difference
after 1 a.m.
128.80
128.80
2.21 10-14
after 3 days
128.80
128.80
-2.21 10-14
after 28 days
128.80
128.80
-3.67 10-5
after 1.25 year
117.49
117.76
0.231
after 3 years
105.06
105.38
0.307
after 5 years
96.77
97.09
0.332

Water concentration at the point x=0.04:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
1.31 10-13
after 3 days
128.80
128.80
-1.77 10-13
after 28 days
128.61
128.66
0.038
after 1.25 year

117.74
112.35
0.543
after 3 years
99.43
100.06
0.634
after 5 years
91.39
91.99
0.661

Water concentration at the point x=0.06:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
2.53 10-11
after 3 days
128.80
128.80
0.002
after 28 days
124.98
125.67
0.552
after 1.25 year
101.32
102.42
1.089
after 3 years
89.60
90.64
1.158
after 5 years
82.33
83.27
1.140

6.2 Comments

One finds the same solution exactly as the law of Mensi.

7 Modeling C

7.1 Characteristics of modeling

One uses the law of diffusion SECH_NAPPE, for which one returns simply the law of diffusion of Mensi.

7.2 Characteristics of the grid

The test-tube is with a grid using 80 QUAD4 regularly distributed. There is only one element in height.

A number of nodes: 162
A number of meshs and type: 80 QUAD4

7.3 Characteristics of the temporal discretization

Initial moment (S)	**Final moment (S)**	**Numbers of steps of time**
0	3600	10

3600 259
200
10
259 200
2 419 200
10
2 419 200
39 420 000
10
39 420 000
94 608 000
10
94 608 000
1 57 680 000
10

7.4
Functionalities tested

Orders Options

“THERMAL” AFFE_MODELE
“AXIS” “ALL”

DEFI_NAPPE NOM_PARA
“TSEC”

DEFI_MATERIAU “SECH_NAPPE”

THER_NON_LINE COMP_THER_NL “SECH_NAPPE”

EVOL_THER_SECH

8
Results of modeling C

8.1 Values
tested

Water concentration at the point x=0.0:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
1.32 10-13
after 3 days
128.80
128.80
8.83 10-14
after 28 days
128.80
128.80
-4.35 10-5
after 1.25 year
117.49
117.51
0.012
after 3 years
105.06

105.04
-0.021
after 5 years
96.77
96.73
-0.037

Water concentration at the point x=0.04:

Identification Reference Aster % difference
after 1 a.m.
128.80
128.80
1.32 10-13
after 3 days
128.80
128.80
-4.41 10-13
after 28 days
128.61
128.65
0.029
after 1.25 year
117.74
112.11
0.328
after 3 years
99.43
99.74
0.318
after 5 years
91.39
91.68
0.319

Water concentration at the point x=0.06:

Identification Reference Aster % difference
after 1 a.m.
128.80
128.80
2.45 10-11

after 3 days
128.80
128.80
0.002
after 28 days
124.98
125.57
0.471
after 1.25 year
101.32
102.18
0.856
after 3 years
89.60
90.35
0.843
after 5 years
82.33
82.99
0.798

8.2 Comments

It is seen here that the error is lower than 1%.

---

9 Modeling
D

9.1
Characteristics of modeling

One uses the law of diffusion of Bazant.

9.2
Characteristics of the grid

The test-tube is with a grid using 80 QUAD4 regularly distributed. There is only one element in height.

A number of nodes: 162
A number of meshs and type: 80 QUAD4

9.3
Characteristics of the temporal discretization

Initial moment (S)
Final moment (S)
Numbers of steps of time
0 3600
10
3600 259
200 20
259 200
2 419 200
20
2 419 200
39 420 000
20
39 420 000
94 608 000
10
94 608 000
1 57 680 000
10

9.4

Functionalities tested

Orders Options

"THERMAL" AFFE_MODELE
"AXIS" "ALL"

DEFI_MATERIAU "SECH_BAZANT"

THER_NON_LINE COMP_THER_NL "SECH_BAZANT"

EVOL_THER_SECH

---

10 Results of modeling D

10.1 Values tested

Water concentration at the point x=0.0:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
0.
after 3 days
128.80
128.80
-3.70 10-7
after 28 days
118.42
118.63
0.175
after 1.25 year
70.36
70.51
2.227
after 3 years
63.63
63.76
0.210
after 5 years
60.67
60.73
0.102

Water concentration at the point x=0.04:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
-2.21 10-14
after 3 days
128.66
128.70
0.031
after 28 days
105.89
106.80

0.853
after 1.25 year
68.25
68.53
0.415
after 3 years
62.24
62.40
0.259
after 5 years
60.06
60.13
0.119

Water concentration at the point x=0.06:

Identification Reference Aster %
difference
after 1 a.m.
128.80
128.80
-1.18 10-11
after 3 days
120.99
122.47
1.225
after 28 days
92.11
93.21
1.192
after 1.25 year
65.16
64.80
0.563
after 3 years
60.62
60.76
0.234
after 5 years
59.43
59.49
0.097

10.2 Comments

It is checked here that the made error is weak since lower than 1.5%.

---

11 Summary of the results

For the whole of modelings, one obtains a difference between solution SCILAB and the solution Code_Aster lower than 1.5% what makes it possible to validate the establishment of the various laws of drying in the code. Let us note simply that one observes a violation of the principle of the maximum at the beginning of simulation with Aster for the law of Mensi. This can be explained (by analogy with thermics) by the "hydrous shock" important due the made-to-order to impose the boundary conditions (water concentration imposed). This problem should be able to be solved by the use of the lumpés elements of same way that in thermics.

Appendix 1 Command file Scilab

Main.sci:

```
getf ("/home/xxxx/librairie.sci");
// PARAMETERS OF THE DIGITAL SIMULATION
//
// discretization of the width
x0 = 0.08;
X = [- 0.080: 0.001: +0.080]; [n1 N2] = size (X);
// water content initial
Cinit = 128.8;
Ci = Cinit*ones (1, N2);
// boundary conditions with 50%HR
CL = [58.8 58.8];.
Ci (1) = CL (1); Ci ($) = CL (2);
Ci_bazant = Ci;
// not of time
dt = 60; // [S]
// coefficients of the law of Bazant
D1 = 3.0E-10; // [m2/s]
= 0.04 have;
N = 6;
TMAX = 5; // years
//______________________________________________________________________________
//
// DIGITAL SIMULATION
//
J = 0;
u=file ("open", "resultat_g", "unknown");
for year = 0: TMAX,
year
for day = 0:364,
```

```
for hour = 0:23,
minute = 0;
for minute = 0:59,
D_bazant
=
diffusion_bazant (D1, has, N, Cinit, 58.8, Ci_bazant, 293,293*ones (Ci), 4700);
Ci_bazant = linear_drying (D_bazant, Ci_bazant, CL, dt, X, “whodunnit”);
yew ((year == 0 & day == 0 & hour == 1 & minute == 0) |…
(year == 0 & day == 3 & hour == 0 & minute == 0) |…
(year == 0 & day == 28 & hour == 0 & minute == 0) |…
(year == 1 & day == 91 & hour == 0 & minute == 0) |…
(year == 3 & day == 0 & hour == 0 & minute == 0) |…
(year == 5 & day == 0 & hour == 0 & minute == 0)) then,
year, day, hour
t=81: 1: 161;
for tk=t,
fprintf (U, “%6.3f %6.3f”, X (tk), Ci_bazant (tk)) ;
end,
end, // yew
end, // for minute
end, // for hour
end, // for day
end, // for year

slip by (“closed”, U);
```

Librairie.sci:

```
//
// NONLINEAR COEFFICIENT OF DIFFUSION FOR THE DRYING OF THE CONCRETE
// LAW OF MENSI D (C) = a.exp (b.C)
// THERMIC ACTION D (C, T) = D (C, T0). (T/T0) .exp [- Q/R* (1/T-1/T0)]
//
// has coefficient of the law of Mensi
// B coefficient of the law of Mensi
// C vector of the water contents [-]
// T0 temperature of reference [K]
// T vector of the temperatures [K]
// Q_R Q/R (being worth 4700 K)
function D = diffusion_mensi (has, B, C, T0, T, Q_R),
D = a*ones (C).*exp (b*C);
D = D.* (T./(T0*ones (T))) ;
D = D.*exp (Q_R* ((ones (T). /T0) - (ones (T). /T))) ;
endfunction,
//
// ______________________________________________________________
//
// NONLINEAR COEFFICIENT OF DIFFUSION FOR THE DRYING OF THE CONCRETE
// LAW OF BAZANT
// THERMIC ACTION D (C, T) = D (C, T0). (T/T0) .exp [- Q/R* (1/T-1/T0)]
//
// D1 coefficient of the law of Bazant
// has coefficient of the law of Bazant (alpha)
// N coefficient of the law of Bazant
// C0 water content with 100%HR
// Cext water content of the surrounding medium
// C vector of the water contents [-]
// T0 temperature of reference [K]
// T vector of the temperatures [K]
// Q_R Q/R (being worth 4700 K-1)
function D = diffusion_bazant (D1, has, N, C0, Cext, C, T0, T, Q_R),
H = ones (C) - 0.5* ((C-C0*ones (C))/(Cext-C0))** 2;
D = (((1-a) *ones (C). /(ones (C)+ (4 ** N) * (ones (C) - H) ** N))+a*ones (C)) *D1;
D = D.* (T./(T0*ones (T))) ;
D = D.*exp (Q_R* ((ones (T). /T0) - (ones (T). /T))) ;
endfunction,
// ______________________________________________________________
```

```
//
// DIFFUSION
// Resolution by the method the finite differences
//
// D vector of the coefficients of diffusion
// Ci vector of the water contents at the moment J [-]
// CL boundary condition in xmin and xmax of the type Dirichlet (C=C0)
// dt not of time [S]
// X vector of the X-coordinates [m]
// mode_ polar/Cartesian
function cf = linear_drying (D, Ci, CL, dt, X, mode_),
[n1, N2] = size (Ci);
dx_ = zeros (1, N2-2); dx_ (1: $) = (X (3: $) - X (1: $-2))*0.5;
// Cf_ = (D*dt* (ones (dx_). /(dx_ ** 2)). * (Ci (3: $) - 2*Ci (2: $-1) +Ci (1: $-2)))+Ci (2: $-1);
dx3 = ((…
(X (2: $-1) - X (1: $-2)). *…
(X (3: $) - X (1: $-2)) …
).* ...
(X (3: $) - X (2: $-1)) …
) ;
d2C_dx2 = 2* (Ci (3: $). * (X (2: $-1) - X (1: $-2))…
here (2: $-1). * (X (3: $) - X (1: $-2))…
+Ci (1: $-2). * (X (3: $) - X (2: $-1)));
```

```
d2C_dx2 = d2C_dx2. /dx3;
```

```
yew (mode_ == "whodunnit") then,
dC_dx = (Ci (3: $). * (X (2: $-1) - X (1: $-2)) ** 2…
here (1: $-2). * (X (3: $) - X (2: $-1)) ** 2);
// here (2: $-1). * ((X (2: $-1) - X (1: $-2)) ** 2 - (X (3: $) - X (2: $-1))** 2)…
dD_dx = (D (3: $). * (X (2: $-1) - X (1: $-2)) ** 2…
- D (1: $-2). * (X (3: $) - X (2: $-1)) ** 2);
// - D (2: $-1). * ((X (2: $-1) - X (1: $-2)) ** 2 - (X (3: $) - X (2: $-1))** 2)…
dC_dx = dC_dx. /dx3;
dD_dx = dD_dx. /dx3;
I = find (x==0); [k1 k2] = size (I);
yew (~ (k1==0)) then, X (I) = X (i+1) /10, end,
// printf ("1st order %s; 2nd order %s", string (min (dC_dx)), string (min (d2C_dx2)));
d2C_dx2 = d2C_dx2 + dC_dx. /x (2: $-1);
end,
Cf_ = Ci (2: $-1) +dt* (D (2: $-1). *d2C_dx2);
yew (mode_ == "whodunnit") then,
Cf_ = Cf_ +dt* (dD_dx.*dC_dx);
end,
Cf = zeros (1, N2); Cf (2: $-1) = Cf_; Cf (1) = CL (1); Cf ($) = CL (2);
endfunction,
//
// ____________________________________________________________________
//
```

Appendix 2 Comparison Aster/Scilab

A2.1 SECH_MENSI/SECH_GRANGER /SECH_NAPPE

Water concentration in the test-tube after 1h
(zoom)
148,8
U
138,8
has
E
128,8
N
118,8
)
3108,8
T
I
one E
Scilab
(l/m 98,8
T
R
has
SECH_GRANGER
N
E
88,8
SECH_MENSI
78,8
onc
SECH_NAPPE
C
68,8
58,8
0,06
0,065
0,07
0,075
0,08
position X (m)

Water concentration in the test-tube after 5ans
)
3 103,8
L
/
m
98,8
U (
93,8
has
E
88,8
N
83,8
Scilab
78,8
T
I
one E
SECH_GRANGER
73,8
T
R
has
SECH_MENSI
N
68,8
E
SECH_NAPPE
63,8
onc
C
58,8
0
0,02
0,04
0,06
0,08
position X (m)

A2.2 SECH_BAZANT

Water concentration in the test-tube after 1h
(zoom)
1,39E+02
3) 1,29E+02
L
/
m
(1,19E+02
water 1,09E+02
in
N 9,88E+01
I
O
SECH_BAZANT
8,88E+01
T
R
At
SCILAB
7,88E+01
cen
N 6,88E+01

O
C 5,88E+01
0,06
0,065
0,07
0,075
0,08
position X (m)

Water concentration in the test-tube after 5 years
6,13E+01
3)
L
/
m
(6,08E+01
water 6,03E+01
in
N
I
O 5,98E+01
SECH_BAZANT
T
R
At
SCILAB
5,93E+01
cen
N
O
C 5,88E+01
0
0,02
0,04
0,06
0,08
position X (m)

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Organization (S): EDF/IMA/MNN

Handbook of Validation
V7.21 booklet: Thermomechanical nonlinear statics of the linear structures
V7.21.100 document

HSNL100 - Heating of a cable per Joule effect

Summary:

This test relates to to it thermal transient independent of the space of the electric cables subjected to the Joule effect
and the dynamic thermoelasticity of these cables.

Interest:

· to test the functions of evolution of the heating of a conducting cable per Joule effect, then of sound cooling with the ambient air (operator DEFI_THER_JOULE [U4.21.09]),
· to test the influence of the variation in temperature of a cable on the evolution of the arrow (operator DYNA_NON_LINE [U4.32.02]).

1
Problem of reference

1.1 Geometry

A cable of section 1.71 103 and range 100 m hangs in the field of gravity, with *temperature of 0°C. It is the seat, during 25 seconds, of a current of short-circuit which carries its temperature with 1636°C. One follows the evolution of the position of balance.*

T = 0°

T = 1636°

1.2

Properties of materials

Properties of conducting metal:

E = 5.4 1010 Pa

= 2761.4 Kg/m3

= 23. 106 °C1

resistivity (T: temperature): (T) = 3.25 108 (1. + 3.6 103 (T20.)) m

CP = 2.457.646 J m3 °C1

Convection coefficient for the losses of heat by the side wall of the cable:

0.5 J m2 °C1

1.3

Boundary conditions and loadings

The cable has its fixed ends. It is subjected to gravity and dilates by the Joule effect due to one current of 70.000 A during 25 seconds.

1.4 Conditions

initial

The cable forms a chain, at the temperature of 0°C.

2

Reference solution

2.1

Method of calculation used for the reference solution

· In first part, the test consists in checking if Aster tabule well two function-temperature of heating and cooling. They are analytical functions, of exponential nature

compared to time, resulting from the exact integration of the equation of heat independent of space but comprising a term of exchange of the Fourier type. This equation and its solution are in [bib1] [R3.08.02].

The numerical value of the coefficients is in [bib2] [U4.21.09].

· In second part, one compares the arrow of the problem of reference, at a given moment, with theoretical arrow of the chain balance static of an inextensible cable, same length, range and temperature. One can make it because the extensionnelle rigidity of the cable (produced EA) is large and that the variation in temperature is slow.

As there is not analytical solution with the problem of reference, it is admitted that one regular heating of 1600° in 25 seconds causes a quasi-static evolution. Speed of descent of the medium of the cable is indeed about 0,3 m/s, whereas the speed of one pendular motion with 0° reaches a value at least 30 times higher.

The static curve of balance of an inextensible cable whose ends are of level [2.1-a], of range S, linear weight W (gA) and of horizontal tension H has as an equation [bib3]:

H
W S
ws
Z =
cosh
- X
cosh
.
éq 2.1-1
W
H

2

-
2H

From where the length L is deduced:

W L
ws
= sinh
.
éq 2.1-2
2H
2H
Z
X

F
O (0, 0)
P (S, 0)

Appear 2.1-a: Curve of balance of a cable

H, which is constant along the cable since there is no horizontal force external, is given, according to [éq 2.1-2], by the transcendent equation:

L
sinh X =
X
éq 2.1-3
S
where:
ws
X =
.
2H

The equation [éq 2.1-3] has a positive root Xo provided that:

L >1.
S
L
S
1
sinh X
X
X0

The arrow F results then from [éq 2.1-1]:

S

F =
(cosh Xo -) 1.
2 Xo
The length of the cable with T O, which intervenes in coefficient in [éq 2.1-3], rises the length data with 0° by the equation of dilation:
L (T) = L ()
0
(1+ T).

2.2 References bibliographical

[1]
Mr. AUFAURE, G. DEVESA: Modeling of the cables in Code_Aster. Document [R3.08.02] (1996).
[2]
Mr. AUFAURE: Operator DEFI_THER_JOULE. Document [U4.21.09] (1994).
[3]
H. MAX IRVINE: Cable structures. The MIT Press (1981).

---

3 Modeling With

3.1 Characteristics of modeling

Cable of 100 m range modelled by 20 elements of cable of the 1st order. No the time of the analysis dynamics: 0.25 seconds.

3.2 Functionalities tested

Order
Key word

Key word
Keys
factor
DEFI_THER_JOULE
PARA_COND_1D
[U4.21.09]
AFFE_CHAM_NO
AFFE
SIZE
[U4.26.01]
GROUP_NO
NOM_CMP
FUNCTION
CREA_RESU
CHAM_GD
TYPE_RESU
[U4.26.02]
NOM_CHAM
LIST_INST
CHAM_NO
AFFE_CHAR_MECA
TEMP_CALCULEE
[U4.25.01]
STAT_NON_LINE
EXCIT
CHARGE
[U4.32.01]
DYNA_NON_LINE
EXCIT
CHARGE
[U4.32.02]
Handbook of Validation
V7.21 booklet: Thermomechanical nonlinear statics of the linear structures
HI-75/96/067/A

Code_Aster ®
Version
3
Titrate:
HSNL100 - Heating of a cable per Joule effect
Date:
03/12/96
Author (S):

Mr. AUFAURE
Key:
V7.21.100-A Page:
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4
Results of modeling A

4.1 Values
tested

Identification	***Reference***	***Aster***	***% difference***
Tabulation of 6 values of a function f01 of heating-cooling			
moment 0.1	*12.0°C*	*12.0°C*	*1E6*
moment 0.	*1.0°C*	*1.0°C*	*1E6*
moment 10.	*44051.93°C*	*44051.93°C*	*1E6*
moment 20.	*2.9999°C*	*2.9999°C*	*1E6*
moment 30.	*88102.86°C*	*88102.86°C*	*1E6*
moment 40.	*4.9998°C*	*4.9998°C*	*1E6*
Tabulation of 3 values of a function f02 of heating-cooling			
moment 0.1	*15.0°C*	*15.0°C*	*1E6*
moment 0.			

15.0°C
15.0°C
1E6
moment 40.
15.0°C
15.0°C
1E6
Cable subjected to one 3rd function of heating f1
arrow at the moment 6.25s (T = 167°C)
1.614397 m
1.583216
1.9
arrow at the moment 12.50s (T = 441°C)
3.682028 m
3.640127
1.1
arrow at the moment 18.75s (T = 892°C)
6.157222 m
6.092494
1.1
arrow at the moment 25.00s (T = 1636°C)
9.244288 m
9.121316
1.3

4.2 Remarks

The dynamic arrow calculated by Aster is lower, from approximately 1%, with the static arrow with same
temperature. This difference results from mechanical inertia.

4.3 Parameters
of execution

Version: 3.06.11
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
280 seconds

5
Summary of the results

The passage of this test guarantees that there no was regression of Code_Aster for the analysis of evolution of the sag of the cables subjected to the Joule effect.

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Code_Aster ®
Version
6.4

Titrate:
HSNV100 - Thermoplasticity in simple traction

Date:
03/11/03
Author (S):
***J.M. PROIX**, I. DEBOST-EYMARD, F.VOLDOIRE Key*
:
V7.22.100-C Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
V7.22.100 document

HSNV100 - Thermoplasticity in simple traction

Summary:

This test treats the thermoplasticity of Von Mises with isotropic work hardening on a three-dimensional problem (modeling A into axisymmetric) and two-dimensional (modeling B in plane constraints). Interest of the test holds with the dependence of the elastic limit with the temperature. It also makes it possible to test the orthotropism in thermoelasticity because it applies to an isotropic material then with an isotropic material declared orthotropic.

This makes it possible to test the functionalities of the orthotropism. One tests there also the calculation of the deformation energy.

Two modelings (C with element PIPE, D with element TUYAU_6M) are added to test thermoplasticity in these elements.

A modeling (E) makes it possible to test the good taking into account of the variation of the coefficients of behavior VMIS_CINE_LINE with the temperature.

A modeling (F) makes it possible to test the calculation of the thermoelastic deformation energy in the beams.

Modeling (G) makes it possible to test the same functionalities as modelings A and B, but in 3D.

The solution is analytical.

1
Problem of reference

1.1 Geometry

Axisymmetric cylinder (modeling A) or plates rectangular (modeling B) or right pipe (modelings C and D)

Z or y
D
C
H
B
has
R or X
0
With
B

Appear 1.1-a: Geometry of the structure

Interior ray: has = 1 mm

external ray: B = 2 mm (width AB: 1 mm)

height: H = 4 mm

1.2
Property of materials

E = 200.000 MPa modulus Young
AND = 50.000 MPa modulates tangent
= 0 3
.
(T)
y
= 0 (1 - S (T - T0) elastic limit
= 400 MPa =
0
y (T0)

S =

-
10 2 °C-1
= -
10 5 °C-1 thermal dilation coefficient
C p = 0
J/(mm3°C) heat voluminal
= -
10 3
W/(mm°C)
thermal conductivity

For isotropic material declared orthotropic, it comes:

E_L = E_T = E_N = E

Nu_LT = Nu_LN = Nu_TN = Naked =

E
G_LT = G_LN = G_TN =
(
= 76923,077
2 1+)

ALPHA_L = ALPHA_T ALPHA_N = ALPHA =

AND
0

AND
y T
( )
E

Appear 1.2-a: Traction diagram of material

1.3
Boundary conditions and loadings

Modeling A into axisymmetric: uz = 0 on the sides AB and CD (Axis OZ fixes)

Modeling B in plane constraints: uy = 0 on sides AB and CD, ux = 0 in A

T (T) = T + T0 = 1°C/s T0 = 0°C.

Modelings C and D: embedding in A, Dy = 0 out of C

2
Reference solution

2.1
Method of calculation used for the reference solution

Axisymmetric case (2D)

déplacemen

of

Fields
T: U = ur (R) er
(
in

blocking
Z)
U '0
0

R
R

déformatio

of

Fields
N:
(U)

= 0
0
0

according to Z

ur

0 0

R

0 0 0

R

constraint

of

Fields
S:
= L0 1 0
limits)

with

conditions

(cf.

according to Z

0 0 0

Parallelepipedic case

déplacemen

of

Fields
T: U = ux (X) E + U
X
y (y) E y
(
in

blocking
Z)
U '0
0

X
X
déformatio

of

Fields
N:
(U)

= 0

0
0

according to Z

0
0 U y '

y
0 0 0

X

constraint

of

Fields
S:
= L0 1 0
limits)
with

conditions

(cf.

according to Z

0 0 0

y

The case could be studied in plane constraints and 3D.
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AND

E
y
2μ = 1+
E
3K =
E
1 - 2

***The law of behavior** is written (variable scalar intern p):*

1
1

=
*tr **Id** +*
D + p +
O

*(T - T) **Id***
9K
2μ

with:
1
D
*= - tr **Id***
(diverter of the constraints)

3

3
D
3

P
&
=
p&
, with
=
D D

2

éq
2
éq
p& =

0 if F (, p) =
-
éq
R (p) < 0
p&

0 if F (, p) = 0

R (p) indicates the function of work hardening:

E E
R (p)
T

= +
p
y

E - AND

The rate &p can be expressed, when F (, p) = 0. Indeed, from &p F identically no one, one draws:
&p &f+ &p F = 0. Thus, when one is on the criterion (F =)
0, necessarily &f = 0. I.e.:

3D &
D

- R,
T
&T - R, p &p = 0
2
éq

3D &
D
E E

+ O
T
y S &
T -
&p = 0
2
E -

E
éq
T

From where:

E - E
D
D

T
3 &

&p
O
=

+ S
y
&T

if &p 0, for
=
éq
R (p)
E AND 2 éq

(criterion reached, in "load")

The stress field being uniaxial, one a:

-1 0 0

D
L
=
0 2

0
3 0 0 - 1

As follows:

=
éq
L

and:

-1 0 0

P
&p
&
=
sgn (L) 0 2 0
2

0 0 - 1

The relation of behavior leads to:

&p
&rr = & = -
&
- sgn
L
(L) + &T (= &xx = &yy for the case of the parallelepiped)

E
2

1
&zz = 0 =
&
L + &p sgn (L) + &T

E

From where:

3
1 -
2
&rr = & = &T +
&L
2
2nd

&p = sgn (
L
L) - &
&
T -
0
if
L R (p)

E =
<

D
D
E - E

T
3 &

= max 0;

+ O

y

&
St

if not

E E
2

T
éq

I.e., in the case L = R (p) (criterion reached):

E - E

&p
Max 0;
T (sgn (
O
=
L) & + S
L
y
&T)
E E

T

2.1.1 Phase rubber band

At the beginning of the thermal loading, L being lower than y, &p is null.

From where:

&

= - E
L
&T; &rr = & = &T (1+).

As follows:

= - E
L
T
(compressionL <) 0

=

rr

= (1+) T

Validity of the elastic solution

The criterion is:

( ) - ( ) =

= - O
T
T
E
T
(1 - S
L
Y
y
T) 0

The criterion is not crossed for T = [0, ty], with:

O

T
y
y
=

(E
O
+ S
y
)
y - L
OY
T
T y

At the moment ty:

E O

y
L (ty) =
-
E + OY S

1
The density of deformation energy is worth: (
W T =

y)

E (T) 2
2

The total deformation energy is worth in the parallelepipedic case:
1
W (T
2
=-
.(-).
y)
E (T) X
X
H
B
With
2

1
(R 2 -
2
R 2).
The total deformation energy is worth in the axisymmetric case: W (T =
.
y)
E (T)
B
With
H
2
2

(for 1 radian)

2.1.2 Phase elastoplastic

T ty. One is on the criterion. Then:

E - E

&p
Max 0;
T (& sgn
O
=
L
(L) + S
y
&T)
E E

T

By admitting that one is "charges some" (&p >)
0, then one eliminate &p to have:

E - E

&

= - E &T + sgn ()
T

S O
L
T

L
y

E AND

then:
E - E

S O

y
&p
T
=
&T- sgn (

L) +

E
E

With T = ty, = - E
L
ty < 0; one integrates then these expressions for T T (T
y & =):

E - E

(T) = - E
T
O
L
T
(T - ty) -
S -
y
L (ty)

E E

T

(
E - E
p T)
T
=

2
[E +soy] (t-ty)

E

Maybe, after rearrangement, (T ty):

E
T

(T) = bone
T
1
1

L
y
T - +
-

E

T
y

O

y (E - AND)
(
T
p T) =

-
1

E 2

T

y

Validity of this elastoplastic solution

It should be made sure that ()
L T remains negative. Knowing that S T < 1, and that T > T y, the preceding result
confirm that ()
L T < 0.

Lastly, it is noticed that:

1-
2
sgn (L)
p +
= (1+)
& &rr
&T
2

from where:

1-
(
2
T) = (T)
rr

= (1+) T +
(

p T), T [
ty, T fine]
2

(since ()
L T < 0).

2.2
Results of reference

,
rr
xx
zz
or and p
ty

in
and with beyond:

Elastic phase: for T < ty

= - E T =
L
rr

= (1+) T
into axisymmetric
= (

1+)
xx
T
in plane constraints.

The yield stress is reached in T
0
y =
66,666 S from where
(
=
E + S
0)

L (ty) = - 1+ S

0

E

Elastoplastic phase: for T ty

E
T
(T) = S
T
1
1

L
T - +
-
0
E

T
y
0 (E - E

T)
(
T
p T) =

-
1
E 2

T

y

1-
2
=
rr
= (1+) T +
(
p T) into axisymmetric
2
1-
2
or
=
xx
= (1+) T +
(
p T) in plane constraints
2

E = 200.000 MPa; = 0 3
,
; =
-
10 5 °C-1; = 10
. s-1

O

= 400 MPa; To = 0 °C; S = -
10 2 °C-1; T
< 100s
y
end

E
= 50.000 MPa
T

From where:

T

= 66 6666
.
S
y

133 333
.

L

(ty) = -
MPa

elastic phase

-
rr
(ty) = (ty) = 0866666
.
10 3
.

w=4.44410- ²
W=0.17778 (PLANE or 3D)
W=0.26666 (axi)

Then, elastoplastic phase:

with T =
S
80 :
( )
80
= -
L
100 0
. MPa
(
p
)
80
=
-
0 3000
.

10 3
.
( )
80
= ( )
80
=
-3
rr

1100
.
10
.

with T *=*
S
90 :
( )
90
= -
L
75 00
.
MPa
(
p
)
90
=
-
0 5250
.
10 3
.
( )
90
= ( )
90
=
3
rr

1275
.
10
.

2.3
Uncertainty on the solution

Analytical solution.
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V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HT-66/03/008/A

---

3 Modeling
With

3.1
Characteristics of modeling

QUAD4 - Axisymmetric

GRN03
Z
N4
N3
D
C

GRN04
GRN02
With
B
N1
N2
GRN01

Appear 3.1-a: Modeling A

3.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4, 4 SEG2

3.3 Functionalities
tested

Orders

DEFI_MATERIAU ELAS_ORTH

DEFI_MATERIAU TRACTION
SIGM

AFFE_CHAR_MECA DDL_IMPO
TEMP_CALCULEE

STAT_NON_LINE COMP_INCR
RELATION
VMIS_ISOT_TRAC

CALC_ELEM OPTION
EPSI_ELNO_DEPL

CALC_ELEM OPTION

EPOT_ELEM_DEPL

CALC_ELEM OPTION
ENEL_ELGA

POST_ELEM ENER_TOTALE

3.4 Remarks

Functionality AFFE_CARTE is also tested but it is not documented in the test.
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HT-66/03/008/A

Code_Aster ®
Version
6.4

Titrate:
HSNV100 - Thermoplasticity in simple traction

Date:
03/11/03
Author (S):
***J.M. PROIX**, I. DEBOST-EYMARD, F.VOLDOIRE Key*
:
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4
Results of modeling A

4.1 Values
tested

Variables Moments
(S) Reference
Aster %
error

Tolerance relative

T = 66.666
8.6666 10-4 8.66658
10-4
0 0.1

rr =
T = 80
1.1000 10-3 1.10029
10-3
0.026 0.1

T = 90
1.2750 10-3 1.27529
10-3
0.023 0.1

T = 66.666
0
0
0
0.1
p
T = 80
3.0000 10-4
3.0000 10-4
0 0.1

T = 90
5.2500 10-4
5.2500 10-4
0 0.1

T = 66.666
-133.333
-133.332
-0.001
0.1
zz
T = 80
-100.000

-100.00
0
0.1

T = 90
-75.000
-75.000
0
0.1
ENEL_ELGA
T = 66.666
4.444. 10-2 4.444.
10-2 0.00 0.1

ENER_TOTALE T = 66.666
0.2666
0.2666
-0.00
0.1
ENER_POT
T = 66.666
0.2666
0.2666
-0.00
0.1

4.2 Notice

One obtains well the same results with isotropic material declared orthotropic as with material isotropic in thermoelasticity, i.e. for the sequence number 1 with T = 66.666 S.

---

5 Modeling B

5.1 Characteristics of modeling

QUAD4 - Plane constraints

y
N4
N3
D
C
With
B
N1
N2

Appear 5.1-a: Modeling B

5.2 Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4, 4 SEG2

5.3 Functionalities tested

Orders

DEFI_MATERIAU TRACTION
SIGM

AFFE_CHAR_MECA DDL_IMPO
TEMP_CALCULEE

STAT_NON_LINE COMP_INCR
RELATION
VMIS_ISOT_TRAC

CALC_ELEM OPTION
EPSI_ELNO_DEPL

CALC_ELEM OPTION
EPOT_ELEM_DEPL

CALC_ELEM OPTION
ENEL_ELGA

POST_ELEM ENER_TOTALE

POST_ELEM ENER_POT

6
Results of modeling B

6.1 Values tested

Variables Moments
(S) Reference
***Aster** %*
error
Tolerance
relative

T = 66.666
8.6666 10-4 8.66658
10-4
0 0.1
xx
T = 80
1.1000 10-3
1.1000 10-3
0 0.1

T = 90
1.2750 10-3
1.2750 10-3
0 0.1

T = 66.666
0
0
0
0.1
p
T = 80

3.0000 10-4
3.0000 10-4
0 0.1

T = 90
5.2500 10-4
5.2500 10-4
0 0.1

T = 66.666
-133.333
-133.332
-0.001
0.1
yy
T = 80
-100.
-100.00
0
0.1

T = 90
-75.000
-75.00
0.001
0.1
ENEL_ELGA
T = 66.666
4.444. 10-2 4.444.
10-2 0.00 0.1

ENER_TOTALE T = 66.666
0.17777
0.17777
-0.00
0.1
ENER_POT
T = 66.666
0.17777
0.17777

-0.00
0.1

---

7 Modeling C

7.1 Characteristics of modeling

1 element PIPE

C
With

7.2 Characteristics of the grid

1 element PIPE

7.3 Functionalities tested

Orders

AFFE_MODELE
MODELING PIPE

STAT_NON_LINE COMP_INCR
RELATION
VMIS_ISOT_TRAC

TUYAU_NCOU
1

TUYAU_NSEC
16

8
Results of modeling C

8.1 Values
tested

Variables Moments
(S) Reference
***Aster** %*
difference

T = 66.666
0
0
0
p
T = 80
3. 10-4
3.003 10-4 0.1

T = 90
5.25 10-4 5.2526
0.05

T = 66.666
-1.333
-1.3313
-0.16
yy
T = 80

-100
-99.82
-0.18

T = 90
-75
-74.85
-0.2

---

9 Modeling D

9.1 Characteristics of modeling

1 element PIPE 6M

C
With

9.2 Characteristics of the grid

1 element PIPE

9.3 Functionalities tested

Orders

AFFE_MODELE MODELING TUYAU_6M

STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_TRAC

TUYAU_NCOU 1

TUYAU_NSEC 16

10 Results of modeling D

10.1 Values tested

Variables Moments (S) Reference Aster % difference

T = 66.666
0
0
0
p
T = 80
3. 10-4

3.003 10-4 0.1

T = 90
5.25 10-4 5.2526
0.05

T = 66.666
-1.333
-1.3313
-0.16
yy
T = 80
-100
-99.82
-0.18

T = 90
-75
-74.85
-0.2

---

11 Modeling
E

11.1 Characteristics of modeling

QUAD4 - Axisymmetric. Test of the variation of the coefficients of VMIS_CINE_LINE according to temperature, in this case AND (given by D_SIGM_EPSI) varies like: AND = 105 (1102 (TT0)).
2nd E
constant of Prager is worth: C
T
=
.
3rd - AND

GRN03
Z
N4
N3
D
C
GRN04
GRN02
With
B
N1
N2
GRN01

Appear 3.1-a: Modeling E

11.2 Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4, 4 SEG2

11.3 Functionalities tested

Orders

DEFI_MATERIAU ECRO_LINE_FO D_SIGM_EPSI

DEFI_MATERIAU PRAGER_FO
C

DEFI_MATERIAU TRACTION
SIGM

AFFE_CHAR_MECA DDL_IMPO
TEMP_CALCULEE

STAT_NON_LINE COMP_INCR
RELATION
VMIS_ECMI_TRAC

CALC_ELEM OPTION
EPSI_ELNO_DEPL

STAT_NON_LINE COMP_INCR
RELATION
VMIS_CINE_LINE

11.4 Notice

One tests the variation of AND (D_SIGM_EPSI) with the temperature per comparison with behavior VMIS_ECMI_TRAC where C (constant of Prager) varies with the temperature in way similar (not of analytical solution).

17/20

12 Results of modeling E

12.1 Values
tested

Variables
Moments (S)
Reference (Aster)
Aster
% error
Tolerance
(VMIS_ECMI_TRAC) (VMIS_CINE_LINE)
relative

T = 66.666
8.6666 10-4 8.66658
10-4 0
0.1

rr =
T = 80
1.112 10-3 1.112
10-3 0 0.1

T = 90
1.303 10-3 1.303
10-3 0 0.1

T = 66.666
-133.333
-133.332
0
0.1
zz
T = 80
-88
-88
0
0.1

T = 90
-47
-47
0
0.1

12.2 Notice

One obtains well the same results with behavior VMIS_CINE_LINE as with behavior VMIS_ECMI_TRAC what validates the taking into account of the temperature in this model.

---

13 Modeling
F

13.1 Characteristics of modeling

1 element POU_D_T

C
With

13.2 Characteristics of the grid

1 mesh SEG2

13.3 Functionalities
tested

Orders

AFFE_MODELE
MODELING TUYAU_6M

STAT_NON_LINE COMP_INCR
RELATION
ELAS

CALC_ELEM OPTION
EPOT_ELEM_DEPL

POST_ELEM ENER_POT

14 Results of modeling D

14.1 Values
tested

Variables Moments
(S) Reference
Aster %
difference
yy
T = 66.666
-1.333
-1.3313
-0.16
ENER_POT
T = 66.666

0.3555
0.3555
0.00

15 Modeling
G

15.1 Characteristics of modeling

3D, H=1

y
N4
N3
D
C
With
B
N1
N2

Appear 5.1-a: Modeling G

15.2 Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8

15.3 Functionalities tested

Orders

DEFI_MATERIAU TRACTION SIGM

AFFE_CHAR_MECA DDL_IMPO TEMP_CALCULEE

STAT_NON_LINE COMP_INCR RELATION VMIS_ISOT_TRAC

CALC_ELEM OPTION EPSI_ELNO_DEPL

CALC_ELEM OPTION EPOT_ELEM_DEPL

CALC_ELEM OPTION ENEL_ELGA

POST_ELEM ENER_TOTALE

POST_ELEM ENER_POT

Handbook of Validation

---

16 Results of modeling G

16.1 Values
tested

Variables Moments
(S) Reference
Aster %
error
Tolerance
relative

T = 66.666
8.6666 10-4 8.66658
10-4
0 0.1
xx
T = 80
1.1000 10-3
1.1000 10-3
0 0.1

T = 90
1.2750 10-3
1.2750 10-3

0 0.1

T = 66.666
0
0
0
0.1
p
T = 80
3.0000 10-4
3.0000 10-4
0 0.1

T = 90
5.2500 10-4
5.2500 10-4
0 0.1

T = 66.666
-133.333
-133.332
-0.001
0.1
yy
T = 80
-100.
-100.00
0
0.1

T = 90
-75.000
-75.00
0.001
0.1
ENEL_ELGA
T = 66.666
4.444. 10-2 4.444.
10-2 0.00 0.1

ENER_TOTALE T = 66.666
4.444. 10-2 4.444.
10-2 -0.00 0.1
ENER_POT
T = 66.666
4.444. 10-2 4.444.
10-2 -0.00 0.1

17 Summary of the results

The results are satisfactory and validate the behaviors thermoplastic of Von Mises with isotropic work hardening and linear kinematics. The finite elements used are the elements 2D (quadrilaterals in plane constraints or axisymetry) and the elements PIPE.

One notes in particular a good modeling of the variation of the elastic limit and constant of Prager with the temperature.

Author (S):
A. RAZAKANAIVO, F. WAECKEL

Organization (S): EDF/IMA/MMN

Document: V7.22.101

HSNV101 - Thermoplasticity and metallurgy uncoupled in simple traction

Summary:
One treats the determination of the mechanical evolution of a cylindrical bar subjected to thermal evolutions
T T

() and metallurgical Z T () known and uniform (the metallurgical transformation is of bainitic type).
The elements used are axisymmetric elements and the relation of behavior is the plasticity of von Mises with linear isotropic work hardening (for modeling B, one also takes account of plasticity of transformation).
The yield stress and the slope of the traction diagram depend on the temperature and the composition metallurgical.
The dilation coefficient depends on the metallurgical composition.
The metallurgical transformations take place with! p = 0 (it is in the sense that the test uncouples plasticity from
transformation of traditional plasticity).
The results provided by Code_Aster are very satisfactory with errors lower than 2%.

1
Problem of reference
1.1 Geometry
Z
Ray: = 0.05 Mr. has.
Height: H = 0.2 Mr.
P
C
D
H
R
With
B
has
1.2
Properties of materials

T
6
E T
E
aust
aust
= 200000.10 Pa

=
+ saust
O
y
O
(T - T) let us note H (T) () ()
= E (T) - (T)
aust
= 0.3

= 400. 106 Pa
H aust = Haust
aust
O
O
O
+
(T - T)

=
-6
-
15. 10
° C 1
saust =
6
-
0.5 10 Pa. ° C 1
H aust
6
fbm
O
= 1250 10 Pa
-6
-1
fbm

fbm

= 23.5 10 ° C

=
+ S fbm
O
aust
6
-1
aust
y
O
(T - T) = 5 10 Pa.°C
-3
fbm

= 2.52 10

= 530. 106 Pa
H fbm = H fbm
fbm
+
(O
T - T)
ref.
O
O
fbm
ref.
T
=
°
900 C
fbm
6
-1
fbm
S
= 0.5 10 Pa.° C
H
6
O
= - 50 10 Pa

-3
-1
-1
-1
fbm
CP = 2.000.000 J.m ° C
= 9999.9 W.m ° C

= - 5.106 P a° -
C 1
m
K =
-10
- 1
1. 10
Pa
**aust*
=
characteristics relating to the austenitic phase
**fbm*
=
characteristics relating to the phases ferritic, bainitic and martensitic
fbm
=
thermal dilation coefficient of the phases ferritic, bainitic and martensitic
aust
=
dilation coefficient of the austenitic phase
ref.
=
deformation of the phases ferritic, bainitic and martensitic at the temperature of reference,
fbm
austenite being regarded as not deformed at this temperature: translated the difference of compactness enters the cubic crystallographic structures to centered faces (austenite) and cubic centered (ferrite).

TRC to model a metallurgical evolution of bainitic type, on all the structure, of the form:
0.

if T1
1 = 60 S
T -
Z
1
fbm
=
if

1 T < 2
2 = 112 S
2 - 1

if T
1.
2

Law of plasticity of transformation: ! Pt
fbm
= K
F (Z fbm)! Z fbm
with F Z
( )
(
)
fbm = Z fbm 2 - Z fbm
1.3
Boundary conditions and loadings
.
uZ = 0 on side AB (condition of symmetry).
p
O T

for T
p
p T
( )=
1
O = 6.106 Pa

for T

.
360.106 Pa

traction imposed on the side CD,
1
1 = 60 S
.
.
T
T O
=
+ µt, µ = -5°C.s-1 on all the structure.
1.4 Conditions
initial
T O = 900°C = Tref
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics
HI-75/98/040/A

2
Reference solution
2.1
Method of calculation used for the reference solution

Before transformation, elastic solution for *T* < 1.

(
T
( )
T) = *p*
E
HT
O T
zz T () = *zz T* () + *zz T* () =
+
E
aust T - *T O*
(
)
aust

The yield stress is reached for '
O
1
=
= 47.06 S.
Po - *saust* × µ

Before transformation, thermoelastoplastic solution, '1 *T1*, 1 = 60 S.

(*T*) = *p*
E
HT
p ()

O T
zz T () = *zz T* () + *zz T* () + *T*
zz
E
T ()
HT
zz T
( ) =
T () = *Z*
E
zz
aust × *aust T* - *T O*
(
)
T () - *aust* + *Saustµ T*
(
)
p
y
zz T
( ) =
Haust
O
+ *austµ T*
During the transformation, thermo-élasto-metallurgical solution, 1 < *T* < 2, 2 = 112 S.
(*T*) = 360.106 Pa

E
HT
Pt
p
zz (*T*)
= *zz T* () + *zz T* () + *T*
60
zz () + *zz* (
)
thzz T () = *Zaust* × *aust T* - *To*
(
) + *Zfbm* ×fbm *T* - *To*
(
) +Zfbm ×reffbm
p
( )

zz T
() = *K fbmF Zfbm Po1*
After the transformation, thermoelastoplastic solution, 2 < *T* < 3, 3 = 176 S.
(*T*) =
6
E
HT
p
Pt
360 10 Pa
zz (*T*) = *zz T* () + *zz T* () + *zz T* () + *zz* 112
( )
T () - *fbm*
(+ *sfbmµt*)
p
O
zz T
( ) =
H fbm + *fbmµ*
O
T

2.2

Results of reference

pzz, and *zz* for T = 47, 48, 64 and 114 seconds.
pzz for T = 60 and 176 seconds.

2.3 Bibliography

[1]
DONORE A.M. - WAECKEL F.: Influence structure transformations in the laws of
behavior elastoplastic Notes HI-74/93/024.

---

3 Modeling
With

3.1
Characteristics of modeling

y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B

With = N4, B = N5, C = N13, D = N12.

3.2
Characteristics of the grid

A number of nodes: 13
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3

3.3 Functionalities
tested

Orders
Keys
DEFI_MATERIAU
META_THER
[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]

STAT_NON_LINE
COMP_INCR
RELATION
META_EP
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics
HI-75/98/040/A

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
pzz T = 47 S
0
0
0
T = 47 S
0

0
0
T = 47 S
282. 106
282. 106
0
zz T = 47 S
4.1125 103
4.1125 103
0
pzz T = 48 S
3.2653 103
3.26537 103
0.011
T = 48 S
1
1
0
T = 48 S
288. 106
288. 106
0
zz T = 48 S
9.3469 104
9.34645 104
0.005
pzz T = 60 S
0.04
0.04
0
pzz T = 64 S
0.040
4.0 10-2
0
T = 64 S
0
0
0
T = 64 S
360. 106
360. 106
0
zz T = 64 S

3.4683 102
3.46908 102
0.023
pzz T = 114 S
0.04107
4.10688 102
+0.004
T = 114 S
1
1
0
T = 114 S
360. 106
360. 106
0
zz T = 114 S
0.03684
3.68407 102
0
pzz T = 176 S
0.06206
6.20680 102
0.000

4.2 Remarks

In this modeling:
Pt (
)
zz T, Z
= 0

4.3 Parameters of execution

Version: 4.02.14
Machine: CRAY C90
Obstruction memory:
8 megawords
Time CPU To use:
109.3 seconds

---

5 Modeling
B
5.1
Characteristics of modeling
y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B
With = N4, B = N5, C = N13, D = N12.
5.2
Characteristics of the grid
A number of nodes: 13
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3
5.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
META_THER

[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
META_PT
STAT_NON_LINE
COMP_INCR
RELATION
META_EP_PT
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

---

6 Results of modeling B

6.1 Values tested

Identification

Reference
Aster
% difference
pzz T = 47 S
0
0
0
T = 47 S
0
0
0
T = 47 S
282. 106
282. 106
0
zz T = 47 S
4.1125 103
4.1125 103
0
pzz T = 48 S
3.2653 103
3.26535 103
0.011
T = 48 S
1
1
0
T = 48 S
288. 106
288. 106
0
zz T = 48 S
9.3469 104
9.34644 104
0.005
pzz T = 60 S
0.04
0.04
0
pzz T = 64 S
0.04
4.0 102
0

T = 64 S
0
0
0
T = 64 S
360. 106
359.99 106
0.004
zz T = 64 S
4.00085 102
4.000268 102
0.015
pzz T = 114 S
0.041071
4.10751 102
+0.004
T = 114 S
1
1
0
T = 114 S
360. 106
360.01 106
0.000
zz T = 114 S
0.072841
7.144112 102
1.915
pzz T = 176 S
0.06206
6.2066 102
0.000

6.2 Remarks

In this modeling, one takes into account the term due to the plasticity of transformation:
! *Pt* (*T*, *Z*) 0
when!
Z 0

6.3 Parameters
of execution

Version: 4.02.14
Machine: CRAY C90
Obstruction memory:
8 megawords

Time CPU To use:
114.11 seconds

7
Summary of the results

The results found with *Code_Aster* are very satisfactory, with percentages of error
lower than 0.025% except for the deformation at moment 114 S where the error reaches 2% for modeling B.

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics
HI-75/98/040/A

Author (S):
A. RAZAKANAIVO, *F. WAECKEL*

Organization (S): EDF/IMA/MMN

Handbook of Validation
V7.22 booklet: Thermomechanical statics nonlinear of the voluminal structures
Document: V7.22.102

HSNV102 - Thermo-metal-worker-plasticity coupled in simple traction

Summary:

One treats the determination of the mechanical evolution of a cylindrical bar subjected to evolutions thermics
T T
() and metallurgical *Z T* () known and uniform (the metallurgical transformation is of martensitic type).
The elements used are axisymmetric elements and the relation of behavior is plasticity of
von Mises with isotropic work hardening (for modeling B, one also takes account of the plasticity of transformation).
The yield stress and the slope of the traction diagram depend on the temperature and the composition metallurgical.
The dilation coefficient depends on the metallurgical composition.
The metallurgical transformations take place with! *p* 0 (it is in the sense that the test **couples the** plasticity of
transformation of traditional plasticity).

1
Problem of reference
1.1 Geometry
Z
C
D
Ray: = 0.05 Mr. has.
H
Height: H = 0.2 Mr.
R
With
B
has
1.2
Properties of materials
T
6
E T
E
aust
aust
= 200 000.10 Pa

=
+ *saust*
O
y

O
(*T* - *T*) let us note *H* (*T*) () ()
= *E* (*T*) - (*T*)
aust
= 0.3

= 50. 106 Pa
Haust = *Haust*
aust
O
O
O
+
(*T* - *T*)

=
-6
-
15. 10
° C 1
saust =
6
-
1.3 10 Pa.° C 1
Haust
fbm
O
= 0 Pa
-6
-1
fbm
fbm

= 23.5 10 ° C

=
+ *S* *fbm*
O
aust
6
-1
aust
y
O

(*T* - *T*) = 1 10 Pa.°C
-3
fbm

= 2.52 10

= 50. 106 Pa
H fbm = *H fbm*
fbm (
O
T - *T*)
ref.
O
O
+
fbm
fbm
6
-1
fbm
S
= 1. 10 Pa.° C
Ho
= 0
-3
-1
-1
-1
fbm
CP = 2.000.000 J.m ° C
= 9999.9 W.m ° C

= - 6. 106

Pa ° -
C 1
F
B
m
K = 0 *K*

= *K* =
-10
-

1. 10
Pa 1

Note:

The indices or exponents fbm relate to the parameters materials of the phases ferrito-perlitic, bainitic and martensitic and the indices or exponents aust relate to austenite.

TRC to model a metallurgical evolution of martensitic type of the form:

0.

if *T*

1
1 = 25 S
1
- *E T* (- 1) if

1 *T* < 2
2 = 40 S
= 0.03 = -10°C.s-1
1.
if *T* 2

1.3
Boundary conditions and loadings

·
***uZ* = 0 on side AB (condition of symmetry).**
· traction imposed on the side CD, (
p T*) = *p T
O
, *Po* = 15.106 Pa.
·
T
T O
=
+ µt, µ = 10°C.s1 on all the structure.

1.4 Conditions
initial

***T O* = 900°C.**

2 Reference solution

2.1 Method of calculation used for the reference solution

Before transformation, thermoelastic solution for *T* < 1 (not of transformation metallurgical ! *Z* = 0).

(*T*) = *Po T*

E
HT
***T* ()**
zz T
() = *zz T* () + *zz T* () =
+
E
aust T* - *T O
(
)
aust

The yield stress is reached for

O
1
=
= 25 *S.*
Po* - *saust* × *K

During the transformation, solution thermo-metal-worker-élasto-plastic, for 1 < *T* < 2 with 2 = 40 S.

(*T*) = *Po T*

E
HT
***p* ()**

Pt
zz T
() = zz T () + zz T () + T + T ()
zz
zz
E
T ()
zz T
( ) =
E
HT
[
]
zz T
() = Zaust × aust T - To
(
) + Zfbm × fbm T - To
(
) + reffbm
T () - Z
aust T
() + Z
fbm
(
)
p
aust × y
fbm ×
T
( ) =
y T
( )
Zaust × Haust T
() + Zfbm × H fbm T
( )

Pt
K
K
T
() = K

(
) 2
m × Po × 1 -
- K
1 - Z

2 × ×
m × Po × T -

2 × ×
After transformation, thermoelastoplastic solution, for T > 2
(T) = Po T

E
HT
p
zz T
() = zz T () + zz T () + (T)
zz
2.2
Results of reference
, zz, p, to 24 S, 26 S, 40 S and 90 S.

---

3 Modeling
With
3.1
Characteristics of modeling

y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B
With = N4, B = N5, C = N13, D = N12.
3.2
Characteristics of the grid
A number of nodes: 13
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3
3.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
META_REFR
[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
STAT_NON_LINE
COMP_INCR
RELATION
META_EP
[U4.32.01]
CALC_ELEM

OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics
HI-75/98/040/A

Code_Aster ®
Version
4.0
Titrate:
HSNV102 - Thermo-metal-worker-plasticity coupled in simple traction
Date:
01/12/98
Author (S):
A. RAZAKANAIVO, F. WAECKEL
Key:
V7.22.102-B Page:
5/8
4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
p T = 24 S
0
0
-
T = 24 S
0
0
-
T = 24 S
360. 106
360. 106
0

zz T = 24 S
3.84 10-3
3.84 10-3
0
p T = 26 S
0.0372
3.7217 10-2
0.047
T = 26 S
1
1
0
T = 26 S
390. 106
390. 106
0
zz T = 26 S
3.428 10-2
3.4283 10-2
p T = 40 S
0.0625
6.2523 10-2
0.038
T = 40 S
1
1
0
T = 40 S
600. 106
600. 106
0
zz T = 40 S
0.06198
6.1977 10-2
0.068
p T = 90 S
0.0741
7.4146 10-2
0.062
T = 90 S
1
1
0

T = 90 S
1350. 106
1350. 106
0
zz T = 90 S
0.069844
6.9854 10-2
0.014

4.2 Remarks

In this modeling:
Pt T
(, Z) = 0

4.3 Parameters of execution

Version: 4.00.06
Machine: CRAY C90
System: 8.0
UNICOS
Obstruction memory:
8 megawords
Time CPU To use:
42.47 seconds

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics
HI-75/98/040/A

---

5 Modeling
B

5.1
Characteristics of modeling

y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B
With = N4, B = N5, C = N13, D = N12.

5.2
Characteristics of the grid

A number of nodes: 13
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3

5.3 Functionalities
tested

Orders
Keys

DEFI_MATERIAU
META_REFR
[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
META_PT
STAT_NON_LINE
COMP_INCR
RELATION
META_EP_PT
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

6
Results of modeling B
6.1 Values

tested
Identification
Reference
Aster
% difference
p T = 24 S
0
0
-
T = 24 S
0
0
-
T = 24 S
360. 106
360. 106
0
zz T = 24 S
3.84 10-3
3.84 10-3
0
p T = 26 S
0.0372
3.7217 10-2
0.047
T = 26 S
1
1
0
T = 26 S
390. 106
390.00 106
0.000
zz T = 26 S
0.051507
5.098 10-2
1.009
p T = 40 S
0.06252
6.2523 10-2
0.037
T = 40 S
1

1
0
T = 40 S
600. 106
600. 106
0
zz T = 40 S
0.10197
1.0093 10-1
1.018
p T = 90 S
0.07407
7.4145 10-2
0.062
T = 90 S
1
1
0
T = 90 S
1350. 106
1350. 106
0
zz T = 90 S
0.10984
1.08806 10-1
0.942

6.2 Remarks

In this modeling, one takes into account the term due to the plasticity of transformation:
! *Pt* (*T*, *Z*) 0
when!
Z 0

6.3 Parameters of execution

Version: 4.00.06
Machine: CRAY C90
System: 8.0
UNICOS
Obstruction memory:
8 megawords
Time CPU To use:
94.44 seconds

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics

7
Summary of the results

Two modelings give very good approximations of the reference solution.

Organization (S): EDF/IMA/MMN

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
Document: V7.22.103

HSNV103 - Thermoplasticity and metallurgy
in plane deformations

Summary:

One treats the determination of the mechanical evolution of a right-angled parallépipède in subjected plane deformations
with evolutions thermics *T T*

() and metallurgical *Z T* () known and uniform (the metallurgical transformation
is of bainitic type).
The elements used are two-dimensional elements in plane deformations and the relation of behavior
is the plasticity of von Mises with linear isotropic work hardening (for modeling B, one also holds
count plasticity of transformation).
The yield stress and the slope of the traction diagram depend on the temperature and the composition
metallurgical.
The dilation coefficient depends on the metallurgical composition.
For modeling A (without plasticity of transformation), the reference solution is obtained by the resolution
analytical of the problem. For modeling B (with plasticity of transformation), the reference solution is
obtained by the numerical resolution of the problem by using axisymmetric elements for which one
impose the condition of plane deformations.
The results provided by *Code_Aster* are very satisfactory with errors lower than 0,5%.
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/98/040/A

1
Problem of reference
1.1 Geometry

y
Width: = 0.05 Mr. has.
Height: H = 0.2 Mr.
C
D
H
R
X
With
B
has

1.2
Properties of materials

T
6
E T
E
aust
aust
= 200000.10 Pa

=
+ *saust*
O
y
O
(*T* - *T*) let us note *H* (*T*) () ()
= *E* (*T*) - (*T*)
aust
= 0.3

= 400. 106 Pa
H aust = *H aust*
aust
O
O
O
+
(*T* - *T*)

=
-6
-
15. 10
° C 1
saust =
6
-
0.5 10 Pa.° C 1
H aust
6
fbm
O
= 1250 10 Pa
-6

-1
fbm
fbm

= 23.5 10 °C

=
+ *S fbm*
O
aust
6
-1
aust
y
O
(*T* - *T*) = 5 10 Pa.°C
-3
fbm

= 2.52 10

= 530. 106 Pa
H fbm = *H fbm*
fbm
+
(*O*
T - *T*)
ref.
O
O
fbm
ref.
T
=
∘
900 *C*
fbm
6
-1
fbm
S
= 0.5 10 Pa.°C
H
6

O
= - 50 10 Pa
-3
-1
-1
-1
fbm
.cp = 2.000.000 J.m °C
= 9999.9 W.m °C

= - 5.106 P a° -
C 1
fbm
K
=
-10
- 1
1. 10
Pa
*aust
=
characteristics relating to the austenitic phase
*fbm
=
characteristics relating to the phases ferritic, bainitic and martensitic
fbm
=
thermal dilation coefficient of the phases ferritic, bainitic and martensitic
aust
=
dilation coefficient of the austenitic phase
ref.
=
deformation of the phases ferritic, bainitic and martensitic at the temperature of reference,
fbm
austenite being regarded as not deformed at this temperature: translated the difference
of compactness enters the cubic crystallographic structures to centered faces (austenite) and
cubic centered (ferrite).

Version
4.0
Titrate:
HSNV103 - Thermoplasticity and metallurgy in plane deformations
Date:
01/12/98
Author (S):
F. WAECKEL
Key:
V7.22.103-B Page:
3/10
TRC to model a metallurgical evolution of bainitic type, on all the structure, of the form:
0.
if *T*

1
1 = 60 S
T -
Z

1
if
1 *T*
fbm
=
< 2 2 =

112 S
2 -

1 if *T*

1
2
.
Law of plasticity of transformation: ! *Pt*
fbm
= *K*
F (*Z fbm*)! *Z fbm*
with *F* (*Z*) = *Z* (*Z* - *Z*
fbm
fbm
fbm)
Notations: *T*

(1) = *T1*
T
(2) = *T2*

1.3
Boundary conditions and loadings

·
uY = 0 on side AB; . uX = 0 in A.
·
T
T O
=
+ µt, µ = 5°C.s1 on all the structure.
· The loading on the structure is due to the phenomena of thermal dilation and metallurgical constrained in direction Z by the condition of plane deformations.

1.4 Conditions
initial

T O = 900°C = *Tref*

2
Reference solution (for modeling A)

2.1
Method of calculation used for the reference solution

Before transformation, thermoelastic solution until *T1* such as:
- *O*

HT
O
y

zz = -
E
= *y T* - *T* =
= 76, °
92 *C*

E + *S*
T1 = 15 38
, *S*
thus for *T T1*

O
zz = -
E (*T* - *T*)
Before transformation, and for *T T1*, thermoelastoplastic solution such as:

p
zz = 0
and *zz* =
R zz + *y*
- (*T*) -
O
E T - *T*
p
y
(
)
of

p
O
zz =
where and *zz* = - *E*
+
T - *T*
E + *R T*
(*zz*
)
( )
(
During the transformation, one remains in load as long as! *HT* < 0
O
-
T -

+
T1 -
T
HT
() *réf*
fbm

2
! = 0 *T* =
(
= 538 °
82 *C*
2 -)
,
T = *t2* = 72,23s
for T > 538,82 °C
there is thus a thermoelastoplastic soution with phase shift:
-
O
y (*T*, *Z*) - *E* (*Z*) *T* - *T*
+ *Z réf*
p
[() *fbm*]

p
O
zz =
and
= - *E*
+
Z T - *T* + *Z*
E + *R* (*T*, *Z*)
zz
(zz () () *réffbm*)
and for T < 538,82 °C
there is thus a thermoelastic soution with phase shift:

O
p
zz = - *E* (*Z*)
[(*T*-*T*) +Zréf +zz (*T*
fbm
2)]
After the transformation, one replastifie when:

p
zz = *R* (*T*, *Z*) *zz* + *y* (*T*, *Z*)

with
zz
O
zz =
+ (*T* - *T*) + *réf* = 0
E
fbm
that is to say *T* = 267
°
06
,
C
and one thus has for *T* < 267,06°C
O
E - *réf*
-
T - *T*
- *y T*, *Z*
p
[
fbm
(
)] ( )

p
zz =
and
= *R T*, *Z*
+
T, *Z*
R (*T*, *Z*)
zz
() *zz y* ()
+ *E*

2.2
Results of reference

, *p*, *xx* and *zz* with *T* =16s
p, *xx* and *zz* with *T* = 60s
p
with *T* = 72s
, *p*,
and *zz* with *T* = 112s
,
xx and *zz* with *T* =176s

2.3 Bibliography

[1]
DONORE A.M. - WAECKEL F. - Influence of structure transformations in the laws of behavior elastoplastic Notes HI-74/93/024.

---

3 Modeling
With
3.1

Characteristics of modeling
y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B
With = N4, B = N5, C = N13, D = N12.

3.2
Characteristics of the grid

A number of nodes: 13.
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3.

3.3 Functionalities
tested

Orders
Keys

DEFI_MATERIAU
META_THER
[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
STAT_NON_LINE
COMP_INCR
RELATION
META_EP
[U4.32.01]

CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/98/040/A

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
xx T = 16 S
2.4599 103
2.4599 103
0.001
T = 16 S
1
1
0
T = 16 S
360.13 106
360.13 106

0
p T = 16 S
7.9345 105
7.9345 105
0.001
xx T = 60 S
1.0309 102
1.0309 102
0.003
p T = 60 S
5.7213 103
5.7213 103
0.001
T = 60 S
265.73 106
265.73 106
0.001
p T = 72 S
5.8420 103
5.8162 103
0.442
T = 112 S
0
0
0
T = 112 S
12.82 106
12.76 106
0.384
p T = 112 S
5.8421 103
5.8162 103
0.444
xx T = 176 S
1.5886 102
1.5886 102
0.003
T = 176 S
1
1
0
T = 176 S
133.55 106

133.55 106
0.002

4.2 Remarks

In this modeling:
Pt
zz (*T*, *Z*)
= 0

The error on the plastic deformation cumulated at 72 seconds comes in fact from the error made on numerical description of the metallurgical transformation which is, at this moment, from approximately 0,5%.

4.3 Parameters
of execution

Version: 4.02.14
Machine: CRAY C90
Obstruction memory:
8 megawords
Time CPU To use:
194.69 seconds

---

5 Modeling
B

5.1
Characteristics of modeling

y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B

With = N4, B = N5, C = N13, D = N12.

5.2
Characteristics of the grid

A number of nodes: 13.

A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3.

5.3 Functionalities
tested

Orders

Keys

DEFI_MATERIAU
META_THER
[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
META_PT
STAT_NON_LINE
COMP_INCR
RELATION
META_EP_PT
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

---

6 Results of modeling B

6.1 Values

tested
Identification
Reference
Aster
% difference
T = 60 S
265.73 106
265.73 106
0.001
p T = 60 S
5.7213 103
5.7213 103
0.001
yy T = 89 S
1.0325 102
1.0326 102
0.012
p T = 89 S
5.7213 103
5.7213 103
0.001
T = 89 S
13.545 106
13.5457 106
0.006
yy T = 112 S
8.9197 103
8.9208 103
0.017
T = 112 S
101.39 106
101.345 106
0.044
p T = 112 S
5.7213 103
5.7213 103
0.001
yy T = 176 S
1.5884 102
1.5889 102
0.03
p T = 176 S
9.3610 102

9.3610 102
0
T = 176 S
130.72 106
130.72 106
0

6.2 Remarks

In this modeling, one takes into account the term due to the plasticity of transformation:
! *Pt* (*T*, *Z*) 0
when!
Z 0
The reference solution is obtained by the numerical resolution of the problem with elements axisymmetric for which one imposes the condition of plane deformations.

6.3 Parameters
of execution

Version: 4.02.14
Machine: CRAY C90
Obstruction memory:
8 megawords
Time CPU To use:
202.42 seconds

7
Summary of the results

The results found with *Code_Aster* are very satisfactory, with percentages of error lower than 0.5%.

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
Document: V7.22.104

HSNV104 - Thermoplasticity and metallurgy in plane deformations with restoration of work hardening

Summary:

One treats the determination of the mechanical evolution of a right-angled parallélipipède in plane deformations
subjected to evolutions thermics T T
() and metallurgical Z T () known and
uniforms (the metallurgical transformation is of bainitic type).

The elements used are two-dimensional elements in plane deformations and the relation of behavior
is the plasticity of von Mises with linear isotropic work hardening. Account of the restoration is taken
of work hardening, but not of the plasticity of transformation.

The dilation coefficient depends on the metallurgical composition.

The reference solution is obtained by the analytical resolution of the problem.

The results provided by *Code_Aster* are very satisfactory with errors lower than 0,8%.

1
Problem of reference
1.1 Geometry
y
Width: = 0.05 Mr. has.
Height: H = 0.2 Mr.
C
D
H
R
X
With
B
has
1.2
Properties of materials
T
6
-6
-1
E T
E
fbm
= 200000.10 Pa
= 20.10 ° C
let us note *H* (*T*)
( ) ( )
= *E* (*T*) - (*T*)
aust
-6
-1
O = 20.10 °C
= 0.3
Haust =
6
-
2000.10 Pa

3
ref.
= 2.52 10
fbm
T ref. =
°
900 C
H fbm = 2000.106 Pa
CP =
-
2000000 J.m3
-
° C 1
= 9999.9 W.m
-1
-
° C 1
*aust
=
characteristics relating to the austenitic phase,
*fbm
=
characteristics relating to the phases ferritic, bainitic and martensitic,
fbm = thermal dilation coefficient of the phases ferritic, bainitic and martensitic,
aust = dilation coefficient of the austenitic phase
ref.
=
deformation of the phases ferritic, bainitic and martensitic at the temperature of
fbm
reference, austenite being regarded as not deformed at this temperature:
translated the difference in compactness between the cubic crystallographic structures with
centered faces (austenite) and cubic centered (ferrite).

TRC to model a metallurgical evolution of bainitic type, on all the structure, of the form:
0.

if *T1*
1 = 60 S
T -
Z
1
fbm
=
if

1 *T* < 2
2 = 112s
2 - 1

if *T*
1.
2

Law of plasticity of transformation: ! *Pt*
fbm
= *K*
F (*Z fbm*)! *Z fbm*
with *F Z*
( )
(
)
fbm = *Z fbm Z* - *Z fbm*
one thus does not take account of the plasticity of transformation one takes *K fbm* = 0
Notations: *T*
(1) = *T1*
T
(2) = *T2*

1.3
Boundary conditions and loadings

·
uY = 0 on side AB; uX = 0 in A.

·
T
T O
=
+ µt, µ = 5°C.s1 on all the structure.
· The loading on the structure is due to the phenomena of thermal dilation and metallurgical constrained in direction Z by the condition of plane deformations.

1.4 Conditions
initial

T O = 900°C = *Tref*

2
Reference solution

2.1
Method of calculation used for the reference solution

Before transformation, thermoelastic solution until *T1* such as in *T1*:
- *aust*

y
zz = - *E HT* = *y*
T - *To* =
= -100°C
E + *has*
T1 = 20s
thus for *T T1*
zz = - *E T* - *To*
(
)

Before transformation, and for *T T1*, thermoelastoplastic solution such as:

HT
p
zz = *zz* + *zz* + = 0
E

p

zz = *R0zz* + *y*
aust
1
1
y
0
p
-
from where (
+) =
- (*T* - *T*) *and zz* = *p* =
R aust
E
aust
aust
0
R0
R0
During the transformation, one is in elastic mode, one thus has a thermoelastic solution with phase shift.
= - *E* (*T* - *T0*) + *Z*
p
réf
+ (
fbm
zz
1)
[
]
After the transformation, there is always a thermoelastic solution until *t2*.
In *t2*:
(
)

zz = R T, Z, EFF
(
) + *y T, Z*
Because of the restoration of work hardening and owing to the fact that one was in elastic mode during all
transformation: R = 0 before replastification.
One thus has in *t2*:
fbm + *E* (
+ *p* (

p
fbm
y
réf fbm
zz
1)
[
]
zz = - *E* (*T* - *T* 0) + *réf*
+ (
(*T* - *T0*) = -
fbm
zz
1)
[
] =y
E
(*T* - *T0*) = -624°C
t2 125s

For T < 276°C one has a thermoelastoplastic solution such as:

p
zz = HT + + (*T*)
E
zz

p
p
zz = R0 zz (*T*) - *zz* (1)

[
] +y
fbm
1
1

from where (
+) = *y*
- (*T* - *T0*) -
- *p* (
R fbm
E
fbm
réf fbm
zz
1)
0
R0

2.2
Results of reference

EFF
EFF
zz,
and with *T* = 60s

EFF
EFF
zz,

and with *T* = 89s

EFF
EFF
zz,
and with *T* = 112s

EFF
EFF
zz,
and with *T* =176s

2.3 Bibliography

[1]
DONORE A.M. - WAECKEL F. - Influence of structure transformations in the laws of behavior elastoplastic Notes HI-74/93/024.
[2]
DONORE.A.M. - WAECKEL.F. - RAZAKANAIVO.A. - Doc. Aster [R4.04.02].

---

3 Modeling

3.1
Characteristics of modeling

y
C
D
N13
N11
N12
N9
N10

N7
N6
N8
N1
N3
N4
N2
N5
With
B
With = N4, B = N5, C = N13, D = N12.
3.2
Characteristics of the grid
A number of nodes: 13.
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3.
3.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
META_THER
[U4.23.01]
THER_LINEAIRE
OPTION
META_ELGA_TEMP
[U4.23.05]
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
META_RE
STAT_NON_LINE
COMP_INCR
RELATION
META_EP_RE
[U4.32.01]
CALC_ELEM
OPTION
EPSI_ELNO_DEPL
[U4.61.01]
RECU_CHAMP
NOM_CHAM
VARI_ELNO_ELGA
[U4.62.01]

---

4 Results

4.1 Values tested

Identification	Reference	*Aster*	% difference
zz T = 60s	4.0792E8	4.080E8	0.02%
EFF T = 60s	3.9604E3	3.9599E3	-0.02%
EFF T = 60s	0.	0.	0.%
zz T = 89s	7.0684E8	7.0152E8	-0.752%
EFF T = 89s			

3.9604E3
3.9599E3
-0.01%
EFF
T = 89s
0.
0.
0.%
zz T = 112s
9.4392E8
9.44E8
0.008%
EFF
T = 112s
0.
0.
0.
EFF
T = 112s
0.
0.
0.
zz T = 176s
12.101E8
12.102E8
0.012%
EFF
T = 176s
0.
0.
0.
EFF
T = 176s
5.068921E3
5.0688E3
-0.002%

4.2 Remarks

In this modeling:
ptzz T
(, *Z*) = 0

The error on zz at 89 seconds comes in fact from the error made on the numerical description of metallurgical transformation which is, at this moment, from approximately 56%.

4.3 Parameters

of execution
Version: 4.02.14
Machine: CRAY C90
Obstruction memory:
8 megawords
Time CPU To use:
188.88 seconds
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/98/040/A

---

5 Summary of the results

The results found with *Code_Aster* are very satisfactory, with percentages of error lower than 0.8%.

Organization (S): EDF/MTI/MMN

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
Document: V7.22.105

HSNV105 - Plate in traction-shearing:
élasto-viscoplasticity with metallurgy

Summary:

This test of nonlinear quasi-static mechanics consists in charging in traction-shearing a square plate.
It is largely inspired by tests SSNP14 [V6.03.104] and SSNP15 [V6.03.105] from guide VPCS. The relation
of behavior which one validates here is a élasto-viscoplastic relation of behavior which one introduced
in Code_Aster for the mechanical analyses taking of account metallurgy. It is an isotropic law of
Norton-Hoff type with an additive work hardening which can be restored.
The temperature and the metallurgical state are constant, one thus considers neither plasticity of transformation nor
metallurgical restoration of work hardening. One does not consider either viscous restoration of work hardening.

The plate is modelled by a voluminal element (HEXA8).

The results obtained by Code_Aster are very close to the analytical solution of reference (variation < 0.04%).

Titrate:

HSNV105 Plates in traction-shearing élasto-viscoplasticity
Date:
17/12/01
Author (S):
A. RAZAKANAIVO, F. WAECKEL Key
:
V7.22.105-A Page:
2/6

1
Problem of reference

1.1 Geometry

Square plate
C

B
D

D
D
D
D
D
With
y
X

1.2
Material properties

Isotropic elasticity
E = 195.000 MPa
= 0.3

Relation of comprise élasto-viscoplastic.
= 600 MPa.sn
N = 3.5
C = 0. MPa
C = 0. (not of viscous restoration of work hardening)
m =20.

1.3
Boundary conditions and loadings

In a: ux = uy = 0

On side AB: ux = 0

One uniformly imposes on the structure a temperature T = 750°C
and the TRC is such as the metallurgical state corresponding to this temperature is 100% ferritic.

Loading:

Way OA below of T = 0 to T = 10 S then maintenance of A until T = 60 S

D (MPa)
With
93.1
0
151.2 D (MPa)

2
Reference solution

2.1
Method of calculation used for the reference solution

Being given the nature of the requests, the solution (forced, deformations and deformation figure cumulated p) is homogeneous. In a point of the way of loading OA, one obtains:

=
xx
D

=
xy
D

=
2 + 3 2
eq
D
D
The elastic strain is worth:
1
exx =
D
E
1 +
exy =
D
E
E
E
yy
= xx
The viscoplastic deformation is worth:
if
- R -
eq
C > 0:
D
vp
xx
& = p& eq
3
D
vp
xy

& =
p&
2
eq
vp
1
& = vp
yy
xx
2

- R - N
eq
C
with
p& =

where
=

R
R p

0
if
:
p& = 0
vp
& = 0 vp
& = 0 vp
eq
C
xx
xy
&yy = 0

Lastly, the total deflection is:

= E
vp
xx +
xx
xx

= E
vp
xy +
xy
xy

= E
vp
yy +
yy
yy

The reference solution is obtained by using a program written in FORTRAN which carries out one resolution step by step of the problem with an implicit diagram of discretization.

2.2
Results of reference

One will be interested in the values of the constraints and the deformations at point A of the way of loading
at the moment T = 10 S and T = 60 S

---

3 Modeling
With

3.1

Characteristics of modeling
Z
N07
N05
N08
N06
y
N03
N01
N04
N02
X

The loading and the boundary conditions are modelled by:

DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
1
1
FORCE_NODALE: (NODE: (N01 N03 N05 N07), FX: -
(T), FY: - T
( ))
D
D

4

4
1
FORCE_NODALE: (NODE: (N03 N04 N07 N08), FX: -
T
( ))
D

4
1
FORCE_NODALE: (NODE: (N02 N04 N06 N08), FY:
T
( ))
D

4

1
FORCE_NODALE: (NODE: (N01 N02 N05 N06), FX:
T
( ))
D

4
One imposes moreover one uniform temperature on the structure being worth at any moment: T = 750°C with the assistance
of operator AFFE_CHAM_NO.

3.2
Characteristics of the grid

A number of nodes:
8
A number of meshs and type:
1 HEXA8

3.3 Functionalities
tested

Orders

DEFI_MATERIAU META_THER

THER_LINEAIRE OPTION
META_ELGA_TEMP

DEFI_MATERIAU META_VISC_FO
ETA

NR

C

M

AFFE_CHAR_MECA FORCE_NODALE NODE

STAT_NON_LINE COMP_INCR
RELATION
META_EVP

CALC_ELEM OPTION EPSI_ELNO_DEPL

4
Results of modeling A

4.1 Values
tested

Variables Moments
(S) Reference
Aster %
difference
xx
10 2.4333E2
2.4337E2
0.018%
yy

10 1.2011E2
1.2014E2 0.018%

xy
10 2.2379E2
2.2383E2
0.019%
xx
30 5.2103E2
5.2118E2
0.029%

yy
30 2.5896E2
2.5903E2 0.029%
xy
30 4.8027E2
4.8041E2
0.029%
xx
60 5.9557E2
5.9576E2
0.032%
yy
60 2.9624E2
2.9633E2 0.032%

xy
60 5.4912E2
5.4929E2
0.032%

4.2 Parameters of execution

Version: 5.07.02

Machine: SGI ORIGINI 2000 - R12000

Obstruction memory:

300 Mo
Time CPU To use:
70 seconds

5
Summary of the results

The results obtained with Code_Aster are close to those of the reference solution (variations < 0.05%)

Organization (S): EDF/IMA/MMN

HSNV120 - Hyperelastic traction
of a bar under thermal loading

Summary:

This quasi-static thermomechanical test consists in heating a parallelepipedic bar uniformly, it to subject to an important traction for finally letting it return in a discharged state. One validates thus kinematics of the great hyperelastic deformations (order STAT_NON_LINE, key word COMP_ELAS) for a relation of elastic behavior non-linear (ELAS_VMIS_LINE and ELAS_VMIS_TRAC) with thermal loading.

The bar is modelled by a voluminal element (HEXA20, modeling A) or quadrangular (QUAD8, assumption of the plane constraints, modeling B).

The results obtained by Aster do not differ from the theoretical solution.

---

1 Problem of reference

1.1 Geometry

y
1.000 (mm)
1
4
2
3
Z
1.000 (mm)

X
1.2
Material properties
The material obeys a law of isotropic nonlinear behaviour hyperelastic to work hardening linear isotropic.
S
E
= 2.105 MPa
AND = 2.103 MPa
y
AND
y = 103 MPa
E

= 0,3

= 104 K1
E

1.3
Boundary conditions and loadings
The bar blocked in direction OX on the face [1,2] is subjected to a uniform temperature T and a tractive effort F distributed on the face [3,4]. The sequences of loading are as follows:
1
4
Tunif
F
2
3

T °
(C)
F (MPa)
120
1298
20
T (S)
0
1
2
3
T (S)
0
1
2
3
Temperature of reference: Tréf = 20°C.
Handbook of Validation
V7.22 booklet: Thermomechanical statics nonlinear of the voluminal structures
HI-75/96/030/A

2
Reference solution

2.1
Method of calculation used for the reference solution

One seeks the field of displacement *U* in the form:

ux

U (*X*, *y*, *Z*) =
vy

vz

The gradient of the transformation, the deformation and its mechanical share are then:

1+ *U*
0
0

F =
0
1+

v
0

0
0
1+ *v*
(
U U + 2)

0
0

2
1
v v
T
+

2
E =
(**F F**)
(
)
1
=
0
0

2

2

v (*v* + 2)
0
0

2

0 *have*

0

EM = **E** - *T*
1 = 0 *B* 0

0 0 *B*
with:

U (*U* + 2)
has

=
- *T*

2

v (*v* + 2)
B

=
- *T*

2
Note:
(**EM**) = *a*-*b* = *a*-*b* (one supposes that >b) *has*
eq

The relation of behavior is written:

2
S
= *K*

xx
(+ *B has*
2) + *G* (*has* - *b)*

3

1
S
= *S*
= *K*
yy
zz
(+ *B has*
2) - *G* (*has* - *b)*

3
with:
E
3K = 1-2
modulate compressibility
To determine *G* by taking account of linear work hardening, one introduces:
E
· the modulus of rigidity: 2µ = 1+
E E
· the module of work hardening: *R*
T
'= *E* -,
AND
The "pseudo variable interns" *p* is worth then:
2µ (**EM**)
y
-
y
eq
2µ (*has* - *b)* -
p =
=
R' + 3µ
R' + 3µ
Finally, *G* is written:
y
+ *R' p*
G =
- *B has*
By taking account of the boundary conditions:

F
Sxx =
(dead load)

1+ *U*
Syy =

0 (free edge)
The system to be solved is written:

2
2µ *has* - *B*
y
-
F
K (*has* + *B*
2)
(
)
y
+ + *R'*
=
3
R

'+ 3µ
1+ *U*

1
2µ *has* - *B*
y
-
K (*has* + *B*
2)
(
)
y
-

+ *R'*
= 0
3
R

' +

3µ

It is also written:

F
3K (+ 2b *has*) =

1+ *U*

F
3µ
3

µ
2 (*has* - *b)* =
1
y
+
µ

1

+ *U*

R′ -
R′
WITH *F* fixed, it is thus about a nonlinear system out of *U* and *v*, since *A* is quadratic out of *U* and *B* quadratic in *v*.
Nevertheless, one can choose to fix *U* (thus *has*) and to solve a linear system out of *F* and *B* (of which one
deduced *p* and *v*):
(
U U + 2)
·
has =
- *T*

2
1 *F* -6 *K B* = 3

K has
1+ *U*
·

3µ
1
3

µ
1+
F + 2µ *B* = 2
y

µ *has*
R′
+
1

+ *U*
R′

2µ (*has - b)*
y
-
.
p =
R' + 3µ
.
v =
1+ (
2 *B* + *has T*
) -1
It then remains to express the constraint of Cauchy:
=
1
F S FT
Det (**F**)
That is to say here:

1+ *U*

xx =

(
S
1+ *v*) 2 *xx*

yy = *zz* =

0
As for the force exerted on the face [3,4], because of assumption of died loads, she is written simply:
F
X = *F So*
where *So*: initial surface of the face [
3,4]
F
y = 0
F
Z = 0

2.2
Results of reference

One will adopt like results of reference displacements, the constraint of Cauchy and the force exerted on the face [3,4] (in 3D only):

At time T = 2 S (*T* = 100°C, traction *F*)

In fact, one seeks *F* such as lengthening:

U = 0 1
,
.
K = 166.666 MPa µ = 76.923 MPa *R'* = 2.020 MPa
.
= 0.095 *have*

0.90909

F - 106 *B* = 47 500
104.76 *F* +153.85 103 *B* = 128.85 103

.
F = 1.298 MPa
B = -.

0 046
.
p = 8.91 10 2
.
v = - 3.70 10 2

9
xx
= 1 399.66 MPa
xy = 0

Fx = 1.298 10 NR
.
yy = 0
xz = 0
Fy = 0
zz = 0
yz = 0
Fz = 0
At time T = 3 S (*T* = 0, *F* =)
0
The bar returned in its initial state:
U

= 0

= 0
p =

0
2.3
Uncertainty on the solution
The solution is analytical. With the rounding errors near, one can consider it exact.
2.4 References
bibliographical
One will be able to refer to:
[1]
E. LORENTZ: A nonlinear relation of behavior hyperelastic - internal Note EDF
DER HI-74/95/011/0

3 Modeling
With
3.1
Characteristics of modeling

Voluminal modeling:
1 mesh HEXA20
1 mesh QUAD8
Z
5
20
8
17
19
18
7
6
16
13
y
15
1
12
4
1.000 (mm)
9
11
2
10
3
X

Boundary conditions:

N2:
U = *U* = *U*
X
y
Z = 0
N9, N13, N14, N5, N17: *U X* = 0
N1:
U = *U*
X
Z = 0
N6:
U = *U*

X
y = 0
Charge: Traction on the face [3 4 8 7 11 16 19 15]
3.2
Characteristics of the grid
A number of nodes: 20
A number of meshs: 2
1 HEXA20
1 QUAD8
3.3 Functionalities
tested
Orders
Keys
STAT_NON_LINE
COMP_ELAS:
DEFORMATION:
"GREEN"
[U4.32.01]
RELATION:
"ELAS_VMIS_LINE"
"ELAS_VMIS_TRAC"
EXCIT:
CHARGE:
THERMICS
CALC_NO
OPTION:
"FORC_NODA"
[U4.61.03]
GEOMETRY:
"DEFORMED"

---

4 Results of modeling A

4.1 Values tested

Identification	**Reference**	***Aster***	**% difference**
T = 2 Displacement DX (N8)	100	100.	0.
T = 2 Displacement DY (N8)	37	37.005	0.013
T = 2 Displacement DZ (N8)	37	37.005	0.013
T = 2 Constraints SIGXX (PG1)	1399.66	1399.67	0.001
T = 2 Constraints SIGYY (PG1)	11013.986	1010	/
T = 2 Constraints SIGZZ (PG1)	0	1010	/
T = 2 Constraints SIGXY (PG1)	0	1012	/
T = 2 Constraints SIGXZ (PG1)	0	1012	/

T = 2 Constraints SIGYZ (PG1)
0
1011
/
T = 2 Variable *p* VARI (PG1)
8.91102
8.91 102
0.
T = 3 Displacement DX (N8)
0
1013
/
T = 3 Displacement DY (N8)
0
1013
/
T = 3 Displacement DZ (N8)
0
1014
/
T = 3 Constraints SIGXX (PG1)
0
1010
/
T = 3 Constraints SIGYY (PG1)
0
1011
/
T = 3 Constraints SIGZZ (PG1)
0
1011
/
T = 3 Constraints SIGXY (PG1)
0
1011
/
T = 3 Constraints SIGXZ (PG1)
0
1011
/
T = 3 Constraints SIGYZ (PG1)
0
1011

/
T = 3 Variable *p* VARI (PG1)
0
0
/
T = 2 nodal Force DX (N8)
1.0817108
1.0817 108
0.003
T = 2 nodal Force DY (N8)
0
105
/
T = 2 nodal Force DZ (N8)
0
106
/

4.2 Remarks

Calculation of the nodal force:

The force applied to the face [3,4], Fx, is distributed between the various nodes according to weighting following:

· nodes tops: 1 12Fx
· nodes mediums: 4/12Fx

4/12
1/12
1/12
4/12
4/12
1/12
1/12
4/12

4.3 Parameters
of execution

Version: NEW 3.03.15
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
47.2 seconds

5 Modeling B

5.1 Characteristics of modeling

Modeling 2D forced plane:

1 mesh QUAD8

1 mesh SEG3

y
8
1
4
5
7
2
X
6
3

Boundary conditions:

N2:
$U X = 0$
$U y = 0$

N1:
$U X = 0$

N5:
$U X = 0$

Loading:

Traction on the face [3 4 7] (mesh SEG3)

5.2 Characteristics of the grid

A number of nodes: 8

A number of meshs: 2

1 QUAD8
1 SEG3
5.3 Functionalities
tested
Orders
Keys
STAT_NON_LINE
COMP_ELAS:
DEFORMATION:
“GREEN”
[U4.32.01]
RELATION:
“ELAS_VMIS_LINE”
“ELAS_VMIS_TRAC”
EXCIT:
CHARGE:
THERMICS

6
Results of modeling B
6.1 Values
tested
Identification
Reference
Aster
% difference
T = 2 Displacement DX (N4)
100

100
0
T = 2 Displacement DY (N4)
37
37.004
0.013
T = 2 Constraints SIGXX (PG1)
1399.66
1399.67
0.001
T = 2 Constraints SIGYY (PG1)
0
1012
/
T = 2 Constraints SIGXY (PG1)
0
1012
/
T = 2 Variable *p* VARI (PG1)
8.91102
8.91 102
0
T = 3 Displacement DX (N4)
0
1014
/
T = 3 Displacement DY (N4)
0
1013
/
T = 3 Constraints SIGXX (PG1)
0
1010
/
T = 3 Constraints SIGYY (PG1)
0
1010
/
T = 3 Constraints SIGXY (PG1)
0
1010
/
T = 3 Variable *p* VARI (PG1)

0
0
/

6.2 Parameters
of execution

Version: 3.03.13
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
123,8 seconds

7
Summary of the results

The numerical and analytical results coincide remarkably. One can however be astonished by execution time manifestly longer for modeling in plane constraints (123,8 S) that for the 3D (47,2 S). The difference is explained by a discretization in time much finer for plane constraints, related to problems of convergence (the algorithm of resolution of the equation nonlinear scalar out of *p* is still rudimentary).

HSNV121 - Traction in great plastic deformations of a bar
Date:
16/11/01
Author (S):
***V. CANO**, E. LORENTZ, Key P. MASSIN*
:
V7.22.121-B Page:
1/14

Organization (S): EDF/MTI/MMN

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
Document: V7.22.121

HSNV121 - Traction in great deformations plastics of a bar under loading thermics

Summary:

This quasi-static thermomechanical test consists in heating a bar of rectangular section uniformly (3D) or cylindrical (axisymmetric 2D) then to subject it to a traction. One validates the kinematics thus of great deformations in plasticity (order STAT_NON_LINE, key word deformation: "SIMO_MIEHE" or "PETIT_REAC") for a relation of behavior in great deformations with isotropic work hardening

linear (order STAT_NON_LINE, key word relation
: “VMIS_ISOT_LINE” and
“VMIS_ISOT_TRAC”) with thermomechanical loading. With modelings hull or plate, them great deformations in plasticity are accessible thanks to the key word deformation: “PETIT_REAC” provided that rotations remain weak.

The bar is modelled by a voluminal element (HEXA20, modeling A) or quadrangular (QUAD4, for an axisymmetric modeling, modeling B) or by elements of plate or hull (DKT for modeling C and COQUE_3D for modeling D).

The solution is analytical.
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

---

1 Problem of reference

1.1 Geometry

y
1.000 (mm)
1
4
2
3
Z
1.000 (mm)
X

1.2 Properties of material

The material obeys a law of behavior in great deformations figure with work hardening isotropic linear, whose characteristics depend on the temperature.
The traction diagram is given in the plan deformation logarithmic curve - rational constraint.

F
F L
=
=
.

S
S
L
O
O

= 0 3
.

=
-4
-
10
1
K
E

= 1000 MPa
T
y

with T
=
∘
20
y
C
E
E
= 250000MPa
E
= 2500
T
MPa
with T
=
∘
120 C
E
= 200000MPa
ln (L/L

E
= 2000 MPa
O)
T

lo and L are, respectively, the initial length and the current length of the useful part of the test-tube.

So and S are, respectively, initial and current surface. Between the temperatures 20°C and 120°C, the characteristics are interpolated linearly.

1.3
Boundary conditions and loadings

The bar, initial length lo, blocked in direction OX on the face [1,2] is subjected to one uniform temperature T and with a mechanical displacement of traction umeca on the face [3, 4]. sequences of loading are as follows:

lo
1
4
Tunif
U meca
2
3

T ()
°C
U
120
293.3 mm
20
T (S)
0
1
2
T (S)
0
1
2

Temperature of reference: Tréf = 20°C.

Note:

Mechanical displacement is measured starting from the configuration deformed by thermal loading (T = 1s). To have total displacement, it is thus necessary to add it thermal displacement obtained at time T = 1s.

2

Reference solution

2.1
Result of the reference solution

For a tensile test according to direction X, the tensor of Kirchhoff is form:

0

0

= 0 0
0

0 0 0

The tensors gradients of the transformation F and F and the isochoric tensor of plastic deformations G p are form:

F
0
0

F =
0 F
2
yy
0
and J=

det F = FF
F = J/F
yy
yy

0
0
Fyy
F
0
0

F = -
J 1 3F
-1/3

F = J
F = 0 Fyy
0
and det F = 1

-

1/2

F = F
0
0
F

yy

yy
p

G
0
0

G p =
0
G p
p
p
p
1/2
yy
0 and det G = 1
G =
-
(G
yy
)

p

0
0
Gyy

By the law of behavior, one obtains the following relation:

3K
9
K (T - Tref)
1
=
2
(J - 1) -
(J +)
2
2
J

that is to say

2
J 3 - (T - T) J 2
3
- J 1
(+
) - 3 (T - T
ref.
) = 0
3K
ref.

The constraint of Cauchy is written:

J =

In plastic load for an isotropic work hardening R linear, such as:

EE
R (p
T
) =
p
E -

AND

one a:

E - E
p
T
=
(-)
E E
y
T

The integration of the law of flow of the plastic deformation G p gives (knowing that
G P (p =)
0 = 1) :

G P
E p
= -2

The component F of the gradient of the transformation is given by the resolution of:

1
F 3 -
F -
= 0

μ G p
(G p 3 2
) /

The field of displacement U (in the initial configuration) is form U = U X + U Y + U Z
X
y
Z
.
The components are given by:

u~
U =
X with u~ = (F -)
1 .l
X
L
O
O
v~
J

U =
Y
with v~ =
-
1 L
y

L
F
O
O

v~
U =
Z
Z
lo

2.2
Results of reference

One will adopt like results of reference displacements, the constraint of Cauchy and cumulated plastic deformation p.

At time T = 2 S (T = 100°C, traction U)

One seeks total displacement (thermal + mechanical) such as the constraint is equal to:
= 1500 Mpa (with T = 120°C)

•
3K = 500.000 MPa µ = 76923 MPa
•
J = 10
. 3
•
= 1453 MPa
•
p = 0,2475
•
G p = 0,609
•
F = 1,289
•
F = 1,303
•
~
U = 303 mm
•
~
v = 110 mm

2.3
Uncertainty on the solution

The solution is analytical. With the rounding errors near, one can consider it exact.

2.4 References
bibliographical

One will be able to refer to:

[1]
V. CANO, E. LORENTZ: Introduction into Code_Aster of a model of behavior in great deformations elastoplastic with isotropic work hardening - internal Note EDF DER HI-74/98/006/0

---

3 Modeling
With

3.1
Characteristics of modeling

Voluminal modeling:
1 mesh HEXA20
1 mesh QUAD8

Z
5
20
8
17
19
18
7
6
16
13
y
15
1
12

4
1.000 (mm)
9
11
2
10
3
X

Boundary conditions:

N2:
U = U = U
X
y
Z = 0
N9, N13, N14, N5, N17: U X = 0

N1:
U = U
X
Z = 0

N6:
U = U
X
y = 0

Charge: Traction on the face [3 4 8 7 11 16 19 15] + assignment of the same temperature on all them nodes.

The total number of increments is 21 (1 increment between T = 0s and 1s, 20 increments between T = 1s and
2s)
Convergence is carried out if the residue resi_glob_rela is lower or equal to 106.

3.2
Characteristics of the grid

A number of nodes: 20

A number of meshs: 2

1 HEXA20

1 QUAD8

3.3 Functionalities
tested

Orders

STAT_NON_LINE
COMP_INCR:
DEFORMATION:
"SIMO_MIEHE"
RELATION
:
"VMIS_ISOT_TRAC"
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
T = 2 Displacement DX (N8)
303

303.063
0.021
T = 2 Displacement DY (N8)
-110
-109.852
-0.134
T = 2 Displacement DZ (N8)
-110
-109.852
-0.134
T = 2 Constraints SIGXX (PG1)
1453
1458.51
0.379
T = 2 Variable p VARI (PG1)
0.2475
0.2504
1.182

4.2 Parameters of execution

Version: NEW 5.04.14
Machine: CLASTER
Obstruction memory:
8 MW
Time CPU To use:
44.5 seconds
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

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5 Modeling B

5.1 Characteristics of modeling

Axisymmetric modeling 2D:
1 mesh QUAD4
1 mesh SEG2

y
4
3
X
1
2

Boundary conditions:

N1:
U y = 0

N2:
U y = 0

Loading:

Traction on the face [3 4] (mesh SEG2) + assignment of the same temperature on all the nodes
The total number of increments is 21 (1 increment between T = 0s and 1s, 20 increments between T = 1s and 2s)

Convergence is carried out if the residue resi_glob_rela is lower or equal to 106.

5.2 Characteristics of the grid

A number of nodes: 4

A number of meshs: 2

1 QUAD4
1 SEG2

5.3 Functionalities
tested

Orders

STAT_NON_LINE
COMP_INCR:
DEFORMATION:
“SIMO_MIEHE”

RELATION
:
“VMIS_ISOT_LINE”

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster %
difference
T = 2 Displacement DX (N3)
-110
-109.85
-0.134
T = 2 Displacement DY (N3)
303
303.06
0.021
T = 2 Constraints SIGYY (PG1)
1453
1458.5
0.379
T = 2 Variable p VARI (PG1)
0.2475
0.2504
1.182

6.2 Parameters
of execution

Version: 5.04.14
Machine: CLASTER
Obstruction memory:
8 MW
Time CPU To use:
32.7 seconds
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

Code_Aster ®
Version
5.0

Titrate:
HSNV121 - Traction in great plastic deformations of a bar
Date:
16/11/01
Author (S):

7 Modeling C

7.1 Characteristics of modeling

Modeling plates DKT thickness 1000 mm:
1 mesh QUAD4, 2 meshs TRIA3
1 mesh SEG2

y
6
1
4
X
2
5
3

Boundary conditions:

N2:
U = 0 U = 0 U = 0 = 0 = 0 = 0
X
y
Z
X
y
Z

N1:
U = 0 U = 0
X
Z

Loading:

Traction on the face [3 4] (mesh SEG2) + assignment of the same temperature on all the nodes
The total number of increments is 21 (1 increment between T = 0s and 1s, 20 increments between T = 1s and 2s)

Convergence is carried out if the residue resi_glob_rela is lower or equal to 106.

7.2
Characteristics of the grid

A number of nodes: 8
A number of meshs: 4

1 QUAD4
2 TRIA3
1 SEG2

7.3 Functionalities tested

Orders

STAT_NON_LINE
COMP_INCR:
DEFORMATION:
"PETIT_REAC"

RELATION
:
"VMIS_ISOT_TRAC"
AFFE_CARA_ELEM
HULL:
THICK

Titrate:

8
Results of modeling C

8.1 Values tested

Identification	*Reference*	*Aster*	*% difference*
T = 2 Displacement DX (N3)	*-110*	*-108.81*	*-1.076*
T = 2 Displacement DY (N3)	*303*	*303.4*	*0.132*
T = 2 Effort NXX (PG1)	*1453 E+03*	*1497.4 E+03*	*3.059*
T = 2 Variable p VARI (PG1)	*0.2475*	*0.246*	*-0.591*

8.2 Parameters of execution

Version: 5.04.14
Machine: CLASTER
Obstruction memory:
8 MW

Time CPU To use:
23.67 seconds
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

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9 Modeling D

9.1 Characteristics of modeling

Modeling coques_3d thickness 1000 mm: 1 mesh QUAD9, 2 meshs TRIA7
1 mesh SEG3

y
12
8
14
1
4
17
15
5
11 9
7
16
X
2
10
6 13
3

Boundary conditions:

N2:
U = 0 U = 0 U = 0 = 0 = 0 = 0
X
y
Z
X
y
Z

N5:
U = 0 U = 0
X
Z

N1:
U = 0 U = 0
X
Z

Loading:

Traction on the face [3 4] (mesh SEG3) + assignment of the same temperature on all the nodes
The total number of increments is 21 (1 increment between T = 0s and 1s, 20 increments between T = 1s and 2s)

Convergence is carried out if the residue resi_glob_rela is lower or equal to 106.

9.2
Characteristics of the grid

A number of nodes: 17
A number of meshs: 4

1 QUAD9
2 TRIA7
1 SEG3

9.3 Functionalities
tested

Orders

STAT_NON_LINE
COMP_INCR:
DEFORMATION:
“PETIT_REAC”

RELATION
:
“VMIS_ISOT_TRAC”
AFFE_CARA_ELEM
HULL:
THICK

---

10 Results of modeling D

10.1 Values tested

Identification Reference
Aster %
difference
T = 2 Displacement DX (N3)
-110
-108.38
-1.476
T = 2 Displacement DY (N3)

303
303.4
0.132
T = 2 Constraint SIXX (PG1)
1453
1496.6
3.001
T = 2 Variable p VARI (PG1)
0.2475
0.2458
-0.680

10.2 Parameters
of execution

Version: 5.04.14
Machine: CLASTER
Obstruction memory:
8 MW
Time CPU To use:
57.88 seconds
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

---

11 Summary of the results

Results found with Code_Aster and deformation: "SIMO_MIEHE" are very satisfactory *with percentages of error lower than 0.4% on the constraint and 1.2% on the variable of work hardening. For elements of plate and hull the use of deformation: "PETIT_REAC" gives satisfactory results with percentages of error of 3% on the effort or the constraint and lower than 0.7% on the variable of work hardening.*

Document: V7.22.122

HSNV122 - Thermoplasticity and metallurgy in great deformations in simple traction

Summary:

One treats the determination of the mechanical evolution of a cylindrical bar subjected to thermal evolutions and metallurgical known and uniform (the metallurgical transformation is of bainitic type) and with one mechanical loading of traction.

The relation of behavior is a model of plasticity in great deformations (order STAT_NON_LINE, motclé DEFORMATION: "SIMO_MIEHE") with linear isotropic work hardening and plasticity of transformation (order STAT_NON_LINE, motclé RELATION: "META_EP_PT").

The yield stress and the slope of the traction diagram depend on the temperature and the composition metallurgical. The dilation coefficient depends on the metallurgical composition.

The bar is modelled by axisymmetric elements.

The mechanical loading applied is a following pressure.

This case test is identical to the case test HSNV101 (modeling B, [V7.22.101]) in the direction where it is about same material, of the same loading and the same thermal and metallurgical evolutions but in a version

in great deformations.
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

Code_Aster ®
Version
5.0
Titrate:
HSNV122 - Thermoplasticity and metallurgy in great deformations
Date:
18/02/00
Author (S):
F. WAECKEL, V. CANO
Key:
V7.22.122-A Page:
2/12

1
Problem of reference

1.1 Geometry

Z
Ray: = 0.05 m has
Height: H = 0.2 m
P
C
D
H
R
With
B
has

1.2
Properties of material

The material obeys a law of behavior in great deformations with isotropic work hardening linear and plasticity of transformation. For each metallurgical phase, the slope of work hardening is data in the plan deformation logarithmic curve - rational constraint.

F
F
L
=
=
.
S

So lo
E phase
T
phase
y
E
ln (L/lo)
lo and L are, respectively, the initial length and the current length of the useful part of the test-tube.
So and S are, respectively, surfaces initial and current.

C
3
-! -1
1
-! -1
p = 2000000. J m
C = 9999 9
. W m
C
E
6
aust
= 200000. 10 Pa
= 400. 106Pa + 0.
5 (T - T O
6
y

) 10 Pa

= .
fbm
0
3
= 530. 106Pa + 0.
5 (T - T O
6
y
) 10 Pa

= 15. -
10 6! C-1
H

= 1250. 106Pa - 5. (T - T O
6
fbm
aust
) 10 Pa

-6! -1
6
O
6
aust = 23 5
. 1
0 C H
fbm = -50. 1
0 Pa - 5. (T - T) 10

Pa
ref.
-3
-1
fbm = 2 5
. 2 1
0 K F = 0. Pa
ref.
T
= 900! C
K
-10

-
B = km = 10 Pa 1
F
fbm = 2. (1 - Z fbm)
with
C
=
heat-storage capacity
p

=
thermal conductivity
E
=
YOUNG modulus

=
Poisson's ratio
**aust*
=
characteristics relating to the austenitic phase
**fbm*
=
characteristics relating to the phases ferritic, bainitic and martensitic

=
thermal dilation coefficient
ref.
=
deformation of the phases ferritic, bainitic and martensitic
fbm
at the temperature of reference, austenite being regarded as not deformed at this temperature

=
yield stress
y
EE
H
=
T
E - AND
K

=
coefficient relating to the plasticity of transformation
F
=
function relating to the plasticity of transformation
The TRC used makes it possible to model a metallurgical evolution of bainitic type, on all structure, of the form:
0.
if T1
1 =
60s

T -
Z

1
if 1 T
fbm
=
< 2 2 =
112 S
2 -

1
.
1
if T

2
1.3
Boundary conditions and loadings
·
uZ = 0 on face AB (condition of symmetry).
· traction imposed (following pressure) on the face CD:
p T
O

for T
1 p = 6 106

Pa

(
p T)

O
=
6
for T
1 1 =

360 10 Pa
60s
Note:
In great deformations, it is essential to use the following pressure to hold
count current surface and not of initial surface (before deformation).
.
T
T O
=
+ µt, µ = 5°C.s1 on all the structure.

1.4 Conditions
initial
T O
900 C T ref.
=
° =

2
Reference solution

2.1
Calculation of the reference solution (cf bib [1] and [3])

For a tensile test according to direction X, the tensors of Kirchhoff and Cauchy are

form:
0 0
0
0

= 0 0 0 and = 0 0
0 with = J

0 0 0

0 0 0
The variation of volume J is given by the resolution of
2
J 3
HT
- (+
) J 2
3
- J
HT
- 3 = 0
3K
where HT is the thermal deformation. Celleci applies to a bainitic austenitic transformation:
HT
ref.
ref.
ref.
= Zaust aust (T - T) + B
Z [fbm (T - T) + fbm]
Note:
The coefficient K is the module of compression (not to be confused with the coefficients Kphase relating to the law of plasticity of transformation)
In plastic load, for an isotropic work hardening R linear, such as:
R = (Z
H

+ Z H

) p
aust aust
B

fbm
the cumulated plastic deformation p is worth
J -
p
y
= Z H + Z H
aust aust
B fbm
with

aust
fbm
y = Zaust y
+ B
Z y

The tensors gradients of the transformation F and F and the tensor of plastic deformations G p are form:
F
0
0

F = 0 F
0 and J= det F

2
yy

= FF
yy
Fyy = J/F

0
0
Fyy
F
0
0
-1/3
-1/3

F = J
F
F = J
F = 0 F
0 and det F

yy

=
1

-

F
1/2
yy = F
0
0
Fyy

G p
0
0

G p = 0
G p

p
p
p -
yy
0 and det G =
1 Gyy = (G) /12

p
0
0
Gyy
The law of evolution of the plastic deformation G P is written:
“G p/G p = -2 “p - 4 K
(1 - Z) “Z
B
B
B
· For
0s T 60s, one has “Zb = 0. There is no plasticity of transformation. One obtains
then:
G p
E p
= -2
· For
60s T 176s, one has = constant.
To integrate the law of evolution of the plastic deformation, it should be supposed that the constraint
of
Kirchhoff varies very little, it estàdire that the variation of volume J is very small. Under this
assumption, one obtains
2
p
-2 p -4
K (Z - Z
B
B
B/2)
G = E
E
The component F of the gradient of the transformation is given by the resolution of:

1
F 3 -
F -

= 0
µ G p

(G p 3 2
) /
Lastly, the field of displacement U (in the initial configuration) is form
U = U X +u Y + U Z
X
y
Z
. The components are given by:
U = (F -)
1 X
X

uy = (J/F -)
1 Y
uz = (J/F -)
1 Z

2.2 Notice

In the case test HSNV101 (modeling B), the coefficients of material were selected of such manner not to have traditional plasticity "p = 0 during the metallurgical transformation which takes place between moments 60 and 122s. Indeed if one writes the criterion of chargedécharge in this interval of time, one obtains
F = - 2750 p
- 250 with =

360 MPa
who cancels only for only one value of the cumulated plastic deformation p.
For the law of behavior written in great deformations, the criterion of chargedécharge is written between these two moments
F = J (T) - 2750 p
- 250 with =

360 MPa
In this case, as long as the variable J remains lower than the value obtained at time T = 60s, one will have
“p = 0. However the value of J is a function only of the value of the thermal deformation (constraint is constant and the coefficient K is independent of the metallurgical phases and of temperature).
In this interval of time, thermal deformation HT is given by the following equation:
HT =
-7

T 2
-
-4

T -
-
8173 10
11807 10
2 90763 10 3
.
.
.

One traces cidessous the thermal deformation as well as the variation of volume J, solution of the equation of the 3rd degree, according to time.
EDF
Mechanical department and Digital Models
Electricity
Evolution of the thermal deformation enters moments 60 and 112s
from France
X
-3
10
-6.0
-6.2
-6.4
-6.6

Thermal deformation
-6.8
-7.0
60
70
80
90
100
110
Time (S)
agraf 08/11/1999 (c) EDF/DER 1992-1999
Thermal deformation according to time
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

Code_Aster ®
Version
5.0
Titrate:
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Key:
V7.22.122-A Page:
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EDF
Mechanical department and Digital Models
Electricity
Variation of J enters moments 60 and 112s
from France
X
-1
10
9.825
9.820
9.815
J 9.810
9.805
9.800
9.795

9.790
60
70
80
90
100
110
Time (S)
agraf 08/11/1999 (c) EDF/DER 1992-1999
Variation of volume J according to time

It is noted that the variable J decreases and increases same manner as the deformation thermics. In this case, to know the moment from which the variable J is higher than the value obtained at time 60s, it is enough to know the moment for which the thermal deformation is identical with that obtained at time T = 60s. One finds by the resolution of the equation cidessus T = 84.46s.

2.3
Uncertainty on the solution

The solution is analytical. Two errors are made on this solution. The first door on calculation of the bainitic proportion of phase created. Preliminary metallurgical calculation does not restore exactly the equation of [§1.2] giving Z fbm according to time, this is why results of reference presented cidessous is calculated with the bainitic proportion of phase calculated by Code_Aster.

The second error is the assumption made on the constraint of Kirchhoff which is not constant on the interval of time ranging between 60 and 176s. This will impact the calculation of ux displacement and of plastic deformation G P.

2.4
Results of reference

One will adopt like results of reference displacement in the direction of the loading of traction, the constraint of Cauchy, the Boolean indicator of plasticity and plastic deformation cumulated p. the various moments of calculations are T = 47, 48, 60, 83, 84, 85 and 176s. For the calculation of displacement, the initial length of the bar in the direction of loading is of 0.2m.

In all the cases, one has
.
3K = 500.000 MPa (module of compression) µ = 76923.077 MPa
At time *T* = 47s, one has *Zb* = 0, *T* =
°
665 *C*, = 282 MPa
HT = -
-
55225
.
10 3

J = 0 983855
.
= 277 45
. MPa
y = 282 5. MPa
p = 0
= 0
p
G = 1
F = 10012
.
U = -
-
8 4347
.
10 4

m
At time *T* = 48s, one has *Zb* = 0, *T* =

°

660 *C*, = 288 MPa
HT = -
-
5 6
. 4 1
0 3 *J* = 0 983508
.
= 28325
. MPa

-3
y = 280. MPa
p = 1327
.
10

= 1
p
G = 0 997
.
F = 100256
.
U = -
-
5 9639
.
10 4

m
At time *T* = 60s, one has *Zb* = 0, *T* =
°
600 *C*, = 360 MPa
HT = -
-
7 0
. 5 1
0 3 *J* = 0 979337
.
= 352 56
. MPa

-2
y = 250. MPa

p = 3 7295
.
10

= 1

p
G = 0 9281
.
F = 103959
.
U =
-
6 47595
.
10 3

m
At time *T* = 83s, one has *Zb* = 0 442138
.
, *T* =
∘
485 *C*, = 360 MPa
HT = -
-
7
07867
.
10 3
J =.
0 979249
= 352.53 MPa

-*2*
y = 249 978
.
MPa
p =.
3

7295 10
= 0
p
-

G = 0 8841277
.
F =.
106514
U =.
1

15441 10 2 m
At time *T* = 84s, one has *Zb* = 0 461361
.
, *T* =
∘
480 *C*, = 360 MPa
HT = -.
-
7 06031 10 3
J =.
0 979305
= 352.55 MPa

-2
y = 249 977
.
MPa
p =.
3 7296 10
= 1
p
-
G = 0 8828104
.
F =.
106593
U =.
1

17051 10 2
At time *T* = 85s, one has *Zb* = 0 480584
.
, *T* =
∘
475 *C*, = 360 MPa
HT = -
-

7
04032
.
10 3
J =.
0 979367
= 352.57 MPa

-*2*
y = 249 976
.
MPa
p =.
3 73044 10
= 1
p
-
G = 0 8815276
.
F =.
106671
U =.
118644 10 2
At time *T* = 176s, one has *Zb* = 1, *T* =
∘
20 *C*, = 360 MPa
HT = -
-
1068
.
10 2

J = 0 968132
.
= 348527
.
MPa

-2
y = 90. MPa
p = 5 9432
.
10

= 1
p
G = 0 82814
.
F = 110053
.
U =
-
17743
.
10 2

m

2.5 References
bibliographical

One will be able to refer to:

[1]
V. CANO, E. LORENTZ: Introduction into *Code_Aster* of a model of behavior in
great deformations elastoplastic with isotropic work hardening Notes intern EDF DER
HI-74/98/006/0
[2]
A.M. DONORE, F. WAECKEL: Influence structure transformations in the laws of
behavior elastoplastic Notes HI74/93/024
[3]
F. WAECKEL, V. CANO: Law of behavior great deformations élasto (visco) plastic
with metallurgical transformations [R4.04.03]

3 Modeling

3.1
Characteristics of modeling
y
C
D
N13
N11
N12
N9
N10
N7
N6
N8
N1
N3
N4
N2
N5
With
B
With = N4, B = N5, C = N13, D = N12.
Charge: the total number of increments is of 102 (4 increments of 0 with 46s, 2 increments of 46 with 48s,
6 increments of 48 with 60s, 26 of 60 with 112s, 4 of 112 with 116s and 60 increments until 176s).
convergence is carried out if the residue (resi_glob_rela) is lower or equal to 106.
3.2
Characteristics of the grid
A number of nodes: 13
A number of meshs and types: 2 meshs QUAD8, 6 meshs SEG3
3.3 Functionalities
tested
Orders
Keys
DEFI_MATERIAU
META_MECA_FO
[U4.23.01]
META_PT
AFFE_CHAR_MECA
PRES_REP
[U4.25.01]
STAT_NON_LINE
EXCIT
TYPE_CHARGE

SUIV
[U4.32.01]
COMP_INCR
RELATION
META_EP_PT
DEFORMATION
SIMO_MIEHE
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HI-75/01/010/A

4
Results of modeling
4.1 Values
tested
Identification
Reference
Aster
% difference
***T* = 47 Displacement DY (N13)**
8.4347 104 m
8.4303 104 m
0.052
***T* = 47 Variable *p* VARI (M1, PG1)**
0.
0.
0.
***T* = 47 VARI (M1, PG1)**
0
0
0

***T* = 47 Constraint SIGYY (M1, PG1)**
282. 106 Pa
282. 106 Pa
1.47 107
***T* = 48 Displacement DY (N13)**
5.9639 104 m
5.9755 104 m
0.194
***T* = 48 Variable *p* VARI (M1, PG1)**
1.3260 103
1.3263 103
0.024
***T* = 48 VARI (M1, PG1)**
1
1
0.
***T* = 48 Constraint SIGYY (M1, PG1)**
288. 106 Pa
288. 106 Pa
6.80 107
***T* = 60 Displacement DY (N13)**
6.476 103 m
6.4553 103 m
0.319
***T* = 60 Variable *p* VARI (M1, PG1)**
3.7295 102
3.7294 103
0.002
***T* = 60 VARI (M1, PG1)**
1
1
0
***T* = 60 Constraint SIGYY (M1, PG1)**
360. 106 Pa
360. 106 Pa
3.36 106
***T* = 83 Displacement DY (N13)**
1.1544 102 m
1.1449 102 m
0.826
***T* = 83 Variable *p* VARI (M1, PG1)**
3.7295 102
3.7294 102

0.002
***T* = 83 VARI (M1, PG1)**
0
0
0
***T* = 83 Constraint SIGYY (M1, PG1)**
360. 106 Pa
360. 106 Pa
2.05 106
***T* = 84 Displacement DY (N13)**
1.1705 102 m
1.1607 102 m
0.833
***T* = 84 Variable *p* VARI (M1, PG1)**
3.7296 102
3.7294 102
0.005
***T* = 84 VARI (M1, PG1)**
1
1
0
***T* = 84 Constraint SIGYY (M1, PG1)**
360. 106 Pa
360. 106 Pa
7.51 106
***T* = 85 Displacement DY (N13)**
1.1864 102 m
1.1762 102 m
0.859
***T* = 85 Variable *p* VARI (M1, PG1)**
3.7304 102
3.7305 102
0.002
***T* = 85 VARI (M1, PG1)**
1
1
0
***T* = 85 Constraint SIGYY (M1, PG1)**
360. 106 Pa
360. 106 Pa
7.64 106
***T* = 176 Displacement DY (N13)**
1.7743 102 m

1.7615 102 m
0.719
***T* = 176 Variable *p* VARI (M1, PG1)**
5.943 102
5.9219 102
0.354
***T* = 176 VARI (M1, PG1)**
1
1
0
***T* = 176 Constraint SIGYY (M1, PG1)**
360. 106 Pa
359.93 106 Pa
0.003
4.2 Parameters
of execution
Version: 5.02.10
Machine: claster
Obstruction memory:
128 Mo
Time CPU To use:
146.5 seconds

5
Summary of the results

The results found with *Code_Aster* are very satisfactory with percentages of error lower than 0.9%, knowing that the analytical solution of reference makes the dead end on certain aspects

what precisely takes into account the solution of *Code_Aster*. This can explain the differences observed.

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Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
V7.22.123 document

HSNV123 - Thermo-metal-worker-mechanics EDGAR

Summary:

This test illustrates a mechanical calculation on a material (Zircaloy) undergoing metallurgical transformations.
Concretely, initially, operator CALC_META calculates the metallurgical evolution associated with a given thermal history. This metallurgical evolution is then provided to STAT_NON_LINE which goes
to carry out a mechanical calculation by taking of account metallurgical phases (in addition to loadings
mechanics). The material of mechanical calculation is defined with ELAS_META_FO, META_ECRO_LINE and
META_VISC_FO.

Titrate:
HSNV123 - Thermo-metal-worker-mechanics EDGAR

Date:
05/09/05
Author (S):
V. CANO, Key S. VANDENBERGHE
:
V7.22.123-A Page:
2/10

1
Problem of reference

It is about a cylindrical bar in creep.

1.1 Geometry

y

F=25 NR

O
X

Appear 1.1-a: Geometry and loading of the problem of reference

It is about a cylinder H= height 1.0 m, and ray R=1.0 Mr.
The square in fat corresponds to axisymmetric modeling used to [§3].

1.2
Material properties

The properties materials are described by the following parameters:

For thermo-metal calculation
(Zircaloy)
CP = 2000000 J.m-3.°C-1
= 9999.9 W.m-1.°C-1

Coefficients for the metallurgy:
teqd = 809 °C, K=1.135E-2, n=2.187
CCT = 831 °C, qsr = 14614, ac = 1.58E-4
m = 4.7, tdr = 949,1°C, Ar = -5.725, Br = 0.05

For calculation thermo-metal-worker-mechanics
· Modulus Young: E= 200000 Pa
· Poisson's ratio: = 0.3

Definition of the elastic characteristics, dilation and elastic limits for modeling of an undergoing material of the metallurgical transformations:
· Tref= 800°C
· Thermal Dilation coefficient average of the cold phases: F (T) = 0
· Thermal Dilation coefficient average of the hot phase: (T) = 0
· Température of definition of the dilation coefficient: T = 800°C
· Choix of the metallurgical phase of reference: heat
· Déformation of the phase not of reference compared to the phase of reference to Tref temperature: = 0
· Limit elastic of the cold phase 1 for a viscous behavior: F_sigm_f (T) = 0
· Limit elastic of the cold phase 2 for a viscous behavior: F_sigm_f (T) = 0
· Limit elastic of the hot phase for a viscous behavior: to see [Figure 1.2-a]

250
200

150
VP
_
S_
C 100
50
0
0
200
400
600
800
1000
Temperature (°C)

Figure 1.2. - has: Elastic limit of the hot phase for a viscous behavior

· Fonction used for the law of mixture on the elastic limit of multiphase material for a viscous behavior: F

1,2
1
0,8
E
G
NR
With
EL 0,6
_
M
VP
S_ 0,4
0,2
0
0
0,2
0,4
0,6
0,8
1
1,2
META

Appear 1.2-b: Law of mixture
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HT-66/05/005/A

Definition of the modules of work hardenings used in the modeling of the phenomenon of linear isotropic work hardening of an undergoing material of the phase shifts metallurgical:

· Pente of the traction diagram for the cold phase 1
30000
25000
I
S 20000
P
M_E
I
G 15000
_S
1_D
F 10000
5000
0
0
200
400
600
800

1000
1200
Tem pérature (°C)

Appear 1.2-c: Traction diagram for the cold phase 1

· Pente of the traction diagram for the cold phase 2:
F (T) = 0

· Pente of the traction diagram for the hot phase:
F (T) = 0

Definition of the viscous parameters of the viscoplastic law of behavior with catch in count metallurgy:

· Paramètre of the viscoplastic law of flow, for the cold phase 1

2500
2000
1500
MT
_
E
F1 1000
500
0
0
200
400
600
800
1000
1200
Temperature (°C)

Appear 1.2-d: Parameter of the viscoplastic law of flow, for the cold phase 1
Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HT-66/05/005/A

Code_Aster ®
Version
8.1

Titrate:

HSNV123 - Thermo-metal-worker-mechanics EDGAR

· Paramètre of the viscoplastic law of flow, for the cold phase 2
300000
250000
200000
With
T 150000
_
E
F2
100000
50000
0
0
500
1000
1500
Temperature (°C)

Appear 1.2-e: Parameter of the viscoplastic law of flow, for the cold phase 2

· Paramètre of the viscoplastic law of flow, for the hot phase:
F (T) = 0
· Paramètre N of the viscoplastic law of flow, for the cold phase 1:
F (T) = 5.76
· Paramètre N of the viscoplastic law of flow, for the cold phase 2:
F (T) = 2.94
· Paramètre N of the viscoplastic law of flow, for the hot phase:
F (T) = 1.0
· Paramètre C relating to the restoration of work hardening of viscous origin, for the cold phase 1 :
F (T) = 13.70539827
· Paramètre C relating to the restoration of work hardening of viscous origin, for the cold phase

2 :
F (T) = 0
· Paramètre C relating to the restoration of work hardening of viscous origin, for the hot phase :
F (T) = 0
· Paramètre m relating to the restoration of work hardening of viscous origin, for the phase cold 1:
F (T) = 5.76
· Paramètre m relating to the restoration of work hardening of viscous origin, for the phase cold 2:
F (T) = 1.0
· Paramètre m relating to the restoration of work hardening of viscous origin, for the phase heat:
F (T) = 1.0

1.3
Boundary conditions and loadings

The base of the cylinder is blocked according to y:
Uy = 0 on the basis of cylinder
A force of traction F=25 NR is imposed on the top of the cylinder

The temperature is imposed on all the cylinder for t=120s.
T (X, y, 120) = 800°C

1.4 Conditions initial

The following variables are initialized:
T (X, y, 0) = 800°C
V1 (X, y, 0) = 1.0
V2 (X, y, 0) = 0.0
V3 (X, y, 0) = 20.

V1: proportion of the cold phase
V2: proportion of the cold phase, mixed with the phase
V3: temperatures with the nodes

2 Reference solution

2.1 Results of reference

The results of reference were obtained with a former version of aster. It is about a test of not-regression.

2.2 Uncertainty on the solution compared to the result of not-regression

Uncertainty is 10%.

---

3 Modeling
With

3.1
Characteristics of modeling

The modeling used in the case test is as follows:

Elements 2D "AXIS" (QUA8)
y
D2
N5
L
D1
X
O
L
Appear 3.1-a: Geometry and grid of modeling

Cutting:
2 meshs QUAD8 according to the x axis

2 meshs QUAD8 according to the y axis

Boundary conditions:
Uy=0 on D1

F=25N on D2

3.2
Characteristics of the grid

A number of nodes: 21
A number of meshs and types: 4 QUAD8, 8 SEG3.

3.3 Functionalities
tested

Orders

DEFI_MATERIAU THER
RHO_CP

LAMBDA

META_ZIRC
TDEQ

K
NR
CCT
QSR_K
AC
M
TDR
AR
Br
CALC_META ETAT_INIT META_INIT_ELNO

COMP_INCR
RELATION
“ZIRC”
DEFI_MATERIAU ELAS_META
E

NAKED
F_ALPHA
C_ALPHA
TEMP_DEF_ALPHA
PHAS_REFE
EPSF_EPSC_TREF

F1_S_VP
F2_S_VP
C_S_VP
S_VP_MELANGE
META_ECRO_LINE
F1_D_SIGM_EPSI

F2_D_SIGM_EPSI
C_D_SIGM_EPSI
META_VISC_FO
F1_ETA

F2_ETA
C_ETA
F1_N

F2_N
C_N
F1_C
F2_C
C_C
F1_M
F2_M
C_M
MODEL AFFE_CHAR_MECA

TEMP_CALCULEE

MODEL STAT_NON_LINE

CHAM_MATER

EXCIT
CHARGE

FONC_MULT

COMP_INCR
RELATION
“META_V_IL”

RELATION_KIT
“ZIRC”

INCREMENT
LIST_INST

NEWTON
STAMP
“TANGENT”

REAC_ITER

CONVERGENCE
RESI_GLOB_RELA

ITER_GLOB_MAXI

4
Results of modeling A

4.1 Values
tested

Identification Size Reference
***Aster** %*
difference
t=120s m3 N5
EPYY
-3.1E-2
-2.888E-2
-6.8%
t=120s m3 N5
SIYY
-25.0

-24.99
-8.90E-5%

5 Comments

This case test of not-regression makes it possible to check the coherence of Code_Aster of a version on the other
with regard to the metallurgy.

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Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
HT-66/05/005/A

Code_Aster ®
Version
8.1

Titrate:
HSNV126 - Thermo-metal-worker-mechanics in simple traction

Date:
05/09/05
Author (S):
V. CANO, Key S. VANDENBERGHE
:
V7.22.126-A Page:
1/10

Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V7.22 booklet: Thermomechanical nonlinear statics of the voluminal structures
V7.22.126 document

HSNV126 - Thermo-metal-worker-mechanics in traction simple

Summary:

This test illustrates a mechanical calculation with nonlinear work hardening on a material (Zircaloy) undergoing metallurgical transformations.
Concretely, initially, operator CALC_META calculates the metallurgical evolution associated with a given thermal history. This metallurgical evolution is then provided to STAT_NON_LINE which goes to carry out a mechanical calculation by taking of account metallurgical phases (in addition to loadings mechanics). The material of mechanical calculation is defined with ELAS_META_FO and META_TRACTION.

1
Problem of reference

It is about a cylindrical bar in creep.

1.1 Geometry

y
F=30 NR
X

Appear 1.1-a: Geometry and loading of the problem of reference

It is about a cylinder H= height 1000 m, and ray R=1000 Mr.
The square in fat corresponds to the axisymmetric modeling used with the §3.

1.2
Material properties
The properties materials are described by the following parameters:

For thermo-metal calculation
(Steel 16MND5)
CP = 5260000 J.m-3.°C-1
= 33.5 W.m-1.°C-1

Coefficients for the metallurgy:

"Standard" TRC
AR3 = 830°C, alpha = -0.0306
MS0 = 400°C, AC1 = 724°C, AC3 = 846°C
1 = 0.034, 3 = 0.034

For calculation thermo-metal-worker-mechanics
· Modulus Young: E= 200000 Pa
· Poisson's ratio: = 0.3

8.1

Titrate:
HSNV126 - Thermo-metal-worker-mechanics in simple traction

Date:
05/09/05
Author (S):
V. CANO, Key S. VANDENBERGHE
:
V7.22.126-A Page:
3/10

Definition of the elastic characteristics, dilation and elastic limits for modeling of an undergoing material of the metallurgical transformations:
· Tref= 20°C
· Thermal Dilation coefficient average of the cold phases:
· F (T) = 10th-6
· Thermal Dilation coefficient average of the hot phase:
· (T) = 0.0001
· Température of definition of the dilation coefficient:
· T = 20°C
· Choix of the metallurgical phase of reference: cold
· Déformation of the phase not of reference compared to the phase of reference to Tref temperature:
= 1E-2
· Limit elastic of the cold phase 1 for a plastic behavior:
F_sigm_f (T) = 100
· Limit elastic of the cold phase 2 for a plastic behavior:
F_sigm_f (T) = 100
· Limit elastic of the cold phase 3 for a plastic behavior:
F_sigm_f (T) = 100
· Limit elastic of the cold phase 4 for a plastic behavior:
F_sigm_f (T) = 100
· Limit elastic of the hot phase for a plastic behavior:
F_sigm_f (T) = 100

· Fonction used for the law of mixture on the elastic limit of multiphase material for a viscous behavior:

1,2
1
0,8

E
G
NR
With
L 0,6
E
M
*SY_*
0,4
0,2
0
0
0,2
0,4
0,6
0,8
1
1,2
META

Appear 1.2-a: Law of mixture

Definition of the 5 traction diagrams used in the isotropic modeling of work hardening not linear of an undergoing material of the metallurgical phase shifts:

· Isotropic Courbe work hardening R according to the cumulated plastic deformation p for cold phase 1
to 20 °C
0,99
250

with 120°C
0,0105
90
0,032
160
0,064
220
0,1125
250
0,1815
270

· Isotropic Courbe work hardening R according to the cumulated plastic deformation p for cold phase 2
idem preceding
· Isotropic Courbe work hardening R according to the cumulated plastic deformation p for cold phase 3
idem preceding
· Isotropic Courbe work hardening R according to the cumulated plastic deformation p for cold phase 4
idem preceding
· Isotropic Courbe work hardening R according to the cumulated plastic deformation p for hot phase
idem preceding

1.3
Boundary conditions and loadings

The base of the cylinder is blocked according to y:
Uy = 0 on the basis of cylinder.
A force of traction F=30 NR is imposed on the top of the cylinder.

The temperature is imposed on all the cylinder for:
T (X, y, T) = 120°C

1.4 Conditions
initial

The following variables are initialized:

Zf (X, y, 0) = 0.7
Zp (X, y, 0) = 0.0
Zb (X, y, 0) = 0.3
Zm (X, y, 0) = 0.0
D (X, y, 0) = 0.0

2
Reference solution

2.1
Results of reference

The results were obtained with a former version of aster. It is about a test of not-regression.

2.2
Uncertainty on the solution compared to the result of not-regression

Uncertainty is of 1E- 10%.

---

3 Modeling
With

3.1
Characteristics of modeling

The modeling used in the case test is as follows:

Elements 2D "AXIS" (QUA8)

y
NO4
NO3
L
NO1
NO2
X
O
L
Appear 3.1-a: Geometry and grid of modeling

Cutting: 1 meshs QUAD4 according to the x axis

1 meshs QUAD4 according to the y axis

Boundary conditions: Uy=0 on NO1 and NO2

F=30N on NO3 AND NO4

3.2
Characteristics of the grid

A number of nodes: 4
A number of meshs and types: 1 QUAD4, 4 SEG2.

3.3 Functionalities tested

Orders

DEFI_TRC HIST_EXP VALE

TEMP_MS
THRESHOLD

AKM

BKM

TPLM

GRAIN_AUST
DREF
With
DEFI_MATERIAU THER
RHO_CP

LAMBDA
META_ACIER
TRC

AR3
ALPHA
MS0
AC1
AC3
TAUX_1
TAUX_3
CALC_META ETAT_INIT META_INIT_ELNO

COMP_INCR
RELATION
“STEEL”
DEFI_MATERIAU ELAS_META_FO E

NAKED
F_ALPHA
C_ALPHA
TEMP_DEF_ALPHA
PHAS_REFE
EPSF_EPSC_TREF

F1_SY
F2_SY
F3_SY
F4_SY
C_SY
SY_MELANGE
META_TRACTION
SIGM_F1

SIGM_F2
SIGM_F3
SIGM_F4
SIGM_C
MODEL AFFE_CHAR_MECA

TEMP_CALCULEE

MODEL STAT_NON_LINE

CHAM_MATER

EXCIT
CHARGE

FONC_MULT

COMP_INCR
RELATION
“META_P_INL”

RELATION_KIT
“STEEL”

INCREMENT
LIST_INST

NEWTON
STAMP
“TANGENT”

REAC_ITER

CONVERGENCE
RESI_GLOB_RELA

ITER_GLOB_MAXI

---

4 Results of modeling A

4.1 Functionalities tested

Orders

DEFI_TRC HIST_EXP VALE

TEMP_MS
THRESHOLD

AKM

BKM

TPLM

GRAIN_AUST
DREF
With
DEFI_MATERIAU THER
RHO_CP

LAMBDA
META_ACIER
TRC

AR3
ALPHA
MS0
AC1
AC3
TAUX_1
TAUX_3
CALC_META ETAT_INIT META_INIT_ELNO

COMP_INCR
RELATION
“STEEL”
DEFI_MATERIAU ELAS_META_FO E

NAKED
F_ALPHA
C_ALPHA
TEMP_DEF_ALPHA
PHAS_REFE
EPSF_EPSC_TREF

F1_SY
F2_SY
F3_SY
F4_SY
C_SY
SY_MELANGE
META_TRACTION
SIGM_F1

SIGM_F2
SIGM_F3
SIGM_F4
SIGM_C
MODEL AFFE_CHAR_MECA

TEMP_CALCULEE

MODEL STAT_NON_LINE

CHAM_MATER

EXCIT
CHARGE

FONC_MULT

COMP_INCR
RELATION
"META_P_INL"

RELATION_KIT
"STEEL"

INCREMENT
LIST_INST

NEWTON
STAMP
"TANGENT"

REAC_ITER

CONVERGENCE
RESI_GLOB_RELA

ITER_GLOB_MAXI

HSNV126 - Thermo-metal-worker-mechanics in simple traction

Date:
05/09/05
Author (S):
***V. CANO,** Key S. VANDENBERGHE*
:
V7.22.126-A Page:
8/10

4.2 Values tested

***Identification Size Reference Aster** %*
difference
t=1.1s NO3
SIYY
60.
59.99
-1.28E-12
t=1.4s NO3
SIYY
142.
142.
-1.62E-12
t=2.0s NO3
SIYY
218.
218
-1.14E-13
t=1.1s NO3
DY
4.
3.999
-6.04E-14
t=1.4s NO3
DY
13.
13.
-2.52E-13
t=2.0s NO3
DY

31.
31.
3.55E-15
t=1.1s NO3
V1
0.
0
0%
t=1.4s NO3
V1
4.9E-3
4.899E-3
-3.79E-12%
t=2.0s NO3
V1
1.91E-2
1.91E-2
-2.54E-13%
t=1.1s NO3
V7
0.
0
0%
t=1.4s NO3
V7
41.1
41.099
-3.96E-12%
t=2.0s NO3
V7
117.58
117.58
-1.72E-12%

Titrate:

5
Results of modeling B

5.1 Functionalities tested

Orders

MODEL STAT_NON_LINE

CHAM_MATER

EXCIT
CHARGE

FONC_MULT

COMP_INCR
RELATION
“META_P_INL”

RELATION_KIT
“STEEL”

DEFORMATION
“SIMO_MIEHE”

INCREMENT
LIST_INST

NEWTON
STAMP
“TANGENT”

REAC_ITER

CONVERGENCE
RESI_GLOB_RELA

ITER_GLOB_MAXI

Modeling B is the exact equivalent one of modeling A by taking into account the large ones deformations via key word DEFORMATION=' SIMO_MIEHE'.

5.2 Values tested

Identification Size
Reference
***Aster** %*
difference
t=1.1s NO3
SIYY
59.72
5.9724891293860E+01
0.005
t=1.4s NO3
SIYY
141.
1.4099749961110E+02
-0.003
t=2.0s NO3
SIYY
215.66

2.1566273036229E+02
0.003
t=1.1s NO3
DY
4.
3.99751357883 90
-0.002
t=1.4s NO3
DY
13.
1.2997513578839E+01
-0.002
t=2.0s NO3
DY
31.
3.0997513578839E+01
-0.002
t=1.1s NO3
V1
0.
0.
0
t=1.4s NO3
V1
4.8787000000000E-03
4.8787703363334E-03
0.001
t=2.0s NO3
V1
1.8866000000000E-02
1.8866871352412E-02
0.005
t=1.1s NO3
V7
0.
0.
0
t=1.4s NO3
V7
41.82
4.1818031454286E+01
-0.005
t=2.0s NO3

V7
117.2
1.17240976649622E+02
0.035

---

6 Comments

This case test of not-regression makes it possible to check the coherence of Code_Aster of a version on the other
with regard to the metallurgy.

Author (S):
Key S. MICHEL-PONNELLE
:
V7.22.129-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.22 booklet: Thermomechanical non-linear statics of the voluminal structures
Document: V7.22.129-A

HSNV129 - Test of compression-dilation for
study of the coupling thermics-cracking

Summary:

One applies to an element of volume obeying the law of Mazars (local and not-local version) a loading thermomechanical in order to check the good taking into account of the dependence of the parameters materials
with the temperature as well as the taking into account of thermal dilation. The loading is homogeneous and
also break up: compression with imposed displacement and constant temperature, then application of a cycle
of heating-cooling.
Handbook of Validation

1
Problem of reference

1.1
Geometry and boundary conditions

Element of volume materialized by a unit cube on side (m):

Z
F
G
E
y
B
C
With
D
X

Appear 1.1-a: Geometry

The loading is such as one obtains a uniform stress and strain state in volume.
Blockings are as follows:
face ABCD: DZ = 0.
face BCGF: DX = 0.

face ABFE: DY = 0.
face EFGH: displacement Uz (T)
The temperature T (T) is supposed to be uniform on the cube; the temperature of reference is worth 0°C.
Uz and T vary according to time in the following way:

moment T
0 100 200 300
Uz (T)
0 Mr.
103 Mr.
103 Mr.
103 Mr.
T (T)
0°C 0°C
200
°C
0°C

A purely mechanical loading is thus carried out, then one heats by blocking the Uz direction,
before cooling. This makes it possible to check the separation of the thermal and mechanical
deformations
as well as the non-recouvrance of the mechanical properties after heating.

1.2
Properties of material

For the model of Mazars, the following parameters were used (value with 0°C):

Elastic behavior:
5
-
1
E = 32.000 MPa, = 0. ,
2 = 1.2 10
-
°C
Thermal characteristics:
1
-
1
-
6
3
-

1
= 2
.
2 W m K
, C p = 2
.
2 10
-
J m
K
Damaging behavior:
D =.
1 0 10 4
-; C
To = 15
.
1
; T
To = 8
.
0; C
B =
.
2000; T
B = 10.000;
06
.
1
0
=

It is considered in addition that E and Bc vary with the temperature. Their evolution is given on figures [Figure 1.2-a] and [Figure 1.2-b].
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V7.22 booklet: Thermomechanical non-linear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
6.0

Titrate:
HSNV129 - Test of compression-dilation

35000
30000
25000
has) *20000*
(MP
E *15000*
10000
5000
0
0
50
100
150
200
T (°C)

Appear 1.2-a: Evolution of the Young modulus with the temperature

2500
2000
1500
Bc
1000
500
0
0
50
100
150
200
T (°C)

Appear 1.2-b: Evolution of BC with the temperature

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HT-66/02/001/A

Code_Aster ®
Version
6.0

Titrate:
HSNV129 - Test of compression-dilation

Date:
14/10/02
Author (S):
Key ***S. MICHEL-PONNELLE***
:
V7.22.129-A Page:
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2
Reference solution

One can analytically determine the solution of the problem arising.
One notes:
· 0 deformation applied in direction Z,
· 1, 2 and 3 principal deformations

2.1
First stage of the loading: simple compression

- 0
0
0

· The tensor of the deformations is worth: 0
- 0 0 with 0 < 0

0
0

0
· The equivalent deformation is worth consequently
:
~
2
2
2
=
E

+ E

+ E

= -

2
1
2
3
0

+
+
+
· Since ~
> d0, there is evolution of the damage which is worth:
d0 (1 - C
With)
With
D = 1
C
-
~
-

[~
exp B (-)
C
D 0]
· Enfin the constraint zz is worth: zz = E 1 (- D) 0

2.2 Second stage of the loading

: thermal dilation in plane deformations

· The tensor of the total deflections is worth:

- 0 + (T - T
1
)(
ref.
+)
0
0

0
- 0 + (T - T
1
)(
ref.
+) 0 with 0 < 0 fixed

0
0
0

· Elastic strain being worth E
= - T
(- ref.
T
*) **Id**, the equivalent deformation is worth:*
~
= 2 ((T -
)
ref.
T
- 0)

· The damage is worth:

-
d0 (1 - C
With)

With

D = MAX D 1, -
-
C

~

[~
exp B (
C -
)
D 0]
· Enfin the constraint zz is worth:

zz = E (1 - D) [- (T - T)
0
ref.]
Handbook of Validation
V7.22 booklet: Thermomechanical non-linear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
6.0

Titrate:
HSNV129 - Test of compression-dilation

Date:
14/10/02
Author (S):
Key ***S. MICHEL-PONNELLE***
:
V7.22.129-A Page:
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Note:

· A a given state, the parameters materials used are those defined in the temperature maximum sight by material and not at the current temperature.
· The evaluation of the damage D utilizes the concept of maximum reaches with the course

history of the loading; the solution is thus not completely analytical but
imply a discretization. If there is no influence of thermics, it
is enough to take ~ equivalent with the maximum equivalent deformation reached. When one
takes into account the thermal aspect, the heating can contribute "to decrease" or
"to delay" the damage with deformation given; it is the case with the evolution of Bc
reserve. In this case, it is necessary in makes rather finely discretize the loading to have
the good value of damage D (which presents indeed a maximum in our
case).

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D
Element MECA_HEXA8

3.2
Characteristics of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8

3.3 Functionalities
tested

The law of behavior MAZARS_FO combined with ELAS_FO.

4
Results of modeling A

4.1 Values
tested

One compares the damage D and the constraint zz with various moments

Identification Reference
Aster
% difference
T = 50
D
0
0

-

-16.0
-16.0
2.33 10-14
zz (MPa)
T = 100
D
0.1702
0.1702
0.007

-26.5532
-26.5532
6.46 10-5
zz (MPa)
T = 150
D
0.4247
0.4247
-0.005

-30.3768
-30.3769
2.91 10-4
zz (MPa)
T = 200
D
0.4626
0.4625
-0.014

-29.2327
-29.2382
0.019
zz (MPa)
T = 250
D
0.4626
0.4625
-0.014

-18.9153
-18.9188

0.019
zz (MPa)
T = 300
D
0.4626
0.4625
-0.014

-8.5979
-8.5994
0.018
zz (MPa)

4.2 Notice

Actually, the maximum damage, i.e. 0.4626 is reached at time T 180 S. Ensuite, it do not evolve/move any more because of the reduction of Bc when the temperature increases.

---

5 Modeling B

5.1 Characteristics of modeling

The use of the delocalized version of the model of Mazars passes by the use of modeling 3D_GRAD_EPSI and implies the use of quadratic elements.
The test is carried out with a null characteristic length.

Modeling 3D_GRAD_EPSI
Element MGCA_HEXA20

5.2 Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 1 HEXA20

5.3 Functionalities tested

The law of behavior MAZARS_FO combined with ELAS_FO within the framework of modeling not-local 3D_GRAD_EPSI.

6 Results of modeling B

6.1 Values tested

One compares the damage D and the constraint zz with various moments

Identification Reference
Aster %
difference
T = 50
D
0
0
-

-16.0
-16.0
2.33 10-14
zz (MPa)
T = 100
D
0.1702
0.1702
0.007

-26.5532
-26.5532
6.46 10-5
zz (MPa)
T = 150
D
0.4247
0.4247
-0.005

-30.3768
-30.3770
8.06 10-4
zz (MPa)
T = 200
D
0.4626
0.4625
-0.014

-29.2327
-29.2382
0.019
zz (MPa)
T = 250
D
0.4626
0.4625
-0.014

-18.9153
-18.9188
0.019
zz (MPa)
T = 300
D
0.4626
0.4625
-0.014

-8.5979
-8.5994
0.018
zz (MPa)

6.2 Notice

Actually, the maximum damage, i.e. 0.4626 is reached at time T 180 S. Ensuite, it
do not evolve/move any more because of the reduction of Bc when the temperature increases.
Handbook of Validation
V7.22 booklet: Thermomechanical non-linear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
6.0

Titrate:
HSNV129 - Test of compression-dilation

Date:
14/10/02

7
Summary of the results

One obtains the analytical solution with a precision lower than 0.02% what makes it possible to be ensured of good establishment of the model of Mazars including when the temperature intervenes. Let us point out them choices which were made for the coupling cracking-thermics and which are checked here:

· linear thermal dilation,
· evolution of the damage only under the effect of the elastic strain and not thermics,
· dependence of the parameters materials with the maximum temperature, i.e. not reversibility of the modifications of the mechanical properties when the concrete is heated then cooled.

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V7.22 booklet: Thermomechanical non-linear statics of the voluminal structures
HT-66/02/001/A

Code_Aster ®
Version
7.1

Titrate:
HSNA120 - Propagation in a network of cracks

Date:
02/06/04
Author (S):
***Mr. SEYEDI**, Key S. TAHERI*
:
V7.23.120-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.23 booklet: Thermomechanical nonlinear statics of the surface structures
V7.23.120 document

HSNA120 - Propagation in a network of cracks
in fatigue thermomechanical

Summary:

This axisymmetric test makes it possible to preserve a methodology of simulation of the propagation in a network
fatigue cracks thermomechanical. It is a question of a method of mending of meshes automatic to follow the projection of cracks and a strategy of propagation in a network. The whole of the method is programmed in PYTHON in the command file.

The test comprises the modeling of the propagation of four parallel cracks in the thickness of a tube subjected to a variation in temperature on its internal skin and a monotonous axial stress.

Handbook of Validation
V7.23 booklet: Thermomechanical nonlinear statics of the surface structures
HT-66/04/005/A

Code_Aster ®
Version
7.1

Titrate:
HSNA120 - Propagation in a network of cracks

Date:
02/06/04
Author (S):
***Mr. SEYEDI**, Key S. TAHERI*
:
V7.23.120-A Page:
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1
Problem of reference

1.1 Geometry

The studied problem consists being studied of the propagation of a network of four parallel cracks of lengths and of arbitrary distances in the thickness of a tube subjected to a variation in temperature on its internal skin. [Figure 1.1-a] the geometry of the model studied as well as the loadings shows and boundary conditions considered. The distances between the cracks and their lengths are data in the tables [Table 1.1-1] and [Table 1.1-2].

127 mm

Appear 1.1-a: Geometry and boundary conditions of the model

Fissure	F1	F2	F3	F4
Length (mm)	0,68	0,70	0,08	0,69

Table 1.1-1: The initial length of the cracks and their distances

Fissure	d12	d23	d34
Outdistance (mm)	2,89	2,06	0,61

Table 1.1-2: The distance enters the cracks

1.2
Material properties

The material is elastic linear isotropic. Mechanical properties and thermal of material are:

Young modulus
E = 2,1E5 MPa
Poisson's ratio
= 0,3
Thermal coefficient of conductivity
= 0,014 W/mm/°C
Voluminal Mass
= 8th-6 Kg/mm3
Specific heat
CP = 450 J/Kg/°C
Thermal dilation coefficient
= 1,5E5 mm/°C

1.3
Boundary conditions and loadings

Mechanics:
Imposed displacements: embedding of the lower part.

Condition of contact between the lips of the cracks:
Conditions of unilateral contact without friction with pairing node-facet (master-slave) are considered to ensure nonthe penetration of the lips of cracks the moment of their closing.

Average constraint:
A average constraint of 60 MPa is applied to the higher edge of the model.

Thermal loading:
The loading applied to constant amplitude is imposed on the internal skin of the tube

T

T = T +
Cos (2)
0
ft
2
where 0
T = 70°C, T
= 100°C and F = 0,1 Hz.

CHART [num_calc] =AFFE_CHAR_MECA (MODELE=MOD_G [num_calc],
TEMP_CALCULEE = TEMPT [num_calc],
);

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2 Reference solution

One does not have an analytical solution for the calculation of the propagation of a network of cracks in tire thermomechanical. Consequently, this case test is a case test of nonregression. The reference is consisted results resulting from version 7.0 of Code_Aster.

2.1 Method of calculation of reference

Methodology used to deal with the problem of propagation of two-dimensional cracks in tiredness relates to a calculation 2D plane or axisymmetric which takes into account a radial or axial cut studied tube. This methodology allows the analysis of the propagation of the cracks in the thickness. The present study consists in testing a numerical procedure of simulation of the propagation of cracks in 2D or axisymmetric [bib1]. It is about a method based on automatic mending of meshes to simulate the propagation of the cracks and a strategy of propagation in a network of cracks in fatigue thermal.
The procedure of mending of meshes is led with GMSH which launches out automatically after each step of propagation of the cracks to remake the grid during calculation. Strategy of propagation of network of cracks is controlled by increments over the lengths of the cracks. The kinetics of propagation of the fatigue cracks can be described by a law of propagation in fatigue of the type Paris. Within the framework of this modeling, a law of propagation of Paris modified (Pellas and Al [bib2]) which takes into account the effect of the threshold of nonpropagation, the report/ratio of load and tenacity material, is used.
By considering a theoretical increment length for all the cracks of the network, one finds fissure which needs the minimum of a number of cycles to be propagated by considering the amplitude of stress intensity factor manpower and the law of propagation. By applying this number of cycles to structure, one finds the propagation of each crack.

2.2 Results of reference

For three stages of propagation, the amplitude of stress intensity factor manpower (K EFF) for the dominant crack and the number of cycles of the stage are compared with the values of reference. These *values are:*

Stage 1:
(K
EFF) = 0.0513, Nétape = 212900
Stage 2:
(K
EFF) = 0.0550, Nétape = 178574
Stage 3:
(K
EFF) = 0.0613, Nétape = 135107
Handbook of Validation
V7.23 booklet: Thermomechanical nonlinear statics of the surface structures
HT-66/04/005/A

---

3 References
bibliographical

[1]
Mr. SEYEDI: (2002) "Simulation of the propagation of a thermal network of faience manufacturing by
Code_Aster", notes intern EDF R & D, HT-64/02/004/A.
[2]
J. PELLAS, G. BAUDIN, and Mr. ROBERT: (1977) "Measurement and calculation of threshold of cracking
after overload", Aerospace Research, vol. 3, pp. 191-201.
[3]

H. YAAKOUB AGA: (1996) "Fault tolerance initial: application to a cast iron G.S. in fatigue", Thesis of doctorate. University Paris 6.

4 Modeling
With

4.1
Characteristics of modeling

Modeling considers a tube runs which contains four cracks leading to its skin intern. An axisymmetric model with the following geometrical characteristics was considered.
H = 60 mm
W = 9,23 mm

4.2
Characteristics of the grid

The grid was created by taking 3 principal blocks. The block medium contains the cracks, it is him even made up of 5 blocks.

A number of nodes: 15650

A number of meshs: 8147
SEG3: 456
TRIA6: 7685

Appear 4.2-a: Grid finite elements and details of the cracks (initial situation)

4.3
The law of propagation

The propagation of the fatigue cracks follows a law of the Paris type. Within the framework of tiredness to large a number of cycles, the threshold of nonpropagation of crack, the report/ratio of load and the tenacity of material can influence the propagation velocity of the cracks. In this case, the law of propagation of the cracks can be written like a law of Paris amended (Pellas and Al (1977) [bib2] and Yaacoub Aga and Al (1998) [bib3]).

da
N
K
G (R) - K
1 -
K
=
R
C K

max
HT
min
EFF with K

=
, G (R) =
and R =

dN
EFF
K
K
HT
1 - m R
R
K max
IC -

G (R)

where K max and Kmin are factors of intensity of the constraints maximum and minimum respectively, Kth the threshold of nonpropagation, R the report/ratio of load and K IC the tenacity of material. The coefficients used are as follows:

C = 9,34 10-4
N = 2,6
Mr. = 0,37
Kth = 4 MPa.m0.5
K IC = 66 MPa.m0.5

5
Results of modeling A

5.1 Values
tested

The values tested are the amplitude of effective stress intensity factor and the number of cycles applied.

Identification Reference Aster
% difference
Stage 1: K
EFF
5.1300 E-2
5.131615 E-2
0.031
Stage 1: NR
2.1290 E+5
2.129012 E+5
5.6 E-4
Stage 2: K
EFF
5.5000 E-2
5.496820 E-2
0.058
Stage 2: NR
1.7887 E+5
1.785738 E+5
1.0 E-4
Stage 3: K

EFF
6.130 E-2
6.130244 E-2
0.004
Stage 3: NR
1.35107 E+5
1.351072 E+5
1.66 E-4

Document: V7.30.102

WTNL102 - Dimensional mono problem of forced convection

Summary:

It is about the dimensional mono transport of heat by a flow constant speed. The water resource is characterized by a linear pressure in space. The reference solution is analytical.

Handbook of Validation

V7.30 booklet: Thermo-hydro-mechanics in porous environment of linear structures

HT-66/04/005/A

1
Problem of reference

1.1 Geometry

One places oneself within the framework of a dimensional mono problem in Cartesian co-ordinates.
"structure" considered, is finally a segment length 1

p = 0

p = P
X = 1

X = 0
T =1

T = 0

1.2
Boundary conditions and loadings

One imposes a pressure varying P in X linearly = 0 to 0 in X = 1: p (X) = P (1 - X)

In X = 0: the temperature is imposed null
In X = 1: the temperature is imposed on 1.

1.3 Conditions initial

T (X) = 0 everywhere
One is interested in steady operation

---

2 Reference solution

2.1 Method of calculation

One leaves the equation of the energy [éq 3.1.3-1] of the document [R7.01.11], which in this case give:
m
H +
Q + Div
& &
*(**M***
*H) + Div (**Q**) = 0*

éq
2.1-1
In which H indicates the enthalpy of water, ***M*** *its flow mass, m the mass water contribution and* ***Q*** *heat flow.*

Taking into account the made assumptions, one sees easily that:
M *= M = P*

éq 2.1-2
X
W H
H = C Pt

éq 2.1-3
W
T

Q *= Q =* **-**

éq 2.1-4
X
T
X

Q = C Pt
&

éq 2.1-5

W

W &

K

is the thermal coefficient of diffusion process,

int

=

is the hydraulic coefficient of diffusion, K

T

H

µ

int

W

the intrinsic permeability, µ, p

C are respectively the density, viscosity and

W

W

W

calorific heat with constant pressure of water.

While deferring [éq 2.1-2], [éq 2.1-3], [éq 2.1-4] and [éq 2.1-5] in [éq 2.1-1] one finds:

p

2

C

W

W

p

H

T

T + C

P

&

éq
2.1-6
W
W
- *T = 0*
2

T
T
X X
One poses:

R = C p H P
W
W T
and
p
wCw
S =

T

One obtains
2
T
T
S & + R
- *T = 0* ***éq***
2.1-7
2
X X

2.2
Results of reference

In order to obtain steady operation more quickly, one chooses coefficients such as:
S
1
=
<<1
R
P
H
The solution of [éq 2.1-7] is then:

X-ray
E -1
T =

R
E -1
Handbook of Validation
V7.30 booklet: Thermo-hydro-mechanics in porous environment of linear structures
HT-66/04/005/A

Code_Aster ®
Version
6.2

Titrate:
WTNL102 - Dimensional mono problem of forced convection
Date:
13/10/04
Author (S):
C. CHAVANT, *R. FERNANDES Key*
:
V7.30.102-A Page:
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3 Modeling With

3.1 Characteristics of modeling A

1
One makes a modeling with 500 elements, each element thus has a length H =
.
500
The coefficients are chosen:

1
W
C p
1
W
μ
1

W

K
100
int

10
T
P
1
1
These values lead to a number of Peclet R = 10 and to a Peclet number local Rh =
.
50

3.2 Functionalities tested

Order
Option

AFFE_MODELE
D_PLAN_THMD

DEFI_MATERIAU
THM_LIQU

THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO
PRE1

TEMP
STAT_NON_LINE COMP_INCR
RELATION KIT_THM

RELATION_KIT
ELAS

LIQU_SATU
HYDR_UTIL

Discretization in time: 10 steps of times of 40 S each one

3.3 Results

X
Temperature of reference
Temperature Aster Error
relative
6,00E-01 0,0182710686
0,0182567
0,079%
7,00E-01 0,0497439270
0,0497269
0,034%
8,00E-01 0,1352960260
0,1352760
0,015%
9,00E-01 0,3678507400
0,3678309
0,005%
1,00E+00 1,0000000000
1,0000000
0,0%

4
Summary of the results

A good agreement is obtained between the temperatures calculated by Code_Aster and the values of reference.

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V7.30 booklet: Thermo-hydro-mechanics in porous environment of linear structures
HT-66/04/005/A

Code_Aster ®
Version
7.4

Titrate:
WTNV100 - Triaxial compression test not drained with model CJS (level 1)
Date:
05/07/05

Author (S):
***C. CHAVANT**, pH. Key AUBERT*
:

Organization (S): EDF-R & D /AMA, CNEPE

Handbook of Validation
V7.31 booklet: Mechanical hydro Thermo in porous environment of voluminal structures
Document: V7.31.100

WTNV100 - Triaxial compression test not drained with the model CJS (level 1)

Summary

This test makes it possible to validate level 1 of model CJS. It is about a triaxial compression test in not drained condition.
In the first two modelings, calculations are carried out only on the solid part of the ground, the aspect not drained being modelled by a null voluminal deformation of the skeleton, they are modelings 3D which differs one from the other only by the grid.
In the third modeling, the hydraulic coupling is taken into account, the sample is completely saturated, the skeleton and the fluid are supposed to be incompressible.

By reason of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test.
The level of containment is of 100 kPa.
The results obtained with model CJS1 are compared with an analytical solution.

1
Problem of reference

1.1 Geometry

Z
E
height:
H = 1 m
width:
L = 1 m
thickness: E = 1 m
C
H
With
B
y
X
L

Co-ordinates of the points (in meters):

With
B
C
X 0. 0.
0.5
y 0. 1.
0.5
Z 0. 0.
0.5

1.2
Material property

E = 22,4 103 kPa
= 0,3
Coefficient of biot b: 1
Water is supposed to be incompressible: UN_SUR_K = 0

Parameters CJS1: = - 0,03
= 0,82
Rm = 0,289
Pa = -100 kPa

1.3
Initial conditions, boundary conditions, and loading

1.3.1 Pure mechanical modeling

Phase 1:
One brings the sample in a homogeneous state: 0
0
0
xx = yy = zz, by imposing the pressure of
containment corresponding on the front, side right-hand side and higher faces. Displacements are blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0). One applies a displacement imposed to the higher face: U (T
Z
), in order to
to obtain a deformation zz = -20% (counted starting from the beginning of phase 2). On the front

faces
and side right-hand side, one imposes respectively displacements U (T
X
) and U (T
y
), in order to have one
null voluminal deformation for the sample, i.e. finally that one imposes

zz
xx = yy = -
. It is the manner of reproducing the behavior of the solid phase during a test
2
triaxial not drained.

1.3.2 Modeling coupled with hydraulics

Phase 1:
One brings the sample in a homogeneous state of effective stresses: 0
0
0
xx = yy = zz, while imposing
corresponding total pressure on the front, side right-hand side and higher faces and while imposing
everywhere null water pressures. Displacements are blocked on the faces postpones (ux = 0),
side left (U y = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and lower (uz = 0).
On all the faces, hydraulic flows are null.
One applies a displacement forced to the higher face in order to obtain a deformation zz = -20% (counted starting from the beginning of phase 2). On the front faces and side right-hand side, one impose boundary conditions in total constraint:

.n = 0 (= 100kPa)

2
Reference solution

2.1
Reference solution for the water pressure into linear

0, 0 p0 indicating the constraints, water deformations and pressures obtained in the phase one a:
-0 = tr (- 0) + 2µ (- 0) - (
B p - 0
p)
m
p - p

=
0 + btr

fl
(-0)

M
1
In this writing, M indicates the module of biot and NR =
.
M
The boundary conditions of null flow and the conservation of the water mass give m = 0
Boundary conditions on the side walls and the fact that the state of stress is homogeneous give:
xx - xx = 0
0

One has thus finally to solve the two equations:

(2
xx +
zz) + 2µ
xx = LP

(
p
B 2
xx +
zz) = -
= - Np

M

And one obtains:

2
zz
B + NR
xx = -

2 b2 + (+ µ) NR

μ
B zz
p = -

b2

+ (+ μ) NR

In our case,

zz
xx = -
;
p = -
μ zz
2

2.2
Development of analytical solution CJS

One has permanently:
zz
for the deformations: xx = yy = -

2
for the constraints: xx = yy

Elastic phase:
While writing the elastic law simply, it comes:

0
xx = xx - μ zz

0
zz = zz + 2 μ zz

Titrate:
WTNV100 - Triaxial compression test not drained with model CJS (level 1)
Date:
05/07/05
Author (S):
C. CHAVANT, pH. Key AUBERT
:
V7.31.100-B Page:
5/14

In addition, it is also known that during this I1 phase (= trace ()) remain constant bus v = 0. One in deduced for the components from the diverter:

I
I 0
I
I 0
S
1
0
1
1
0
1
xx = xx -
= xx -
- μ zz = - μ zz and S = -
= -
+ 2 μ = 2 μ
3
3
zz
zz
zz
zz
zz
3
3
that is to say: sII = - 6 μ zz and det (S) = 2 3 3
μ zz

1/6

Consequently: (
H = 1 -
S)
( )
Thus when one reaches the criterion F D = 0, one a:

S (1) 1/6 R I 0 = - 6
1/6
0
-
+
1
µ (1 -) + R I
II
m
zz
m
= 0
1

I.e. the transition enters the states rubber band and perfectly plastic is done for one axial deformation equalizes with:
0
trans
m
R I1
zz
=

µ (-) 1 6
6
1
/
The corresponding state of stresses is noted:
R I 0
R I 0
trans
0
m 1
trans
0
m 1
xx

= xx - μ
and zz
= zz + 2 μ

μ (-) 1 6
6
1
/
6 μ (1 -) 1/6

Plastic phase:
One notes s-d the diverter of the reverse of the tensor S
Generally, there are the following sizes:

1
1
- 3
- 3
S
= - (-) = S
-
- D
xx
zz
xx
yy S
=
S
=

3
xx

xx
zz -

xx
2 (zz - xx)
2
3
S
-1
3
- D

zz =
(zz - xx) S =
S
=
3
zz
2 (
zz
-
zz - xx)
zz
xx

2
2
3
that is to say: sII = -
(zz - xx) and det (S) = (zz - xx)
3
33

1/6
Consequently: (
H S) = (1 -)

One deduces some:
1
2
Q
1/6
1/6
xx =
(1 -) and Qzz = - (1 -)
6
3

F D
1
D
1/6
F
2
1/6
moreover:

=
(1-) +
= -
1-
+

Rm and
(
)
Rm
xx
6
zz
3

S

R

Like one a: =
(
sign S
II
m
ij I
& J)
-
1

1 =

scII =
-
Rc

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Code_Aster ®
Version
7.4

Titrate:

then tensor N is written:

1
1

1

2

N

xx =

+
1 and N
-
+1
2

zz =
+ 6

3
2
+
3

3

It comes then for G D:

1/6
1
1/6

1-
+ 3
D
m 1

xx =
(1-)
( )
R
G
+ Rm -

+
1
6
2
+ 3
6

1/6
2
1/6
1-
+ 3

2

D
m
1

zz = -
(-)
( )
R
G
+ Rm -
-
+1
3
2
+ 3

3

One also has according to the elastic law:

trans
trans
xx = xx
+
xx and zz = zz +
zz
where:

D
D
D
D
D
D
D
D
D
xx = 2 µ (xx - Gxx) + (v - tr (G) = - µ zz - 2 µ Gxx - (2 Gxx + Gzz)

D
D
D
D
D
D
D
D
D
zz = 2 µ (zz - Gzz) + (v - tr (G) = 2 µ zz - 2 µ Gzz - (2 Gxx + Gzz)

and with:
trans
trans
xx = xx - xx
and zz = zz - zz

maybe, according to what precedes, one has for sII:
2
S
trans
trans
trans
D
D
D
II = -

3 µ

2 µ

3 [(zz
- xx) +
(zz - zz) -
(G - G
zz
xx)]
2
= strans
trans
D
D
D
II
-
3 µ

2 µ

3 [
(zz - zz) -
(G - G
zz
xx)]
and for I1:
I = I trans - (+ µ)
D

(Gd +Gd
1
1
3
2
2 xx
zz)

One deduces from it that the function of load déviatoire is written:

1/6
2
F D = strans
trans
D
D
D
1/6
II
(1-) -
3 µ

2 µ

1
3 [
(zz - zz) -
(G - G
zz
xx)] (-)
+R I trans
1
- R
D
D
D
m
m (3 + 2 µ)

(2 G +G
xx
zz)
By taking account of the fact that F D (trans

) =0, one finds then for the plastic multiplier:

3 µ 1 - 1/6
D
( )
=
(trans
zz - zz
)
3
2 µ (D
D
D
D
Gzz - Gxx) -
Rm (3 + 2 µ) (2 Gxx + Gzz)
2

---

what gives with the formulas of G D
D
xx and Gzz the preceding ones:

2 µ (1 -) 1/6 (2 +) 3
D =
3
(

trans
zz - zz

R
1/6
1/6
m - (1 -)
) (2μ (1) - (3+2μ) Rm) (
)

One concludes from it finally the analytical expression from the constraints:

While posing:
has = (1 -) 1/6;
B = (2

+)3
One a:

trans
xx - xx
=

2
1
has + 3
1

R
- has
m
R
(m)

μ has B 2 μ
has +

1
3

m
R -

+ +

3

6
B

6

B

- µ
trans
+

-

(
zz zz
m
R -) (2 µa has - (3 + 2 µ) m
R)
(
)

trans
zz - zz
=

2

2
+ 3 R have
2

R
- has

m
(m)

μ has B 2 μ

-
+ R has

1 3

m -
-
+ +

3

3
B

3

B

2 μ
trans
-

-

(
zz zz
Rm - has) (2 μa - (3 + 2 μ) Rm)
(
)

2.3
Results of reference

Constraints xx, yy and zz at points A, B and C.

2.4
Uncertainty on the solution

Exact analytical solution for CJS1.
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---

3 Modeling With

3.1 Characteristics of modeling

3D:
Z
B
y
X

Cutting: 1 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 0
0
0
xx = yy = zz: 100 kPa.
Level 1 of model CJS

3.2 Characteristic of the grid

A number of nodes: 8
A number of meshs and types: 1 HEXA8 and 6 QUA4

3.3 Functionalities
tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
“CJS”

4
Results of modeling A

4.1 Values
tested

Localization Number Deformation
Constraint
Reference
***Aster** %*
difference

of order axial** zz **(%)
(kPa)
Not A and B
1
-0.25
xx
-78.461538 -78.461538 <
10-5
2
-0.50
xx
-56.923077 -56.923077 <
10-5
3
-0.75
xx
-53.606 -53.606 <
10-5
4
-1.0
xx
-54.480 -54.480 <
10-5
8
-5.0
xx
-68.467 -68.467 <
10-5
23
-20.0
xx
-120.918 -120.918
<
10-5
1
-0.25
yy
-78.461538 -78.461538 <
10-5
2
-0.50
yy
-56.923077 -56.923077 <

10-5
3
-0.75
yy
-53.606 -53.606 <
10-5
4
-1.0
yy
-54.480 -54.480 <
10-5
8
-5.0
yy
-68.467 -68.467 <
10-5
23
-20.0
yy
-120.918 -120.918
<
10-5
1
-0.25
zz
-143,07692 -143,07692
<
10-5
2
-0.50
zz
-186.153846 -186.153846
<
10-5
3
-0.75
zz
-196.818 -196.818
<
10-5
4
-1.0
zz

-200.028 -200.028
<
10-5
8
-5.0
zz
-251.383 -251.383
<
10-5
23
-20.0
zz
-443.961 -443.961
<
10-5

5 Modeling B

5.1 Characteristics of modeling

This modeling differs from the preceding one by the smoothness of the grid
3D:

Z
B
y
X

Cutting: 2 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 0
0
0
xx = yy = zz: 100 kPa.
Level 1 of model CJS

5.2
Characteristic of the grid

A number of nodes: 27
A number of meshs and types: 8 HEXA8 and 24 QUA4

5.3 Functionalities
tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR
RELATION
“CJS”

6
Results of modeling B

6.1 Values tested

Localization Number Deformation
Constraint
Reference
***Aster** %*
difference
of order axial** zz **(%)
(kPa)
Not A, B and C 5
-0.2
xx
-82.76923 -82.76923 <
10-5
10
-0.4
xx
-65.53846 -65.53846 <
10-5
20
-0.8
xx
-53.78079 -53.78079 <
10-5
40
-1.6

xx
-56.578176 -56.578176 <
10-5
60
-5.6
xx
-70.565109 -70.565109 <
10-5
100
-20.0
xx
-120.918065 -120.918065
<
10-5
5
-0.2
yy
-82.76923 -82.76923 <
10-5
10
-0.4
yy
-65.53846 -65.53846 <
10-5
20
-0.8
yy
-53.78079 -53.78079 <
10-5
40
-1.6
yy
-56.578176 -56.578176 <
10-5
60
-5.6
yy
-70.565109 -70.565109 <
10-5
100
-20.0
yy
-120.918065 -120.918065

<
10-5
5
-0.2
zz
-134.46154 -134.46154
<
10-5
10
-0.4
zz
-168.92308 -168.92308
<
10-5
20
-0.8
zz
-197.460849 -197.460849
<
10-5
40
-1.6
zz
-207.731697 -207.731697
<
10-5
60
-5.6
zz
-259.085935 -259.085935
<
10-5
100
-20.0
zz
-443.961194 -443.961194
<
10-5

7 Modeling C

7.1 Characteristics of modeling

3D_HM:
Z
B
y
X

Cutting: 1 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 0
0
0
xx = yy = zz: 100 kPa.
Level 1 of model CJS
Coefficient of biot: 1
UN_SUR_K of water: 0

7.2 Characteristic of the grid

A number of nodes: 20
A number of meshs and types: 1 HEXA20 and 6 QUA8

7.3 Functionalities tested

Orders

DEFI_MATERIAU CJS

STAT_NON_LINE COMP_INCR RELATION "KIT_HM"

"RELATION_KIT":
"CJS" "LIQU_SATU" "HYDR_UTIL"

---

8 Results of modeling C

8.1 Values tested

Localization Number Deformation

Constraint
Reference
Aster *%*
difference
of order axial *zz* ***(%)***
(kPa)
Not A and B
1
-0.25
xx
78.461538 7,8462E+01
<
10-5
2
-0.50
xx
56.923077 5,6923E+01
<
10-5
3
-0.75
xx
53.606 5,3606E+01 <
10-5
4
-1.0
xx
54.480 5,4480E+01 <
10-5
8
-5.0
xx
68.467 6,8467E+01 <
10-5
23
-20.0
xx
120.918 1,2092E+02 <
10-5
1
-0.25
yy
78.461538 7,8462E+01

<
10-5
2
-0.50
yy
56.923077 5,6923E+01
<
10-5
3
-0.75
yy
53.606 5,3606E+01 <
10-5
4
-1.0
yy
54.480 5,4480E+01 <
10-5
8
-5.0
yy
68.467 6,8467E+01 <
10-5
23
-20.0
yy
120.918 1,2092E+02 <
10-5
1
-0.25
zz
143,07692 1,4308E+02
<
10-5
2
-0.50
zz
186.153846 1,8615E+02
<
10-5
3
-0.75
zz

196.818 1,9682E+02 <
10-5
4
-1.0
zz
200.028 2,0003E+02 <
10-5
8
-5.0
zz
251.383 2,5138E+02 <
10-5
23
-20.0
zz
443.961 4,4396E+02 <
10-5

1
-0.25
pressure water 2,1538E+04
2.15385E+04
< 10-5

2
-0.50
pressure water 4,3077E+04
4.30769E+04
< 10-5

For the water pressure, one with the reference as long as the behavior is elastic linear

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Code_Aster ®
Version
7.4

Titrate:
WTNV100 - Triaxial compression test not drained with model CJS (level 1)

9
Summary of the results

The values of Code_Aster are in perfect agreement with the values of reference. Concerning coupling with hydraulics, this test proves that by means of computer, coupling CJS/THM functions and that the equations of hydraulics are at least able to give again the null variation of volume when water is incompressible.

Titrate:
WTNV101 - Triaxial compression test not drained with the model of Laigle
Date:
13/10/04
Author (S):
***R. FERNANDES**, C. CHAVANT Key*
:
V7.31.101-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.31 booklet: Mechanical hydro Thermo in porous environment of voluminal structures
Document: V7.31.101

WTNV101 - Triaxial compression test not drained with the model of Laigle and with hydraulic coupling

Summary

This test makes it possible to validate the model of Laigle with hydraulic coupling. It is about a triaxial compression test in not drained condition. The aspect not drained is modelled by a null voluminal deformation of the skeleton and it hydraulic coupling is taken into account, the sample is completely saturated, the skeleton and the fluid being presumedly incompressible.
By reason of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test.
The level of containment is 8 MPa.

V7.31.101-A Page:
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1
Problem of reference

1.1 Geometry

Z
E
height:
H = 1 m
width:
L = 1 m
thickness: E = 1 m
C
H
With
B
y
X
L

Co-ordinates of the points (in meters):

With
B
C
D
X 0. 0.
0.5 1.
y 0. 1.
0.5 1.
Z 0. 0.
0.5
0.

1.2
Material property

E = 1500 103 kPa
= 0,27

=
;
132
.
0
ult
=
;
005
.
0
E
m =
;
0
.
2
ult
m =
;
0
.
7
E
has =
;
65
.
0
E
m
=
;
0
.
15
peak
has =
;
5
.
0

peak
=
;
45
.
0
=
;
25
.
0
=
;
7
.
0
cjs
=
10

09
.
9
6
;
Pa
1
p
=
10

05
.
23
6
;
Pa
p2

1.3
Initial conditions, boundary conditions, and loading

1.3.1 Modeling coupled with hydraulics

Phase 1:
One brings the sample in a homogeneous state of effective stresses: 0 = 0 = 0
xx
yy
zz, while imposing
corresponding total pressure on the front, side right-hand side and higher faces and while imposing
everywhere null water pressures. Displacements are blocked on the faces postpones (ux = 0),
side left (U y = 0) and lower (uz = 0).

Phase 2:
One maintains displacements blocked on the faces postpones (ux = 0), side left (uy = 0) and
lower (uz = 0). On all the faces, hydraulic flows are null.
One applies a displacement forced to the higher face in order to obtain a deformation
zz = -20% (counted starting from the beginning of phase 2). On the front faces and side right-hand side, one
impose boundary conditions in total constraint:
.
0
N = (= 8MPa)

2 Modeling
With

2.1
Characteristics of modeling

3D:
Z
B
y
X

Cutting: 1 in height, in width and thickness.

Loading of phase 1:
Confining pressure: 0 = 0 = 0
xx
yy
zz: 8 MPa.
Coefficient of biot: 1
UN_SUR_K of water: 0
Modeling: 3D_HM

2.2
Characteristic of the grid

A number of nodes: 20
A number of meshs and types: 1 HEXA20 and 6 QUA8

2.3 Functionalities
tested

Orders

DEFI_MATERIAU LAIGLE

STAT_NON_LINE COMP_INCR RELATION “KIT_HM”

“RELATION_KIT”:
“LAIGLE”, “LIQU_SATU”, “HYDR_UTIL”

3
Results of modeling A

3.1 Values
tested

Localization
Sequence number

Constraint (MPa)
Aster
Not D
1
xx
6.91788E+06
2
xx
5.44150E+06
3
xx
3.96513E+06
4
xx
2.64978E+06
8
xx
-8.68544E+06
23
xx
1.22666E+07
1
yy
6.91788E+06
2
yy
5.44150E+06
3
yy
3.96513E+06
4
yy
2.64978E+06
8
yy
8.68544E+06
23
yy
1.22666E+07
1
zz
1.01642E+07
2

zz
1.31170E+07
3
zz
1.60697E+07
4
zz
1.87406E+07
8
zz
3.21306E+07
23
zz
3.68000E+07
1
pressure
water
1.08211E+06
2
pressure
water
2.55849E+06

4
Summary of the results

This case test is a test of nonregression developed to validate the model of Laigle with coupling hydraulics.
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HT-66/04/005/A

Code_Aster ®
Version
7.3

Titrate:
WTNV101 - Triaxial compression test not drained with the model of Laigle
Date:
13/10/04
Author (S):
R. FERNANDES*, C. CHAVANT Key*

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Organization (S): EDF/IMA/MNN

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V7.31 booklet: Thermo-hydro-mechanics in porous environment of voluminal structures
V7.31.107 document

WTNV107 - Subjected saturated porous surface with a thermohydraulic shock

Summary:

One considers a surface problem (in 3D) of behavior of a saturated porous environment subjected to one
thermohydraulic loading.

One studies a transient state, for the problems of coupled thermohydraulic diffusion (however the part mechanics does not intervene, indeformable porous surface).

The model is 3D surface, with a linear thermohydraulic behavior for modeling 3D_JOINT_CT.

The test validates in particular the taking into account of the curve of surface (portion of cylinder).

---

1 *Problem of reference*

1.1 *Surface geometry: quarter of cylinder of axis Z, ray R = 6 m, of height H = 10 m*

Z
Co-ordinates of the points:

With
6 -6
5
R = 6 m
10 m
B
3,7
-5,5
5
C
1,76
-4,24
5
D
4,57
-2,3
5
y
X

1.2
Material properties

The values chosen for the characteristics of materials are not representative of the properties of usual continuous porous materials (clay), more than of the characteristics of rock "joint". orders of magnitude of the loadings are not realistic. The other thermal characteristics are presumedly null.

Hydraulic thermics Coupling
heat
modulate of Biot

voluminal
M
m

(MPa)
(K-1)
C

0
(

J.m3)
3.3 10-10 3.
109 4.
10-11

Density Entropy
Porosity
Conductivity Conductivity
hydraulic thermics
fluid
mass

T
H
(kg m3)
fluid Sm
0
(W.m1K1)
(m2. Pa1 s1)
J.kg1

103
10 0.5 3. 10-8 3.
10-8

Thermal characteristics
decrease 0
(s1)
0

1.3
Boundary conditions and loadings

· Left Bord: pressure of the fluid = 10 Pa temperature 10°K
· Other edges: heat flux and hydraulics null

1.4 Conditions
initial

The fields of displacement, pressure, temperature are initially all null.

2
Reference solution

2.1
Method of calculation used for the reference solution

In the absence of voluminal forces, the hydrothermal system of coupled equations is written (for one nonheating material) (being the surface Laplacian):

· *thermal equation of evolution*

C0 T

P
T T =
- 3
R

T

m
T
T

· *hydraulic equation of evolution*

1 P

T
H P =
- 3

M
m
T
T

By choosing the boundary conditions identical for the two problems, and of the coefficients such that the equations are identical one brings back to the solution of only one equation:

C

0
T
T
3
T
=
-
Tr
m T

P = T and

1
C
with
and
0
T = H
=

M
Tr

It is an equation of the diffusion type of the heat defined on a surface.
One chose a cylindrical surface, the problem depends only on the angle (unidimensional problem of diffusion).

One can seek solutions by separating the variables (space and time), which gives a solution in product the exponential ones of the time and cosine of the variable of space.
To check the initial conditions, one obtains a development in series (resolution semi-analytical problem).

2.2 Results of reference

Value of components of the temperature and the pressure for certain nodes and the moment of calculation T = 20s.

Not Urgent
component
Reference
To 20
TEMP
9.74
B 20
NEAR
9.76
C 20
TEMP
9.81
D 20
NEAR
9.89

Uncertainty on the solution: analytical solution
Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in porous environment of voluminal structures
HI-75/96/063/A

Code_Aster ®
Version
3

Titrate:
WTNV107 Surfaces porous saturated subjected to a thermohydraulic shock Date:
03/12/96
Author (S):
***J.M. PROIX**, J. WABINSKI Key*
:
V7.31.107-A Page:
4/6

3 Modeling
With

3.1
Characteristics of modeling

Elements: meshs QUAD8 and TRIA6 of modeling 3D_JOINT_CT

Z
y
X

Modeling 3D_JOINT_CT

Discretization in time: calculation with 20s in a step. Implicit scheme (= 1).

Boundary conditions:

DDL_IMPO
(GROUP_NO: l1
NEAR: 10 TEMP: 10
)
FLUX_THM_REP
(GROUP_MA: l2
FLUN: 0. FLUN_HYDRO: 0)

(GROUP_MA: high FLUN: 0. FLUN_HYDRO: 0)
(GROUP_MA: low
FLUN: 0. FLUN_HYDRO: 0)

3.2
Characteristics of the grid

4 meshs TRIA6, 2 meshs QUAD8
1 in height, 6 in length.
10 meshs SEG3

3.3 Functionalities
tested

Orders

Keys
AFFE_MODELE 3D_JOINT_CT

[U4.22.01]
DEFI_MATERIAU PORO_JOINT
[U4.23.01]
AFFE_CHAR_MECA DDL_IMPO
NEAR, TEMP
[U4.25.02]
FLUX_THM_REP
FLUN, FLUN_HYDRO
STAT_NON_LINE PARM_THETA
[U4.32.01]
Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in porous environment of voluminal structures
HI-75/96/063/A

Code_Aster ®
Version
3

Titrate:
WTNV107 Surfaces porous saturated subjected to a thermohydraulic shock Date:
03/12/96
Author (S):
***J.M. PROIX**, J. WABINSKI Key*
:

4 Results of modeling A

4.1 Values tested

***(node/not) Urgent
Component
Reference Aster %
difference***
*N18 A
20
TEMP
9.74 9.74804 < 0.082
N8 B
20
NEAR
9.76 9.76372 < 0.038
N7 C
20
TEMP
9.81 9.81803 < 0.008
N6 D
20
NEAR
9.89 9.8895 < -0.005*

4.2 Remarks

The calculated solution is close to the reference solution, the curve of surface is well taken in count.

4.3 Parameters of execution

Version: 3.06.13

Machine: CRAY C90

Obstruction memory:
8 MW
Time CPU To use:
3.7 seconds

5
Summary of the results

These results validate modeling 3D_JOINT_CT.

Date:
27/09/04
Author (S):
***G. DEBRUYNE**, J. EL GHARIB Key*
:
V7.31.122-A Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in porous environment of structures
voluminal
Document: V7.31.122

WTNV122 - Triaxial compression test not drained with the law CAM_CLAY

Summary:

This test makes it possible to validate the mechanical law elastoplastic Cam_Clay specific to the grounds normally
consolidated. This law integrates an elastoplastic hydrostatic mechanism (of which the elastic part is non-linear and the threshold of flow corresponds to the pressure of consolidation) coupled to a mechanism
deviatoric elastoplastic the elastic part is linear. The behavior is hardening or

softening according to the combination of the two mechanisms.
Three different modelings are carried out in 3D. In each modeling, the test is carried out in hydro-mechanical coupling and it include/understand two ways of loading:

Modeling A is characterized by:

·
a hydrostatic way of compression in condition drained until the pressure of consolidation,
·
a way not-drained by maintaining the pressures lateral confining on the sample and by imposing one vertical displacement of compression which induces a triaxial state of stresses, and a plastic mode contractor.

Modeling B is characterized by:

·
a hydrostatic way of compression in condition drained until the critical pressure, equalizes with half of the pressure of consolidation,
·
a way not-drained by maintaining the pressures lateral confining on the sample and by imposing one vertical displacement of compression which induces a triaxial state of stresses up to the critical point.

Modeling C is characterized by:

·
a hydrostatic way of compression in condition drained until a pressure lower than critical pressure,
·
a way not-drained by maintaining the pressures lateral confining on the sample and by imposing one vertical displacement of compression which induces a plastic state of stresses triaxial dilating.

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

height: H = 1m
width: L = 1 m
thickness: E = 1 m

1.2
Properties of material

E = 22.4E6 Pa
= 0.3
= 1.E - 5
Parameters specific to CAM_CLAY:

PORO = 0.14, = 0.25, = 0.05, M = 0.9, CLOSE _ CRIT =.
3 E5 Pa, Pa = 1.E5 Pa

1.3
Boundary conditions and loadings

The first way of loading is carried out with a state of hydrostatic stresses:
= = = P. One makes a first elastic design to P = Pa (to establish an initial state
xx
yy
zz
plastically acceptable). One increases then P to P, the pressure of water is maintained
sup
null
1
PRE = 0 (drained condition). For the second way, one maintains the pressure P on the faces
side and one imposes then a vertical displacement imposed in compression to model one
triaxial compression test, calculation is now not drained, which corresponds to a hydrostatic flow no one on
all faces.
For modeling a: P
= P
= .
6 E5Pa = 2P (final state contracting)
sup
ion
consolidat
Cr
For modeling b: P
= P (final state criticizes with null voluminal variation)
sup
Cr
For modeling C: P
= .
2 E5Pa < P (final state dilating)
sup
Cr

1.4 Conditions initial

The plastic condition of compatibility requires that in an initial state the hydrostatic constraint be strictly higher than zero. To initialize this constraint, one chose to carry out at the beginning a calculation purely elastic while making evolve/move pressure of 0. with 1.E5 Pa. One only extracts from this calculation the stress field at the points of gauss. This stress field resulting from the elastic design is regarded as the initial state of the hydrostatic constraint necessary to the law Cam_Clay of calculation according to.

2
Reference solution

An exact solution exists as much as the loading is hydrostatic (cf SSNV160). For the second triaxial way, an analytical solution is not obvious to find. In the same way, one does not have data and of triaxial experimental test results allowing to compare with calculations.
This test is a test of not-regression.

Code_Aster ®
Version
7.3

Titrate:
WTNV122 - Triaxial compression test not drained with law CAM_CLAY

Date:
27/09/04
Author (S):
***G. DEBRUYNE**, J. EL GHARIB Key*
:
V7.31.122-A Page:

4/10

3 Modeling
With

Modeling A is characterized by:

.
a hydrostatic way of compression in condition drained until the pressure of consolidation,
.
a way not-drained by maintaining the pressures lateral confining on the sample and while imposing a vertical displacement of compression which induces a triaxial state of stresses, and a mode contracting plastic.

3.1
Characteristics of modeling

Modeling 3D
Z
NO3
NO5
NO8
NO2
NO7
y
NO1
NO4
NO6
NO12
NO10
NO9
NO11
X
NO15
NO17
NO20
NO14
NO19
NO13
NO18
NO16

3.2
Characteristics of the grid

A number of nodes:
20
A number of meshs:
1 of type HEXA 20

6 of type QUAD 8

The following meshs are defined:

RIGHT-HAND SIDE
NO3 NO5 NO8 NO10 NO12 NO15 NO17 NO20
LEFT
NO1 NO4 NO6 NO9 NO11 NO13 NO16 NO18
IN FRONT OF
NO6 NO7 NO8 NO11 NO12 NO18 NO19 NO20
BEHIND
NO1 NO2 NO3 NO9 NO10 NO13 NO14 NO15
LOW
NO13 NO14 NO15 NO16 NO17 NO18 NO19 NO20
HIGH
NO1 NO2 NO3 NO4 NO5 NO6 NO7 NO8

To represent the 1/8ème structure, the boundary conditions in displacement imposed are:

On the LOW face: DZ = 0
On the LEFT face: DY = 0
On the face BEHIND: DX = 0

The loading is consisted of the same pressure divided into compression on the 3 meshs: `HIGH, "RIGHT" and "IN FRONT" to simulate a hydrostatic test, and of a null water pressure to simulate the condition of drainage (
1
PRE = 0). Then, the pressure distributed is maintained constant on
side faces "RIGHT-HAND SIDE" and "IN FRONT OF", a displacement DZ is imposed on the variable face "HIGH"
with time, and one changes the hydraulic loading (null flow) to simulate the condition not drained.

3.3 Functionalities tested

Orders

DEFI_MATERIAU CAM_CLAY

STAT_NON_LINE COMP_INCR
RELATION= `KIT_HM'

`RELATION_KIT'=

"CAM_CLAY"

"LIQU_SATU"

"HYDR_UTIL"
NEWTON
STAMP = "TANGENT"

3.4 Sizes tested and results

The components, and of the constraint are tested at moments 3. , 6. , 15. and 20. and

xx
yy
zz
value of the pressure of water PRE1 at moment 20 with node NO8. The values of reference are values of not-regression.

Values of and:
xx
yy

Moment
Reference
Aster
1st loading
3. -3.000000+05
-3.000000+05
1st loading
6. -6.000000+05
-6.000000+05
2nd loading
15. -2.590356+05
-2.590355371917+05
2nd loading
20. -2.495777+05
-2.495776491115+05

Values of:
zz

Moment
Reference
Aster
1st loading
3. -3.000000+05
-3.000000+05
1st loading
6. -6.000000+05
-6.000000+05
2nd loading
15. -5.650431+05
-5.650429335188+05
2nd loading
20. -5.578873+05
-5.578813428168+05

Values of PRE1:

Moment
Reference
Aster
2emechargement
20. 3.50422+05
3.50422350888+05

---

4 Modeling B

Modeling B is characterized by:

- *a hydrostatic way of compression in condition drained until the critical pressure, equalize with half of the pressure of consolidation,*
- *a way not-drained by maintaining the pressures lateral confining on the sample and while imposing a vertical displacement of compression which induces a triaxial state of stresses until not criticizes.*

4.1 Characteristics of modeling

Idem modeling A

4.2
Characteristics of the grid

Idem modeling A

4.3 Functionalities
tested

Idem modeling A

4.4
Sizes tested and results

The components, and of the constraint are tested at moments 3. , 6. , 15. and 20. and
xx
yy
zz
value of the pressure of water PRE1 at moment 20 with node NO8. The values of reference are values of not-regression.

Values of and:
xx
yy

Moment
Reference
Aster
1st loading
3. -2.000000+05
-2.000000+05
1st loading
6. -3.000000+05
-3.000000+05
2nd loading
15.
-2.100000+05
-2.099999 +05
2nd loading
20.
-2.100000+05
-2.100000+05

Values of:
zz

Moment
Reference
Aster
1st loading
3. -2.000000+05
-2.000000+05
1st loading
6. -3.000000+05
-3.000000+05
2nd loading
15. -4.800000+05
-4.799999+05
2nd loading
20. -4.800000+05
-4.800000
+05

Values of PRE1:

Moment
Reference
Aster
2emechargement
20. 9.00000+E4
9.00000+E4

---

5 Modeling C

Modeling C is characterized by:

- *a hydrostatic way of compression in condition drained until a pressure lower than critical pressure,*
- *a way not-drained by maintaining the pressures lateral confining on the sample and while imposing a vertical displacement of compression which induces a triaxial state of stresses dilating plastic.*

5.1 Characteristics of modeling

Idem modeling A

5.2 Characteristics of the grid

Idem modeling A

5.3 Functionalities tested

Idem modeling A

5.4 Sizes tested and results

The components, and of the constraint are tested at moments 3. , 6. , 15. and 20. and
xx
yy
zz
value of the pressure of water PRE1 at moment 20 with node NO8. The values of reference are values of not-regression.

Values of and:
xx

yy

Moment
Reference
Aster
1st loading
3. -2.000000+05
-2.000000+05
1st loading
6. -2.200000+05
-2.200000+05
2nd loading
15.
-1.560470+05
-1.560470100963+05
2nd loading
20.
-1.815567+05
-1.815567285399+05

Values of:
zz

Moment
Reference
Aster
1st loading
3. -2.000000+05
-2.000000+05
1st loading
6. -2.200000+05
-2.200000+05
2nd loading
15. -4.156324+05
-4.156324653437+05
2nd loading
20. -4.382215+05
-4.382215080457+05

Values of PRE1:

Moment
Reference
Aster

2emechargement
20. 3.844327+E4
3.844327146008+E4

6
Summary of the results

tr ()
By interpreting the diagram, (P, Q), P = -
and Q = - (-) for three modelings of
3
3
1
this case test, one notes well that in modeling A [Figure 6-a], the loading remains hydrostatic up to a value of 6.E5Pa. Once vertical displacement is imposed and vary with time, the pressures on the side faces being maintained constant, a diverter constraints is induced and increases with time with a positive work hardening. When one bring closer the point Q = MP, one tends towards perfect plasticity with plastic flow without work hardening and without variation of constraints (see [§6] Doc. [R7.01.14]).

MP
Q =

Appear 6-a: Q according to P (modeling A)

In modeling B [Figure 6-b], after a hydrostatic loading which reaches the critical pressure with 3.E5Pa, the second loading is only deviatoric with a hydrostatic pressure maintained with 3.E5Pa. When one reaches the point criticizes, one touches the critical slope, where plasticity is perfect with plastic flow without work hardening and variation of constraints.

Appear 6-b: Q according to P (modeling B)

In modeling C [Figure 6-c], vertical displacement is imposed before the loading hydrostatic reached the critical pressure. The diverter of the constraints varies with time, during that the pressures on the side faces are maintained constant. Like the criterion of plasticity is reached in the field of dilatancy, work hardening is negative and the diverter of the constraints decrease with time.

Appear 6-c: Q according to P (modeling C)

Intentionally white left page.

Titrate:
WTNV123 - Triaxial compression test with fixed suction: model of BARCELONA
Date:

26/10/04
Author (S):
***G. DEBRUYNE**, J. EL GHARIB Key*
:
V7.31.123-A Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in saturated porous environment
Document: V7.31.123

WTNV123 - Triaxial compression test with suction fixed with model of Barcelona

Summary:

This test makes it possible to validate the model of Barcelona, which integrates an elastoplastic mechanical law coupled to hydraulics (and possibly with thermics) in condition of nonsaturation of the liquid phase. This law integrate an elastoplastic hydrostatic mechanism (of which the elastic part is non-linear and the threshold of flow corresponds to a pressure of variable consolidation with suction) coupled to a mechanism deviatoric elastoplastic. The characteristics of these mechanisms depend on suction (i.e. difference between gas pressure and pressure of liquid). There are in particular two mechanisms

of work hardening in completely coupled pressure and suction. the surface of load of the model of Barcelona
present (in the diagram pressure hydrostatic-diverter and for a given suction) in the form
of an ellipse cutting the hydrostatic axis in two points: the value of the pressure of consolidation and cohesion of material proportional to suction. In condition of complete saturation, this criterion is reduced to
that of the Cam_Clay model specific to the saturated normally consolidated grounds.
This test carried out in hydro-mechanical coupling (modeling HHM) is declined in three modelings:

Modeling A includes/understands two ways of mechanical loading, suction being fixed at a value correspondent with a degree of saturation of 90%:

1) a hydrostatic way of compression
2) a way maintaining the pressures lateral confining on the sample and imposing a vertical pressure additional which induces a triaxial state of stresses, until reaching the surface of load and
to generate plastic deformations in the contracting field.

Modeling B takes again modeling A but with a criterion of convergence of balance on each generalized constraint.

Modeling C continues modeling B by a deviatoric discharge then hydrostatic conclusive by
a deviatoric refill plasticizing in the dilating field.

All these modelings are carried out in 3D on an element hexaedric.
Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in saturated porous environment
HT-66/04/005/A

1
Problem of reference

1.1 Geometry

Z
E
H
y
X
L

height: H = 1m
width: L = 1 m
thickness: E = 1 m

1.2
Properties of material

Thermoelastic properties:

7
E =
4
.
22 10 Pa
= 0.3

Parameters specific to the model of CAM_CLAY:

.

Initial porosity PORO = 0.14

.

Modulate plastic compressibility with of saturated = 0.25,

.

Modulate elastic compressibility = 0.05,

.

Slope of the right-hand side criticizes M = 0.9,

.

Critical pressure equalizes with half of the pressure of consolidation to saturation
CLOSE _ CRIT
7
= .
3 10 Pa,

.

Pressure of reference
5
Pa = 10 Pa

Parameters specific to BARCELONA:

.

Parameters allowing to calculate the module of compressibility according to suction
(p) = (
C
[)
0 1
(- R) exp (- p) + R,
C
]
-6
R =
,
75
.
0
=
5
.
12 10
.

Slope of cohesion K =
6
.

0
C

.
Initial threshold of suction PC0_INIT
7
p ()
0 = 882
.
4
10
c0

.
Modulate elastic compressibility of suction =
01
.
0
S

.
Modulate plastic compressibility of suction =
05
.
0
S

Hydraulic properties: the hydraulic properties of material which are independent of the model from Barcelona but nevertheless necessary to carry out coupled calculation are presented in table below:

Liquid water
Density (kg.m-3)
1.103
Heat with constant pressure (J.K-1)
4180
thermal dilation coefficient of the liquid (K-1)
10-4
Skeleton
Heat-storage capacity with constant constraint
800
Initial State
Porosity
0,14
Temperature
293°K
Capillary pressure
1.51 107

Gas pressure
105

Initial saturation in liquid
0,9
Constants
Constant of perfect gases
8,315
Coefficients
Homogenized density
2400
homogenized capillary Curve
S (
9
-
C
P) = 0 99

. (1- .
6 10
PC)
Coefficient of Biot
1

1.3
Boundary conditions and loadings

For all modelings, one starts with a hydrostatic way of loading, with one
PRE constant capillary pressure
7
1 = 51
.
1
10 Pa starting from a hydrostatic initial state until one
total hydrostatic pressure of
7
= 4 10 Pa. The gas pressure is maintained constant
T
PRE
5
2 = 10 Pa. Then, one maintains the pressure P on the side faces and one increases
vertical pressure until
7
= 7 10 Pa in compression in order to obtain a state of stress
T11
biaxial of revolution. The capillary pressure and the gas pressure are maintained constant. One
the plastic threshold in the contracting field crosses then.
For modeling C, one continues the loading by carrying out a discharge of the constraint
deviatoric (of
7
7 10 Pa with
7
4 10 Pa), then a hydrostatic discharge (of
7
4 10 Pa with
7
75
.
1
10 Pa) and finally a deviatoric refill in order to plasticize in the dilating field.

1.4 Conditions

initial

The initial constraint (forced effective of Bishop) is selected in such way that the constraint used in the behavior (
D
= T + pgz1) does not violate the criterion. Initial capillary pressure, correspondent with a degree of saturation of 0.9, is equal to 15.1 MPa.

2
Reference solution

An exact solution for displacement exists as much as the loading is hydrostatic. For second way the analytical solution is not available.

---

3 Modeling With

3.1 Characteristics of modeling

Modeling 3D
Z
NO3
NO5
NO8
NO2
NO7
y
NO1
NO4
NO6
NO12
NO10
NO9
NO11
X
NO15
NO17
NO20
NO14
NO19
NO13
NO18
NO16

3.2 Characteristics of the grid

A number of nodes:
20
A number of meshs:

1 of type HEXA 20

6 of type QUAD 8

The following meshs are defined:

RIGHT-HAND SIDE
NO3 NO5 NO8 NO10 NO12 NO15 NO17 NO20
LEFT
NO1 NO4 NO6 NO9 NO11 NO13 NO16 NO18
IN FRONT OF
NO6 NO7 NO8 NO11 NO12 NO18 NO19 NO20
BEHIND
NO1 NO2 NO3 NO9 NO10 NO13 NO14 NO15
LOW
NO13 NO14 NO15 NO16 NO17 NO18 NO19 NO20
HIGH
NO1 NO2 NO3 NO4 NO5 NO6 NO7 NO8

To represent the 1/8ème structure, the boundary conditions imposed in displacement are:

On the LOW face: DZ = 0
On the LEFT face: DY = 0
On the face BEHIND: DX = 0

The loading is consisted of the same pressure divided into compression on the 3 meshs: `HIGH, "RIGHT" and "IN FRONT" to simulate a hydrostatic test. Then, the pressure distributed is maintained constant on the side faces "RIGHT-HAND SIDE" and "IN FRONT OF", the vertical pressure increases on
the face "HIGH".

3.3 Functionalities tested

Orders

DEFI_MATERIAU BARCELONA

STAT_NON_LINE COMP_INCR
RELATION= `KIT_HHM'

`RELATION_KIT'=

"BARCELONA"

"LIQU_SATU"

"HYDR_UTIL"
NEWTON
STAMP = TANGENT

3.4
Sizes tested and results

It is about a homogeneous test, the place of observation of the fields is indifferent. It will be tested uz displacement with node 8 at moment 6 (end of the hydrostatic way) like at moment 20 (end of the test) as well as the variables intern of indicator of plasticity and critical pressure to the same node.

Values of uz:

Moment
Reference Aster
Difference (%)
1st loading
6. -7.031-02 -7.03158-02 5.25
10-5
2nd loading

20. X 2.06016-01

Plastic indicator (mechanical threshold, hydrous threshold):

Moment
Reference Aster Difference
(%)
1st loading
6. 0
0
0
2nd loading
20. 1
1
0

Pressure criticizes in condition of saturation:

Moment
Reference Aster Difference
(%)
1st loading
6. 3.+07
3+07
-7.45
10-14
2nd loading
20. X
3.4371+07

Value of the hydrous threshold:

Moment
Reference Aster Difference
(%)
1st loading
6. 4.882+07
4.882+07 -4.58
10-14
2nd loading
20. X
7.79806+07

4 Modeling
B

It acts exactly of the same modeling as previously but with a test of convergence on each generalized constraint. The results are appreciably the same ones.

---

5 Modeling
C

5.1
Characteristics of modeling

It always acts of the same modeling but with a prolongation of the loading until plasticization in the dilating field.

5.2 Functionalities
tested

Orders

DEFI_MATERIAU BARCELONA

STAT_NON_LINE COMP_INCR
RELATION= `KIT_HHM'

`RELATION_KIT'=

“BARCELONA”

“LIQU_SATU”

“HYDR_UTIL”
NEWTON
STAMP = TANGENT

5.3
Sizes tested and results

One tests uz displacement with node 8 at moment 34 (deviatoric discharge), at moment 46 (hydrostatic discharge) and finally at moment 60 as well as the variables intern of indicator of plasticity and critical pressure and hydrous threshold with the same node and the same moments.

Values of uz:

Moment
Reference Aster
Difference (%)
1st loading
6. -7.031-02 -7.03158-02
3.41
10-5
2nd loading
20. X 2.06016-01

3rd loading
34. X 8.67365-02

4th loading
46 X 7.48391-02

5th loading
60 X 3.73485-01

Plastic indicator (mechanical threshold):

Moment
Reference Aster
Difference (%)
1st loading
6. 0
0
0
2nd loading
20. 1
1
0
3rd loading
34. 0
0
0
4th loading
46 0
0
0
5th loading
60 1
1
0

Pressure criticizes in condition of saturation:

Moment
Reference Aster
Difference (%)
1st loading
6. 3.+07 3.+07
-7.45
10-14
2nd loading
20. X
3.4371+07

3rd loading
34. X
3.4371+07

4th loading
46 X 3.4371+07

5th loading
60 X 3.34488+07

Value of the hydrous threshold:

Moment
Reference Aster
Difference (%)
1st loading
6. 4.882+07 4.882+07
-4.58
10-4
2nd loading
20. X
7.79804+07
3rd loading
34. X
7.79804+07
4th loading
46 X
7.79804+07
5th loading
60 X
7.1012+07

6
Summary of the results

The only results of reference relate to the first hydrostatic loading, in this case them displacements and the thresholds in pressure and suction are calculated with a precision higher than 1%.

WTNV124 - Test of désaturation-consolidation
with the model of Barcelona

Summary:

This test makes it possible to validate the model of Barcelona, which integrates an elastoplastic mechanical law coupled to
hydraulics (and possibly with thermics) in condition of nonsaturation of the liquid phase. This law integrate an elastoplastic hydrostatic mechanism (of which the elastic part is non-linear and the threshold
of flow corresponds to a pressure of variable consolidation with suction) coupled to a mechanism deviatoric elastoplastic. The characteristics of these mechanisms depend on suction (i.e.
difference between gas pressure and pressure of liquid). There are in particular two mechanisms of work hardening in completely coupled pressure and suction. The surface of load of the model of Barcelona
present (in the diagram pressure hydrostatic-diverter and for a given suction) in the form
of an ellipse cutting the hydrostatic axis in two points: the value of the pressure of consolidation and cohesion of material proportional to suction. In condition of complete saturation, this criterion is reduced to
that of the Cam_Clay model specific to the saturated normally consolidated grounds.
This test carried out in hydro-mechanical coupling (modeling HHM) includes/understands two ways of
loading:

1) a way of desaturation while making increase the capillary pressure beyond the threshold of plasticity
hydrous.
2) a hydrostatic way of compression on the désaturé sample.

Modeling is carried out in 3D.
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Version
7.3

1
Problem of reference

1.1 Geometry
Z
E
H
y
X
L

height: H = 1m
width: L = 1 m
thickness: E = 1 m

1.2
Properties of material

Thermoelastic properties:

E = 22.4E7 Pa
= 0.3
3
= 2500 kg/m

Parameters specific to the model of CAM_CLAY:

.
Initial porosity PORO = 0.14
.
Modulate plastic compressibility with of saturated = 0.25,
.
Modulate elastic compressibility = 0.05,
.

Slope of the right-hand side criticizes M = 0.9,

.

Critical pressure equalizes with half of the pressure of consolidation to saturation
CLOSE _ CRIT = E

.

3 7Pa,

.

Pressure of reference Pa = 1.E5 Pa

Additional parameters specific to BARCELONA:

.

Parameters allowing to calculate the module of compressibility according to suction
(p) = (
C
[)
0 1
(- R) exp (- p
) + R,
C
]
R =
,
75
.
0
=
5
.
12th - 6
.
Slope of cohesion K =
6
.
0
C

.
Initial threshold of suction PC0_INIT p
( )
0 = 6 7
c0
E
.

Modulate elastic compressibility of suction =
01
.
0
S

.
Modulate plastic compressibility of suction =
05
.
0
S

Hydraulic properties: the hydraulic properties of material which are independent of the model from Barcelona but nevertheless necessary to carry out coupled calculation are presented in table below:

Liquid water
Density (kg.m-3)
1.103
Heat with constant pressure (J.K-1)
4180
Opposite of the coefficient of compressibility (Pa-1)
0.510-9
Intrinsic permeability (m2)

1.10-18
viscosity
1.10-3
Initial State
Porosity
0,14
Temperature
293°K
Capillary pressure
1.51 107
Gas pressure
1.51 105
Initial saturation in liquid
0,99
Constants
Constant of perfect gases
8,315
Coefficients
Homogenized density
2400
homogenized
Capillary curve
S (
9
-
C
P) = 0 99
. (1 - 6 10 PC)
Coefficient of Biot
1

1.3
Boundary conditions and loadings

The first way of loading consists in carrying out a desaturation, with a pressure hydrostatic constant P = E
.
1 7 Pa (the gas pressure is maintained constant with PRE2 = E
.
1 5 Pa during all the test). The capillary pressure varies from zero until PRE1 = E

.
7 7 Pa, beyond the threshold of plasticization equal initially to PRE1 = E
.
6 7 Pa.
Work hardening due to the increase in suction causes an increase in the threshold of consolidation, since two work hardenings hydrous and mechanical are coupled in the model of Barcelona. One checks while following the second way consisting in exerting a hydrostatic pressure exceeding it initial threshold (P
= E
.
6
Pa
idiot
7
) without causing plasticization.

1.4 Conditions
initial

The initial constraint (forced effective of Bishop) is selected in such way that the constraint used in the behavior (
D
= T + pgz1) is inside the surface of load.

2
Reference solution

In the absence of loading deviatoric, an exact solution is available for the deformations and thresholds of work hardening at all the stages of the loading:

P
Reversible voluminal deformation in mechanical loading =
Ln
v

1+ e0
0
P

S
PC + p
Reversible voluminal deformation in hydrous loading
atm
v =
Ln

1+ E
p
0
atm

Total voluminal deformation in hydrous loading, after crossing of the threshold
:
+
S

PC + patm
=
Ln
if p > p
v
-
C
0
1
(
C
+ e0)
PC + patm

Total voluminal deformation in mechanical loading, after crossing of the threshold of
(p) dP
consolidation: D
C
v =

1+ E
P
0
dp 0
- dP
Coupling of the thresholds:
C
Cr
=

PC + p
0
atm
S - S Cr
P
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Titrate:

3 Modeling
With

3.1
Characteristics of modeling

Modeling 3D
Z
NO3
NO5
NO8
NO2
NO7
y
NO1
NO4
NO6
NO12
NO10
NO9
NO11
X
NO15
NO17
NO20
NO14
NO19
NO13
NO18
NO16

3.2
Characteristics of the grid

A number of nodes:
20
A number of meshs:
1 of type HEXA 20

6 of type QUAD 8

The following meshs are defined:

RIGHT-HAND SIDE
NO3 NO5 NO8 NO10 NO12 NO15 NO17 NO20
LEFT
NO1 NO4 NO6 NO9 NO11 NO13 NO16 NO18
IN FRONT OF
NO6 NO7 NO8 NO11 NO12 NO18 NO19 NO20
BEHIND
NO1 NO2 NO3 NO9 NO10 NO13 NO14 NO15
LOW
NO13 NO14 NO15 NO16 NO17 NO18 NO19 NO20
HIGH
NO1 NO2 NO3 NO4 NO5 NO6 NO7 NO8

To represent the 1/8ème structure, the boundary conditions in displacement imposed are:

On the LOW face: DZ = 0
On the LEFT face: DY = 0
On the face BEHIND: DX = 0

The loading is consisted of the same pressure divided into compression on the 3 meshs: `HIGH, "RIGHT" and "IN FRONT" to simulate a hydrostatic test. All the nodes are compelled with one constant pressure of gas and with a suction varying of 0 with 7.107Pa
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Titrate:
WTNV124 Test of désaturation-consolidation: model of BARCELONA Dates:
27/09/04
Author (S):

3.3 Functionalities tested

Orders

DEFI_MATERIAU BARCELONA

STAT_NON_LINE COMP_INCR
RELATION= `KIT_HHM'

`RELATION_KIT'=

"BARCELONA"

"LIQU_SATU"

"HYDR_UTIL"
NEWTON
STAMP = "TANGENT"

3.4 Sizes tested and results

It is about a homogeneous test, the place of observation of the fields is indifferent. It will be tested uz displacement with node 8 at moment 1 (end of the hydrostatic way), at moment 6.0 (crossing of hydrous threshold) as well as the variables intern of indicator of plasticity and pressure criticizes with same node. One tests then same the fields at moment 10 (loading purely hydrostatic in crossing the old threshold thus without plasticization) and finally at the moment 20 where the new one is crossed mechanical threshold (plasticization).

C
p
6
10
20

1
C
p
C
p 0
C
L 0
C
L
1
C
L
2
1
P

Values of uz:

Moment
Reference
Aster
1st loading
1. -5.607E-02
-5.593E-02
2nd loading
6.0 -7.565E-02
-7.647E-02
3rd loading
10.0 -1.3097E-01
-1.3097E-01
4th loading
20. -2.11952E-01
-2.11951E-01

Plastic indicator (mechanical threshold):

Moment
Reference
Aster
1st loading
1. 0
0
2nd loading
6.0 0
0

3rd loading
10.0 0
0
4th loading
20. 1
1

Hydrous indicator of irreversibility:

Moment
Reference
Aster
1st loading
1. 0
0
2nd loading
6.0 1
1
3rd loading
10.0 0
0
4th loading
20. 0
0

Value of the hydrous threshold:

Moment
Reference
Aster
1st loading
1. 6E+07
6E+07
2nd loading
6.0 7E+07
7E+07
3rd loading
10.0 7E+07
7E+07
4th loading
20. 1.108E+10
1.108E+10

Value of the mechanical threshold:

Moment
Reference
Aster
1st loading
1. 3E+07
3E+07
2nd loading
6.0 5.6661E+08
5.7459E+08
3rd loading
10.0 5.74596E+08
5.74596E+08
4th loading
20. 25.0631E+08
25.0630E+08

4
Summary of the results

One obtains results on displacements which present a variation compared to the solution analytical of about 0.2% in the reversible field and of 1% in the plastic range.
even report can be made on the values of the thresholds of consolidation.

Organization (S): EDF-R & D /AMA

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Document: V7.31.127

WTNV127 Désaturation of a porous environment without air (modeling 3D_THV)

Summary:

One heats a porous environment whose pores are filled with a mixture of water and steam. Saturation initial in liquid is 50%, the loading is a uniform heat flux on the edges of the field.
modeling made by only one cubic element corresponds to the modeling of a homogeneous problem in space.

The reference solution is an approximate analytical solution.

1

Problem of reference

1.1 Geometry

H
G

D
C

E
F

WITH B

Co-ordinates of the points (m):

With
0
0
100
E
0
0
0
B 100
0.100 F 100
0 0
C 100.100.100 G 100.100 0
D
0.100.100 H
0 100 0

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (thermal conductivity, moduli of elasticity…) who finally

do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
103
Heat with constant pressure (J.K-1)
4180
thermal dilation coefficient of the liquid (K-1) 0.
Vapor
Heat-storage capacity (J.K-1)
1900
Initial enthalpy (latent heat of vaporization) 2,5E6.
Mass molar (kg.mol-1)
0,018
Skeleton
Heat-storage capacity with constant constraint (J.K-1) 1050
Initial State
Porosity
0,3
Temperature (K)
300
Pressure of liquid (Pa)
1E5
Steam pressure (Pa)
3700
Initial saturation in liquid
0,5
Constants
Constant of perfect gases
8,315
Coefficients
Homogenized density (kg.m-3)
2200
homogenized Isothermal of sorption
S (
=
- -
-
-
C
P)
12
0 5

.
10
(
0
0
C
P
vp
P
C
P)
With 0 = 3700
vp
P

0
5
= 10
-
C
P

1.3
Boundary conditions and loadings

On all the faces:

Heat flux
6
Q .n = 10
ext.

Hydraulic flow no one

2
Reference solution

2.1
Method of calculation

2.1.1 Calculation of the steam pressure starting from the temperature

We suppose the linear curve of saturation. It is thus written:

S = S + S
0
CP
éq
2.1.1-1

[R7.01.11] equation [éq 3.2.1-2] give then:

m

=
-0 0 0
lq
lq S
C
P
lq
Slq

éq
2.1.1-2
m

= - 0 0 1-

-
0
0 0
vp
(vp vp) (S) S vp
C
P

It is written that the total water mass is preserved (because there is no water flow at the edge) and one obtains:

m + m = 0

lq
vp
(
éq
2.1.1-3
-
lq
vp) S
P +
C
(
0
-
vp
vp) (1 - S0) = 0

[R7.01.11] equation [éq 4.4-1] gives in addition

p
ol
vp M
=
vp
1
ln
P +
0
p
RT
lq
vp

lq
éq
2.1.1-4
M ol
vp (
ol
0
M
0
H - 0
H
vp
lq) 1
1
vp
p
p
T
T

- +
(C - C
vp
lq)

0

ln
+
-
0

1
R
T
T
R
T T

Coupling of the equations [éq 2.1.1-3] and [éq 2.1.1-4], for which it is necessary to add the equation

of perfect gases
for the vapor, is a strongly nonlinear system which we will solve in small disturbance, it
who allows to linearize it.

All made calculations, one obtains:

ol
ol

1 S M
M
Pvp (- 0
lq
vp)
(- 0)

vp
S +
- (- 0
lq
vp)

S
vp
T

P
1 S p
0

=
lq
(
0) 0

-

vp
2

RT

R
0
T

éq 2.1.1-5
P
M ol
M ol
vp -
vp
P =
vp
lq
(0h - 0h
vp
lq) T

0
0
2

p
RT
R
0

vp
lq
T

2.1.2 Calculation of the temperature

[R7.01.11] equation [éq 3.2.4.3 - 1] gives:
Q
m
= - T p

+ C0
3
T

gz
vp

éq
2.1.2-1
(since the other dilation coefficients are null).
Equation [éq 3.2.4.3 - 2] gives:
1-
m
(Slq)
=
gz

éq
2.1.2-2
T
3
One thus obtains:
Q
= - (
- S
+ 0
1

lq) p
C T
vp

éq
2.1.2-3

In this problem, Q
is anything else only the heat brought per unit of volume.
By calling Flight the total volume of the part and Surfing its side surface and T
the time of application
flows:
Surfing
Q
= T

Q
N
.
ext.
éq
2.1.2-4
Flight

2.1.3 System to be solved

1-
ol
S M
ol
M
(- 0
lq
vp)
(
0)
vp
S +
- (- 0
lq
vp)

vp
S
S p

0
- (1 - 0) 0

vp
2
0
RT
RT

P
0
ol
ol
0
0
vp

1
M vp
M vp (H -
vp
lq
H)

-
-
lq
P =
0

0
0
2

p
RT
R
0

vp
lq
T

Surfing

T
T
Q
N
.

0
- (
1 - S
C
Flight
lq)

0

ext.

éq 2.1.2-5

2.2
Results of reference

One gives the value of the temperature, the pressure of liquid and the steam pressure, solution system (10) with the data summarized in the paragraph [§1.2] and pointed out Ci below. For calculation of the heat-storage capacities, one uses the following relations:

(0
1-)
0
0 0
=
-
- -

S
0
R

lq Sl
(0
1 Sl) 0 0vp
C 0 =

(1-)
S
p

+

+ 1-

Sc
lq Sl C
S
C
lq
(
L)
p
vp
vp
0
0
C = C, this last relation being true because the dilation coefficient of the grains is null.

S

0
S
0
T
0
p

vp
0
vp
H
0
vp (calculated)
lq
5,00E-01 -1,00E-12 3,00E+02
3,70E+03
2,50E+06
2,67E-02 1,00E+03

0
R
0

S (calculated)
S
C
p
C
C
C
lq L
p
vp
0
(calculated)
2,20E+03 3,00E-01 2,93E+03
1,05E+03
4,18E+03
1,90E+03 2,78E+06

Q
N
.
ext.

T

Surfing
Flight

1,00E+06 100
6,00E+04
1,00E+06

After resolution, one obtains the following results:

vp
P

425
lq
P L
-1,4E+06

T

2E+00

2.3 Uncertainties

Uncertainties are rather large because the analytical solution is an approximate solution of fact of the linearization of the equations.

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3 Modeling With

3.1 Characteristics of modeling A

Modeling in plane deformations. A Q8 element.

3.2 Functionalities tested

Order Option

AFFE_MODELE
3D_THVD

DEFI_MATERIAU
THM_LIQU

THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

TEMP
STAT_NON_LINE COMP_INCR
RELATION KIT_THV

RELATION_KIT
LIQU_VAPE

HYDR_UTIL

Discretization in time: only one step of time: 102 S.

3.3 Values
tested

Node
Type of value
Moment (S)
Reference
***Aster** Difference*
(%)
(analytical)
NO1
DEPL/TEMP
102 2 2,15 8%

NO1
DEPL/PRE1
102 -1,4
106 -1,46
106 4%

NO1
VARI_ELNO_ELGA/V3
102 425 460
8%

One thus finds results relatively close to the analytical results. Uncertainty remaining enough broad because of linearization equations.

Titrate:
WTNV127 Désaturation of a porous environment without air (3D)

Date:
04/05/06
Author (S):
Key ***S. GRANET***
:
V7.31.127-B Page:
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4 Modeling B

Even modeling but into selective.

4.1 Characteristics of modeling B

Modeling in plane deformations. A Q8 element

4.2 Functionalities tested

Order
Option

AFFE_MODELE
3D_THVS

DEFI_MATERIAU
THM_LIQU

THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

TEMP
STAT_NON_LINE COMP_INCR
RELATION KIT_THV

RELATION_KIT

LIQU_VAPE

HYDR_UTIL

Discretization in time: only one step of time: 102 S.

4.3 Values tested

Node
Type of value
Moment (S)
Reference
Aster *Difference*
(analytical)
(%)
NO1
DEPL/TEMP
102 2
2,15 8%

NO1
DEPL/PRE1
102 -1,4
106 -1,46
106 4%

NO1
VARI_ELNO_ELGA/V3
102 425
460
8%

One thus finds results relatively close to the analytical results. Uncertainty remaining enough broad because of linearization equations.

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04/05/06
Author (S):
***C. CHAVANT**, V. GERVAIS Key*
:
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Organization (S): EDF-R & D /AMA, CS-SI

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Document: V7.31.128

WTNV128 - Triaxial compression test not drained with the model of Hoek-Brown modified in effective constraints

Summary

This test makes it possible to validate the law of elastoplastic behavior of Hoek-Brown modified in constraints effective, that is to say HOEK_BROWN_EFF with hydraulic coupling. It is about a triaxial compression test in condition not drained. The aspect not drained is modelled by a null voluminal deformation of the skeleton and the coupling hydraulics is taken into account. The sample is completely saturated, the skeleton and the fluid being supposed

incompressible.
For reasons of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test.
The level of containment applied is 5 MPa.
It is about a test of nonregression.

Modeling A is a modeling of the 3D_HM type with integration at the points of Gauss.
Modeling B is a modeling of the 3D_HMS type with integration at the points of Gauss or the nodes (see Doc. [R7.01.10]).

Contents

1
Problem of reference

1.1 Geometry

One considers here a cube of dimension 1m × 1m × 1m.

Z

1 m

· D

· C

1 m

With
B

.
.

y

X
1 m

Co-ordinates of the points (in m):

WITH B C D
X 0 0.0.5 1
y 0 1.0.5 1
Z 0 0.0.5 1

1.2
Properties of material

Parameters of the elastic law of behavior:
E = 4500 MPa
= 0.3

Parameters of the law of Hoek-Brown modified:
rup
= 0.005
LMBO
= 0.017
2 end
(S) = 225 MPa2
C
2 rup
(S) = 482.5675 MPa2
C
end
(m) = 13.5 MPa
C
rup

(m) = 83.75 MPa
C
= 3 MPa
rup
= 15°
LMBO
= 30°
= 3.3

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Titrate:
WTNV128 - Triaxial compression test not drained with the model of Hoek-Brown
Date:
04/05/06
Author (S):
C. CHAVANT, V. GERVAIS Key
:
V7.31.128-A Page:
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1.3 Conditions
initial,
with the limits and loading

The test breaks up into two phases:

1) Initially, one brings the sample in a homogeneous state 0
0
0
= =. For
xx
yy
zz
that, the corresponding confining pressure is imposed on the front faces (X = 1),
side right-hand side (y = 1) and higher (Z = 1), the water pressures are taken null everywhere and displacements are taken null on the faces postpones (U

= 0), side left
X x=0
(U
= 0) and the lower (U
= 0).
y y=0
Z z=0
2) Once the homogeneous state obtained, displacements are maintained blocked on the faces back, side left and lower. Hydraulic flows are null on all the faces. One displacement is forced on the higher face (U (T)) in order to obtain a deformation
Z
equalize to 25% starting from the beginning of the second phase, by increments of deformation
zz
constant
= 2
- .5E - 4. On the front faces and side right-hand side, one imposes conditions
zz
with the limits in total constraint: N
0
= = 5
- MPa.

---

2 Modeling
With

2.1
Characteristics of modeling

Modeling 3D
Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = - MPa

5
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0
Coefficient of Biot: 1
UN_SUR_K of water: 0 (coefficient of incompressibility of water)
Modeling: 3D_HM

2.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

2.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR RELATION

"KIT_THM"
"RELATION_KIT" =
"HOEK_BROWN_EFF", "LIQU_SATU", "HYDR_UTIL"

3
Results of modeling A

3.1 Values
tested

Localization Number
of order Forced
(MPa) Code_Aster
Not D
16

xx
-0.239568
28

xx
-0.257851
36

xx
-1.10550

44

xx
-4.29762
52

xx
-7.28266
80

xx
-15.7587
16

yy
-0.239568
28

yy
-0.257851
36

yy
-1.10550
44

yy
-4.29762
52

yy
-7.28266
80

yy
-15.7587
16

zz
-16.0195
28

zz
-20.4913
36

zz
-24.7968
44

zz
-28.9045
52

zz
-33.7174
80

zz
-54.1101
16
Pressure
water
5.23957
44
Pressure
water
0.702380
80
Pressure
water
-10.7587

7/8

4 Modeling
B

4.1
Characteristics of modeling

Modeling 3D
Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = - MPa

5
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0
Coefficient of Biot: 1
UN_SUR_K of water: 0 (coefficient of incompressibility of water)
Modeling: 3D_HMS

4.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

4.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR RELATION
“KIT_THM”
“RELATION_KIT” =
“HOEK_BROWN_EFF”, “LIQU_SATU”, “HYDR_UTIL”

Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in porous environment of voluminal structures
HT-62/06/005/A

5
Results of modeling B

5.1 Values tested

Localization Number
of order Forced
(MPa) Code_Aster
Not D
16

xx
-0.239568
28

xx
-0.257851
36

xx
-1.10550
44

xx
-4.29762
52

xx
-7.28266

80

xx
-15.7587
16

yy
-0.239568
28

yy
-0.257851
36

yy
-1.10550
44

yy
-4.29762
52

yy
-7.28266
80

yy
-15.7587
16

zz
-16.0195
28

zz
-20.4913
36

zz
-24.7968
44

zz
-28.9045
52

zz
-33.7174
80

zz
-54.1101
16
Pressure
water
5.23957

44
Pressure water
0.702380

80
Pressure water
-10.7587

6
Summary of the results

This case test is a test of not-regression developed to validate the model of Hoek-Brown modified in effective constraints, HOEK_BROWN_EFF, with hydraulic coupling.

One obtains the same results with two modelings 3D_HM or 3D_HMS.

Organization (S): EDF-R & D /AMA, CS-SI

Handbook of Validation
V7.31 booklet: Thermo-hydro-mechanics in porous environment of voluminal structures
Document: V7.31.129

WTNV129 - Triaxial compression test not drained with the model of Hoek-Brown modified in total constraints

Summary

This test makes it possible to validate the elastoplastic law of behavior of Hoek-Brown modified in constraints total is HOEK_BROWN_TOT with hydraulic coupling. It is about a triaxial compression test in not drained condition.
The aspect not drained is modelled by a null voluminal deformation of the skeleton and the hydraulic coupling is taken into account. The sample is completely saturated, the incompressible skeleton and the fluid being supposed.
For reasons of symmetry, one is interested only in the eighth of a sample subjected to a triaxial compression test.
The level of containment applied is 5 MPa.

It is about a test of nonregression.

Modeling A is a modeling of the 3D_HM type with integration at the points of Gauss.
Modeling B is a modeling of the 3D_HMS type with integration at the points of Gauss or the nodes (see Doc. [R7.01.10]).

Contents

1
Problem of reference

1.1 Geometry

One considers here a cube of dimension 1m × 1m × 1m.

Z

1 m

· D

· C

1 m

With
B

.
.

y

X
1 m

Co-ordinates of the points (in m):

WITH B C D
X 0 0.0.5 1
y 0 1.0.5 1
Z 0 0.0.5 1

1.2
Properties of material

Parameters of the elastic law of behavior:
E = 4500 MPa
= 0.3

Parameters of the law of Hoek-Brown modified:
rup
= 0.005
LMBO
= 0.017
2 end
(S) = 225 MPa2
C
2 rup
(S) = 482.5675 MPa2
C
end
(m) = 13.5 MPa
C
rup
(m) = 83.75 MPa
C
= 3 MPa
rup

= 15°
LMBO
= 30°
= 3.3

1.3 Conditions
initial,
with the limits and loading

The test breaks up into two phases:

1) Initially, one brings the sample in a homogeneous state 0
0
0
= =. For
xx
yy
zz
that, the corresponding confining pressure is imposed on the front faces (X = 1),
side right-hand side (y = 1) and higher (Z = 1), the water pressures are taken null everywhere and
displacements are taken null on the faces postpones (U
= 0), side left
X x=0
(U
= 0) and the lower (U

= 0).
y y=0
Z z=0
2) Once the homogeneous state obtained, displacements are maintained blocked on the faces back, side left and lower. Hydraulic flows are null on all the faces. One displacement is forced on the higher face (U (T)) in order to obtain a deformation
Z
equalize to 25% starting from the beginning of the second phase, by increments of deformation
zz
constant
= 2
- .5E - 4. On the front faces and side right-hand side, one imposes conditions
zz
with the limits in total constraint: N
0
= = 5
- MPa.

---

2 Modeling
With

2.1
Characteristics of modeling

Modeling 3D

Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = - MPa

5
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0
Coefficient of Biot: 1
UN_SUR_K of water: 0 (coefficient of incompressibility of water)
Modeling: 3D_HM

2.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

2.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR RELATION
“KIT_THM”
“RELATION_KIT” =
“HOEK_BROWN_TOT”, “LIQU_SATU”, “HYDR_UTIL”

Handbook of Validation

3
Results of modeling A

3.1 Values
tested

Localization Number
of order Forced
(MPa) Code_Aster
Not D
16
'

1,14121
xx
28 '

1,94894
xx
36 '

1,49781
xx
44 '

-2,69068
xx

52 '

-1,24045 101
xx
80 '

-3,72255 101
xx
16 '

yy
1,14121
28 '

yy
1,94894
36 '

yy
1,49781
44 '

yy
-2,69068
52 '

yy
-1,24045 101
80 '

yy
-3,72255 101
16 '

-1,74245 101
zz
28 '

-2,23066 101
zz
36 '

-2,62168101
zz
44 '

-2,95247 101
zz
52 '

-3,24666 101
zz
80 '

-5,2947 101
zz
16
Pressure
water
6,14121
44
Pressure
water
2,30931

80
Pressure water
-3,2225 101

---

4 Modeling
B

4.1
Characteristics of modeling

Modeling 3D
Cutting: 1m in height, 1m in width
Loading of phase 1: 0
0
0
= = = - MPa

5
(confining pressure)
xx
yy
zz
Boundary conditions: U
= U
= U
= 0
X x=0
y y=0
Z z=0
Coefficient of Biot: 1
UN_SUR_K of water: 0 (coefficient of incompressibility of water)
Modeling: 3D_HMS

4.2
Characteristics of the grid

A number of nodes: 20
A number of meshs and types: 6 QUAD8 and 1 HEXA20

4.3 Functionalities
tested

Orders

DEFI_MATERIAU HOEK_BROWN

STAT_NON_LINE COMP_INCR RELATION

"KIT_THM"
"RELATION_KIT" =
"HOEK_BROWN_TOT", "LIQU_SATU", "HYDR_UTIL"

5
Results of modeling B

5.1 Values
tested

Localization Number
of order Forced
(MPa) Code_Aster
Not D
16
'

1,14121
xx
28 '

1,94894
xx
36 '

1,49781

xx
44 '

-2,69068
xx
52 '

-1,24045 101
xx
80 '

-3,72255 101
xx
16 '

yy
1,14121
28 '

yy
1,94894
36 '

yy
1,49781
44 '

yy
-2,69068
52 '

yy
-1,24045 101
80 '

yy
-3,72255 101
16 '

-1,74245 101
zz
28 '

-2,23066 101
zz

36 '

-2,62168 101
zz
44 '

-2,95247 101
zz
52 '

-3,24666 101
zz
80 '

-5,2947 101
zz
16
Pressure
water
6,14121
44
Pressure
water
2,30931

80
Pressure water
-3,2225 101

6
Summary of the results

This case test is a test of not-regression developed to validate the model of Hoek-Brown modified in total constraints, HOEK_BROWN_TOT with hydraulic coupling.

One finds the same results with two modelings 3D_HM and 3D_HMS.

Version
7.2

Titrate:
WTNP103 - Diffusion of air dissolved in water (plan)

Date:
20/10/04
Author (S):
S. GRANET, C. CHAVANT Key
:
V7.32.103-A Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.103

WTNP103 - Diffusion of air dissolved in water (plan)

Summary:

Here a problem at temperature and constant saturation are considered. By boundary conditions

suitable
one imposes a water pressure and a steam pressure constants. A gas pressure is imposed on one
edge of the field (null flows of the other with dimensions). Only pressures of dry air and dissolved air connected by the law of
Henry evolve/move. This problem brings back in an equation for the pressure of dry air of type "equation of
heat". The reference solution will be then a thermal calculation ASTER.
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

---

1 Problem of reference

1.1 Geometry

y
C

D

With
X
B

Co-ordinates of the points (m):

To 0 0
C
1 0,5
B
1
0
D 0 0,5

1.2 Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (thermal conductivity, moduli of elasticity…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
103
Specific heat with constant pressure (J.K-1)
0.
Dynamic viscosity of liquid water (Pa.s)
0.001
thermal dilation coefficient of the liquid (K-1)
0.
Permeability relating to water
Kr

W (S) = 0 5
.
Vapor
Specific heat (J.K-1)
0.
Mass molar (kg.mol-1)
0,01
Gas
Specific heat (J.K-1)
0.
Mass molar (kg.mol-1)
0,01
Permeability relating to gas
Kr

gz (S) = 0 5
.
Viscosity of the gas (kg.m-1.s-1)
0.001
Dissolved air
Specific heat (J.K-1)
0.
Constant of Henry (Pa.m3.mol-1)
50000
Initial State
Porosity
1

Temperature (K)
300
Gas pressure (Pa)
1.01E5
Steam pressure (Pa)
1000
Capillary pressure (Pa)
1.E6
Initial saturation in liquid
0,4
Constants
Constant of perfect gases
8,32
Coefficients
Homogenized density (kg.m-3)
2200
homogenized
Isotherm of sorption
S (P

c) =
.
0 4
Coefficient of Biot
0
Fick Vapor (m2.s-1)
FV=0
Fick dissolved air (m2.s-1)
FA=6. E-10
Intrinsic permeability (m2)
Kint = 1.E-19
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
WTNP103 - Diffusion of air dissolved in water (plan)

Date:

1.3 Boundary conditions and loadings

On the whole of the field, one wants:

0
p = cte = p
W
W
1 = 0
0
= cte =
K
W
W
W
0
p = cte = p
vp
vp
F = 0

vp
S (p) = cte = S
C
0
0
T = cte = T
= 1
ol
ol
ol
M
= M = M
have
vp

AD

On all the edges: Hydraulic flows and null thermics.

One now will linearize pvp according to pw.

Linear writing of pvp function of pw:

Section 4.2.3 of the reference document Aster [R7.01.11] gives us the relation
:
ol
dp
M
vp
vp dpw
=
. If this expression is linearized one obtains
:
p
RT
vp
W
0
ol
p M

0
ol
p M

p = vp
vp p + 0
p - vp
vp
0
p which one can write in the form:
vp
0
W
vp
0
W
RT

RT
W

W

p = Ap + B

éq 1.3-1
vp
W

0
ol
p M
0
ol
p M
with
vp
vp
With =
and
0
vp
vp
0
B = p -
p
0
RT
vp
0
W
RT
W
W

On
:

AB
edge

p
= 115000
gz

PC = 10E6

---

2 *Reference solution*

2.1 *Method of calculation*

2.1.1 Calculation of the conservation of the mass of air

The conservation of the gas mass is written:

*to dmair + div (**M** + **M**) = 0* ***éq***
2.1.1-1
have
AD
dt

It is written that the total water mass and the total mass of air are preserved (because there is no flow from gas water nor at the edge) and one obtains:

m
= m + m = S (
0
-) + 1
(- S) (
0
-)
air
have
AD
0
AD
AD
0
have
have
thus
D (m + m) = S D + 1
(- S) D ***éq***
2.1.1-2
have
AD
0
AD
0
have
ol
M
ol
have
D
=
dP
M AD

have
have and D
=
dP
RT
AD
have
K H
DM

M ol
M ol dP
air = S
have + 1
(- S
have
have
)

dt

0. K
0
RT dt

H

Calculation speeds:
Farmhouse *= (- P)*
éq
2.1.1-3
gz
have
have
since F = 0 and P = 0
vp
vp

and

M
= (- P) - F C with C =
AD

AD
lq
lq
AD
AD
AD
AD

RT
Like P = P + P = P =
P
lq
W
AD
AD
have
K H
ol
RT
M AD
M
=
(- P) -.
. F P
AD
AD
lq
have
AD
have
K
K
H
H

[éq 2.1.1-1] can then be simplified in the following form:
dPas
C
= Ldiv (P)
have
dt

ol
ol

M
M
C =
have
S
+ 1
(-
have
S)

.
0 K
0
RT
with
H

ol
0
RT
0
M have
L = +
+
F
.

have
gz
AD
lq
AD
K
K
H
H

Equation of the heat whose one knows the result.
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

Code_Aster ®

2.2
Results of reference

With the preceding numerical values, one finds:

P =
RT
105
0
0
P =
P = 4992
have
AD
have
K H
ol
M
ol
M
0
have
0
=
P = 4
.
0 and 0
AD

0
=
P = 02
.
0

have
have
RT
AD
AD
RT

0
3
=
4.10-
=

vp
vp

The constants of the equation of heat are then:

-6
C =,
2 4810
16
L =,
1 4.10-

2.3 Uncertainties

Uncertainties are rather large because the analytical solution is an approximate solution of fact of the linearization of the equations.

---

3 Modeling With

3.1 Characteristics of modeling A

Modeling in plane deformations. 20 elements QUAD8.

3.2 Functionalities tested

Order Option

AFFE_MODELE
D_PLAN_THH2D

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_VAPE_GAZ
THM_AIR_DISS
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2
TEMP
STAT_NON_LINE COMP_INCR

RELATION
KIT_THH

RELATION_KIT
ELAS

LIQU_AD_GAZ_VAPE
HYDR_UTIL
Discretization in time: 100 steps of time of 5E7 S each one

3.3 Results

X (m)
Time (S)
PRE2 Aster
Thermal PRE2 calculation
Relative error
0,2 3E9s 1.128E4 1.120E4 0.73%
0,2 5E9s 1.127E4 1.224E4 0.24%

Comparison near
Sion of dry air, thermal calculation

1,14E+05

1,12E+05

Not; t=5E8s

1,10E+05

Not; t=3E9s

1,08E+05

S
Not; t=5E9s

1,06E+05
Pa

TEMP; t=5E8s
1,04E+05

TEMP; t=3E9s

1,02E+05

TEMP; t=5E9s

1,00E+05

9,80E+04

0
0,5
1

X

4
Summary of the results

The Aster results are in very good agreement with the semi-analytical solution.

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
WTNP103 - Diffusion of air dissolved in water (plan)

Date:
20/10/04
Author (S):
S. GRANET, C. CHAVANT Key
:
V7.32.103-A Page:
8/8

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Code_Aster ®
Version
8.2

Titrate:
WTNP104 - Diffusion of air dissolved in water (plan THH2M)
Date
: 04/05/06
Author (S):
Key S. GRANET
:
V7.32.104-A Page:
1/9

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.104

WTNP104 - Diffusion of air dissolved in water (plan
THH2M)

Summary:

Here a problem at temperature and constant saturation are considered. By boundary conditions suitable
one imposes a water pressure and a steam pressure constants. A gas pressure is imposed on one edge of the field (null flows of the other with dimensions). Only pressures of dry air and dissolved air connected by the law of
Henry evolve/move. This problem brings back in an equation for the pressure of dry air of type "equation of
heat". The reference solution will be then a thermal calculation ASTER. It is exactly about the same case
test that the WTNP103 but in modeling THH2M.

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-62/06/005/A

---

1 Problem of reference

1.1 Geometry

y

C

D

With
X
B

Co-ordinates of the points (m):

To 0 0
C
1 0,5
B
1
0
D 0 0,5

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (thermal conductivity, moduli of elasticity…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
103
Specific heat with constant pressure (J.K-1)
0.
Dynamic viscosity of liquid water (Pa.s)
0.001
thermal dilation coefficient of the liquid (K-1)
0.
Permeability relating to water
Kr

W (S) = 0 5
.
Vapor
Specific heat (J.K-1)
0.
Mass molar (kg.mol-1)
0,01

Gas
Specific heat (J.K-1)
0.
Mass molar (kg.mol-1)
0,01
Permeability relating to gas
Kr

gz (S) = 0 5
.
Viscosity of the gas (kg.m-1.s-1)
0.001
Dissolved air
Specific heat (J.K-1)
0.
Constant of Henry (Pa.m3.mol-1)
50000
Initial State
Porosity
1
Temperature (K)
300
Gas pressure (Pa)
1.01E5
Steam pressure (Pa)
1000
Capillary pressure (Pa)
1.E6
Initial saturation in liquid
0,4
Constants
Constant of perfect gases
8,32
Coefficients
Homogenized density (kg.m-3)
2200
homogenized
Isotherm of sorption
S (P

c) =
.
0 4

Coefficient of Biot
0
Fick Vapor (m2.s-1)
FV=0
Fick dissolved air (m2.s-1)
FA=6. E-10
Intrinsic permeability (m2)

Kint = 1.E-19

1.3
Boundary conditions and loadings

On the whole of the field, one wants:

0
p = cte = p
W
W
1 = 0
0
= cte =
K
W
W
W
0
p = cte = p
vp
vp
F = 0

vp
S (p) = cte = S
C
0
0
T = cte = T
= 1

ol
ol
ol
M
= M = M
have
vp
AD

On all the edges: Hydraulic flows and null thermics.

One now will linearize pvp according to pw.

Linear writing of pvp function of pw:

Section 4.2.3 of the reference document Aster [R7.01.11] gives us the relation
:
ol
dp
M
vp
vp dpw
=
.
p
RT
vp
W
0
ol
p M

0
ol
p M

If this expression is linearized one obtains: p
= vp
vp p + 0
p - vp
vp
0
p

vp
0
W
vp
0
W
RT
RT
W

W

that one can write in the form:

p = Ap + B

éq 1.3-1
vp
W

0
ol
p M
0
ol
p M
with
vp
vp
With =
and
0
vp
vp
0
B = p -
p
0

RT
vp
0
W
RT
W
W

On
:

AD
left

edge

p
= 115000Pa
gz

PC
6
= 10 Pa

2
Reference solution

2.1
Method of calculation

2.1.1 Calculation of the conservation of the mass of air

The conservation of the gas mass is written:

*to dmair + div (**M** + **M**) = 0* ***éq***
2.1.1-1
have
AD
dt

It is written that the total water mass and the total mass of air are preserved (because there is no flow from gas water nor at the edge) and one obtains:

m
= m + m = S (
0
-) + 1
(- S) (
0
-)
air
have
AD
0
AD
AD
0
have
have
thus
D (m + m) = S D + 1
(- S) D ***éq***
2.1.1-2
have
AD
0

AD
0
have
ol
M
ol
have
D
=
dP
M AD

have
have and D
=
dP
RT
AD
have
K H
DM

M ol
M ol dP
air = S
have + 1
(- S
have
have
)

dt

0. K
0
RT dt

H

Calculation speeds:
***Farmhouse** = (- P)*
éq
2.1.1-3

gz
have
have
since F = 0 and P = 0
vp
vp

and

M
= (- P) **-** *F C with C =*
AD
AD
lq
lq
AD
AD
AD
AD

RT
Like P = P + P = P =
P
lq
W
AD
AD
have
K H
ol
RT
M AD
M
=
(- P) -.
F
.
P
AD
AD
lq
have
AD
have

K
K
H
H

[éq 2.1.1-1] can then be simplified in the following form:
dPas
C
= Ldiv (P)
have
dt

ol
ol
M
M
C =
have
S
+ 1
(-
have
S)

.
0 K
0
RT
with
H

ol
0
RT
0
M have
L = +
+
F
.

have
gz

AD
lq
AD
K
K
H
H

Equation of the heat which one treats by a thermal calculation Aster.

2.2
Results of reference

With the preceding numerical values, one finds:

P =
RT
105
0
0
P =
P = 4992
have
AD
have
K H

ol
M
ol
M
0
have
0
=
P = 4
.
0 and 0
AD
0
=
P = 02
.
0

have
have
RT
AD
AD
RT

0
3
=
4.10-
=

vp
vp

The constants of the equation of heat are then:

-6
C =,
2 4810
16
L =,
1 4.10-

2.3 Uncertainties

Uncertainties are rather large being given that the quasi-analytical solution (fruit of a calculation thermics) is a solution approached because of linearization of the equations.

3 Modeling
With

3.1
Characteristics of modeling A

Modeling in plane deformations D_PLAN_THH2MD. 20 elements QUAD8.

3.2 Functionalities
tested

One is in the same case as for wtnp103, mechanics blocked moreover.

Order Option

AFFE_MODELE
D_PLAN_THH2MD

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_VAPE_GAZ
THM_AIR_DISS
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2
TEMP
DX
DY
STAT_NON_LINE COMP_INCR
RELATION
KIT_HHM

RELATION_KIT
ELAS

LIQU_AD_GAZ_VAPE
HYDR_UTIL
Discretization in time: 100 steps of time of 5E7 S each one.

3.3 Results

It is pointed out that the temperature resulting from thermal calculation corresponds to the pressure of dry air of our
calculation thermo-hydro-mechanics. The steam pressure being constant one a:

DDL
init
P = PRE2
+ PRE
= P0
2
+ P
gz
vp
have

X (m)
Time (S)
PRE2 Aster
Thermal PRE2 calculation
Relative error
0,2 3E9s 1.128E4 1.120E4 0.75%
0,2 5E9s 1.127E4 1.224E4 0.25%

---

4 Modeling B

4.1 Characteristics of modeling B

Even modeling that of A in selective, model D_PLAN_THH2MS.

4.2 Functionalities tested

One is in the same case as for wtnp103, mechanics blocked moreover.

Order Option

AFFE_MODELE
D_PLAN_THH2MS

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_VAPE_GAZ
THM_AIR_DISS
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2
TEMP
DX
DY
STAT_NON_LINE COMP_INCR
RELATION
KIT_HHM

RELATION_KIT
ELAS

LIQU_AD_GAZ_VAPE
HYDR_UTIL
Discretization in time: 100 steps of time of 5E7 S each one.

4.3 Results

It is pointed out that the temperature resulting from thermal calculation corresponds to the pressure of dry air of our
calculation thermo-hydro-mechanics. The steam pressure being constant one a:

DDL
init
P = PRE2
+ PRE

= P0
2
+ P
gz
vp
have

X (m)	Time (S)	PRE2 Aster	Thermal PRE2 calculation	Relative error
0,2	3E9s	1.128E4	1.120E4	0.74%
0,2	5E9s	1.227E4	1.224E4	0.25%

---

5 Summary of the results

The Aster results are in very good agreement with the semi-analytical solution.

Version
7.2

Titrate:
WTNP106 - Heating of a porous environment désaturé with dissolved air
Date:
13/10/04
Author (S):
S. GRANET, C. CHAVANT Key
:
V7.32.106-A Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.106

WTNP106 - Heating of a désaturé porous environment with dissolved air

Summary:

One heats a porous environment of which the pores are filled with a mixture of water (liquid and vapor) and of air (dry and

dissolved in water). Initial saturation in liquid is 50%, the loading is a uniform heat flux on the edges of the field. The modeling made by only one element corresponds to the modeling of one homogeneous problem in space.

The reference solution is an approximate analytical solution.
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

1
Problem of reference

1.1 Geometry

y
D
C
1
m
F
E
X
Z
h=
With
B
1m

Co-ordinates of the points (m):

To -0,5 -0,5
C
0,5 0,5
B
0,5 -0,5
D -0,5 0,5

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (thermal conductivity, moduli of elasticity…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
103
Heat with constant pressure (J.K-1)
4180
thermal dilation coefficient of the liquid (K-1) 0.
Dynamic viscosity of liquid water (Pa.s)
0.001
Permeability relating to water

Kr

W (S) = 1
Vapor
Specific heat (J.K-1)
1900
Initial enthalpy (latent heat of vaporization) 2,5E6.
J/Kg
0,018
Mass molar (kg.mol-1)
Gas
Specific heat (J.K-1)
1900
Mass molar (kg.mol-1)
0,018
Permeability relating to gas
Kr

gz (S) = 1
Viscosity of the gas (kg.m-1.s-1)
1,8E-5
Dissolved air
Specific heat (J.K-1)
1900
Constant of Henry (Pa.m3.mol-1)
50000
Skeleton
Heat-storage capacity with constant constraint (J.K-1) 1050
Initial State
Porosity
0,3
Temperature (K)
300
Gas pressure (Pa)
1E5
Steam pressure (Pa)
3700
Initial saturation in liquid (Pa)
0,5
Constants
Constant of perfect gases
8,315
Coefficients

Homogenized density (kg.m-3)
2200
homogenized Isothermal of sorption
S (
=
- -
-
-

C
P)
12
0 5
.
10
(
0
0
C
P
vp
P
C
P)
With 0
vp
P = 3700
0
P

C = 0

1.3
Boundary conditions and loadings

On all the edges:
Heat flux
6
Q .n
ext.
= 10
Hydraulic flow no one

Handbook of Validation

2
Reference solution

2.1
Method of calculation

2.1.1 Calculation of the steam pressure starting from the temperature

We suppose the linear curve of saturation. It is thus written:

S = S0 + S
CP
éq
2.1.1-1
The equation [éq 2.2.3.3 - 2] of the reference document [R7.01.11] gives then:
m

= S P

W
W
C
m

= - 0 0
1 - S

0 - S 0
0
P

vp
(vp vp) (
)
vp
C
éq
2.1.1-2
m

= - 0
0
S

0 + S 0
0
P

AD
(AD AD)
AD
m

= - 0 0
1 - S

0 - S 0
0
P

have
(have ace) (
)
have
C

It is written that the total water mass and the total mass of air are preserved (because there is no flow from gas water nor at the edge) and one obtains:

m
m

W +
vp = 0

(

éq
2.1.1-3
W -
vp) S
PC + (
0
vp -
vp) (1 - S
=
0)
0
m
m

AD +
have = 0

(

éq 2.1.1-4
AD -
have) S
PC + (
0
have -
have) (1 - S) + (
0
AD -
S
AD
=
0
) 0
0

[R7.01.11] [éq 4.1.4-1] gives in addition:

p
ol
ol
ol
ln
M
1
1
M
M
vp = vp (
-
)
0
0
(p p0
p
p0
p
p0
gz
-
) + vp
gz
0
(vp -) - vp
vp
0
+ (C -
c)+

p

RT
K
K
RT
vp
W
H

W
H
W
éq
2.1.1-5
ol
MR. R
T
M
vp
ln
0
(
ol
T
dT
p
p
H
H
vp
-
)

+ vp
gz
0

(mvp - MW)

K
T
R
2
0
T
W
H

T

Coupling of the equations [éq 2.1.1-3], [éq 2.1.1-4] and [éq 2.1.1-5], for which it is necessary to add

the equation of
perfect gases for the vapor, the dry air and the dissolved air as well as the law of Henry are strongly a system
nonlinear that we will solve in small disturbances, which makes it possible to linearize it.

All made calculations, one obtains:

ol
0
P
1 S M

vp (W -
vp
RT
0
vp)
(- 0)

S

+
- (W - 0 S P
P
S
0
vp)

W +

0

have (W - vp)

. 1-
+

RT

K H

ol
0

RP
MR. P
- (

W -
0) S. have
vp
- vp vp
S
T
2
(1- 0)

=

0

0

K H
RT

0
P

vp (
RT
ol
S
S
0
AD -
0
have) S)
- (0ad - 0as)

S
Pw + P

0
0
1
0
-

0
have (AD - have)
(
)

S. 1
+ Mr.
vp
+

+

0

K
K
RT

H
H

ol

RP
MR. P
- (0

AD -
0) S. have
have
- vp have
S
T
2
(1- 0)

= 0

0

K H
RT

ol

1
M vp

P

vp -
+
Pw +

0
0

P

vp
RT
W

ol
ol
m
m

M vp P
M
H
H
have
R
vp
vp
W
T
0
0 (1 -
)
-

+
= 0

2

0

K T
R
W
H
T

éq 2.1.1-6

2.1.2 Calculation of the temperature

The equation [éq 3.2.4.3 - 1] of the reference document [R7.01.11] gives:
Q
m
= - T p

+ C0
3
T

éq
2.1.2-1
gz
gz
(since the other dilation coefficients are null).

The equation [éq 3.2.4.3 - 2] gives:
1-
m
(Slq)
=
gz

éq
2.1.2-2
T
3

One thus obtains:
Q
= - (- S + + 0
1

éq
2.1.2-3
lq) (p
p
vp
have)
C T

In this problem, Q
is anything else only the heat brought per unit of volume.
By calling Flight the total volume of the part and Surfing its side surface and T
the time of application
flows:

Surfing
Q
= T

Q
N
.
ext.
éq
2.1.2-4
Flight

:
V7.32.106-A Page:
6/8

2.1.3 System to be solved

1-
ol
S M
ol
0
0
M
(
RP
RT
W
- 0vp
) (0) vp
S+
- (W
- 0
vp
have
S
S p
S
S
0
vp)

- (1 - 0) 0
.
vp
- (W - 0
2
vp)
(W 0vp) 1. (-)

RT

0
RT
H
K
H
K

0
ol 0
RP
MR. P

0
RT
have
vp have

0
0
0
0
0
0
0
0
ol
S
1
0
- *S*

(AD
- *have*
)
S
- *(AD*
- *have*
)
S
- *(AD*

- have
)
S.
-
(1 - 0S) S
M
2
(AD have)
(0)

. 1 - + vp
K
0

.
+
0

H
RT

H
K
H
K
RT

1
ol
ol 0
ol m
vp
M
vp
M have
P
vp
M

vp
H - m
H

-
1
(-)
R +
W
0

0
0
0
0
2
P
RT
K T
R
0
vp
W
W H

T

0

- (
1 - lq
S)
0
C
- (
1 - lq
S)

vp
P

0

W
P
0

×
= Surfing

T T
Q.
ext.
N

Flight
P

have
0

éq
2.1.2-5

S

0
S
0
T
0
p

vp
0
vp
H
0
vp (calculated)
lq
5,00E-01 -1,00E-12 3,00E+02 3,70E+03 2,50E+06 2,67E-02 1,00E+03

0
R
0

S (calculated)
S
C
p
C
C
C
lq L
p
vp
0
(calculated)
2,20E+03 3,00E-01 2,93E+03 1,05E+03 4,18E+03 1,90E+03 2,78E+06

Q
N
.
ext.

T

Surfing
Flight

1,00E+06
10
400

1,00E+04

The following results are obtained:

After resolution of this system, one obtains:

Pvp
4
.
29

Pw -

99500

=

T 144
.
0

P
7
.
45

have

What gives in term of result Aster (increment):

PRE1 PRE2
DT PVP
(V3)
9.95E4 7.5E1 1.44E-1 2.94E1

2.2 Uncertainties

Uncertainties are rather large because the analytical solution is an approximate solution of fact of the linearization of the equations.
Handbook of Validation

---

3 Modeling With

3.1 Characteristics of modeling A

Modeling in plane deformations. A Q8 element.
Discretization in time: only one step of time: 10 S.

3.2 Functionalities tested

Order Option

AFFE_MODELE
D_PLAN_THH2D

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_VAPE_GAZ
THM_AIR_DISS
THM_DIFFU

THM_INIT
ELAS
AFFE_CHAR_MECA FLUX_THM_REP
FLUN_HYDR1

STAT_NON_LINE COMP_INCR RELATION
KIT_THH

RELATION_KIT
ELAS

LIQU_AD_GAZ_VAPE
HYDR_UTIL

3.3 Values tested

Node Urgent Field Component
(S)
Reference
Aster *Difference*
(%)
(analytical)
NO1
DEPL
TEMP 10 S 0.1440 0.1439
0.08%

NO1
DEPL
PRE1
10 S
9.95 104 9.95
104 0.02%

NO1
DEPL
PRE2
10 S
75
73.3
2.21%

NO1
VARI_ELNO_ELGA V3
10 S
29.4
29.5
0.2%

4
Summary of the results

The solution ASTER is in very good agreement with the analytical solution except for the gas pressure.
The weak differences are due to the linearization.

Date:
20/10/04
Author (S):
Key ***S. GRANET***
:
V7.32.110 - A Page:
1/4

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.110

WTNP110 - Orthotropic flow saturated 2D

Summary:

The test presented here makes it possible to check the correct operation of the operators used for the resolution of
equations of a flow in orthotropic saturated medium. This test corresponds to test 1.2 of the plan of qualification
project ALLLIANCES [bib1].

The reference solution is an analytical solution.
Handbook of Validation

1
Problem of reference

1.1 Geometry

D C

(0 ;0)

WITH B

Co-ordinates of the points (m):

With -0,1
-0,1
C 0,1 0,1

B 0,1 -0,1
D -0,1 0,1

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (moduli of elasticity,…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
1
Viscosity
1
Parameters
Intrinsic permeability (component in X)
1
homogenized
Intrinsic permeability (component in Y)
3/4
Intrinsic permeability (component in Z)
1
Initial State
Porosity
1
Pressure of liquid
0

1.3
Boundary conditions and loadings

1.3.1 Modeling
With

On AB P = P (X) = -45X+30.5
On BC P = P (X) = -80Y+18
On CD P = P (X) = -45X+14.5
On DA P = P (X) = -80Y+27

2
Reference solution

The analytical solution in pressure is a polynomial of degree in X and y, speed is constant and horizontal:

P (X, y) = -45x - 80y +
5
,
22

V (X, y) = (45K 80
; K) = (
)
60
;
45
X
y

2.1
Results of reference

One gives the value of the pressure and speed in 3 points:

X -0,05 0,00 +0,05
y -0,05 0.00 0.05
P 28,8 22.5 16.3
Vx 45 45 45
Vy 60 60 60

3 Modeling
With

3.1
Characteristics of modeling A

*Modeling in plane deformations. 20*20 Q8 elements*

3.2 Functionalities
tested

Order Option

AFFE_MODELE
D_PLAN_HMD

DEFI_MATERIAU
THM_LIQU

THM_DIFFU
PERMIN_X

PERMIN_Y
PERMIN_Z
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO
PRE1

DX
DY
STAT_NON_LINE COMP_INCR RELATION
KIT_HM

RELATION_KIT

ELAS
LIQU_SATU
HYDR_UTIL

Discretization in time: only one step of time: 1 S.
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

3.3 Values
tested

Standard node
of
Moment (S)
Reference
Aster Difference
value
(analytical)
(%)
N441
PRE1 1 16,3
16,25 0,3
%
(0.05 ;0.05)

N689
PRE1 1 28,8

28,5 0.96
%
(-0.05 ;-0.05)
N341
PRE1 1 22,5
22,5 0.
%
(0 ;0)

Meshs Standard
of
Moment (S)
Reference
Aster Difference
value
(analytical)
(%)
RIGHT FH11X
1 45
45 0
%
RIGHT FH11Y
1 60
60 0
%

4
Summary of the results

Very good agreement with the reference solution.

5 Bibliography

[1]
Project Alliances plan of qualification, notes ANDRA CNT-ASCS 02-075B
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/04/005/A

Code_Aster ®
Version
7.3

Titrate:
WTNP112 - Resaturation of a column

Date:
03/01/05
Author (S):
Key S. GRANET
:
V7.32.112-A Page:
1/8

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.112

WTNP112 - Resaturation of a column

Summary:

The test presented here makes it possible to check the correct operation of the operators used for the resolution of
equations of a flow in unsaturated medium. This test corresponds to test 3.1 of the plan of qualification of the project
ALLLIANCES [bib1]. It represents the resaturation of a column.

---

1 Problem of reference

1.1 Geometry

The studied field is a semi medium infinite horizontal. In practice it measures 3m.

y
C

D

With
X
B

Co-ordinates of the points (m):

To 0 0
C 3 0.1
B 3 0
D 0 0.1

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (moduli of elasticity,…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
1000
Viscosity
1
Parameters
Permeability K
1,625E-5m/s
homogenized
Porosity
0.3

0 81667
.
Isotherm of sorption
S (

C
P) = 0 1833
.
+
.
0

[
.
2 0304
1 + (2 9227

.
P)
C
] 5075

Relative permeability
W
Kr (C
P) = (7,3Pc)
E

0 49
.
1 97
.

.
0 82

.
2 5 .
-

1
S -

0 18
,

= E

Initial State
Pressure
P0 =
m
15
.
1

C

1.3
Boundary conditions and initial

They are expressed on the capillary pressure:

P (X)
0
, = P0 =
m
15
.
1

C
C
P (,
0 T) = 0 and P
,
3
(T) =
m
15
.
1

C
C

One is in condition of Richards: P (X, T) = atm
1

gz
Handbook of Validation

2 *Reference solution*

The reference solution is the semi-analytical solution of Phillips [bib1].

3 Modeling With

3.1 *Characteristics of modeling A*

Modeling THHD in plane deformations. 40 Q8 element

3.2 Functionalities tested

Order Option

AFFE_MODELE
D_PLAN_THHD

DEFI_MATERIAU
THM_LIQU

THM_GAZ

THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2
TEMP
STAT_NON_LINE COMP_INCR
RELATION KIT_THH

RELATION_KIT
LIQU_GAZ

HYDR_UTIL

Discretization in time: 20 steps of 0,5 hours time.

3.3 Results

The table below presents the capillary profiles of pressures and saturation along the bar and to each hour: One intercalates between the 2 profiles, that corresponding to the semi-analytical solution of Philips.

Capillary pressure along the column

40 elements

1 hour
1,2

2 hours

1

3 hours

0,8
4 hours

0,6
5 hours

PC
6 hours

0,4

7 hours

0,2
8 hours

0
9 hours

10 hours

0
1
2
3

X (m)

Semi-analytical solution of Pillips

1,2
1h

2h

1

3h

0,8
4h

0,6
PC
5h

0,4
6h

7h

0,2

8h

0
9h

0
1
2
3

10h

X (m)

Saturation along the column 40 elements

1 hour

1
2 hours

0,9
3 hours

4 hours

0,8

5 hours

***S** 0,7*
6 hours

0,6
7 hours

0,5
8 hours

9 hours

0,4
10 hours

0
1
2
3

X (m)

3.4 Value
tested

X (m)	***Time (S)***	***PRE1 Aster***	***Capillary pressure (Phillips)***	***Relative error***
1.	*36000s*	*0.461*	*0.460*	*0.2%*

---

4 Modeling B

4.1 Characteristics of modeling B

Modeling THHD in plane deformations. 80 Q8 elements

4.2 Functionalities tested

Order Option

AFFE_MODELE
D_PLAN_THHD

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2
TEMP
STAT_NON_LINE COMP_INCR RELATION
KIT_THH

RELATION_KIT
LIQU_GAZ

HYDR_UTIL

Discretization in time: 20 steps of 0,5 hours time.

4.3 Results

The table below presents the capillary profiles of pressures and saturation along the bar and to each hour, as for modeling A one intercalates the semi-analytical solution of Phillips:

Capillary pressure along the column 80 elements
1,2
1 hour
1
2 hours

0,8
3 hours
0,6
4 hours
PC
5 hours
0,4
6 hours
0,2
7 hours
8 hours
0
9 hours
0
0,5
1
1,5
2
2,5
3
10 hours
X (m)

Semi-analytical solution of Pillips
1,2
1h
2h
1
3h
0,8
4h
0,6
PC
5h
0,4
6h
7h
0,2
8h
0
9h
0
1
2
3
10h
X (m)

4.4 Value
tested

X (m)
Time (S)
PRE1 Aster
Capillary pressure (Phillips)
Relative error
1. 36000s 0.459
0.460
0.1%

Saturation along the column 80 elements
1 hour

1
2 hours
0,9
3 hours
0,8
4 hours
5 hours
***S** 0,7*
6 hours
0,6
7 hours
0,5
8 hours
0,4
9 hours
0
0,5
1
1,5
2
2,5
3
10 hours
X (m)

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Code_Aster ®
Version
7.3

Titrate:
WTNP112 - Resaturation of a column

Date:
03/01/05
Author (S):
*Key **S. GRANET***
:

5 Modeling C

5.1 Characteristics of modeling C

Modeling THH2D in plane deformations. 80 Q8 elements. It is exactly the same case as modeling B but with a structure THH2D and a coefficient of infinite Henry. This modeling has only for goal to bring back itself to a structure of data THH2D which is that known by Alliances.

5.2 Functionalities tested

Order Option

AFFE_MODELE
D_PLAN_THH2D

DEFI_MATERIAU
THM_LIQU
THM_GAZ
THM_DIFFU
THM_AIR_DISS
THM_VAPE_GAZ
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2
TEMP
STAT_NON_LINE COMP_INCR
RELATION KIT_THH

RELATION_KIT
LIQU_AD_GAZ_VAPE
HYDR_UTIL

Discretization in time: 20 steps of 0,5 hours time.

5.3 Results

The results are obviously the same one as for modeling B.

6 Modeling
D

6.1
Characteristics of modeling D

Modeling HMD in plane deformations. 80 Q8 elements. It is exactly the same case as modeling B but with the mixing rate LIQU_GAZ_ATM specific to the modeling of Richards (equivalent to modeling unsaturated with gas pressure imposed). One is blocked in mechanics.

6.2 Functionalities
tested

Order Option

AFFE_MODELE

D_PLAN_HMD

DEFI_MATERIAU
THM_LIQU
THM_GAZ
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO PRE1

DX
DY
STAT_NON_LINE COMP_INCR
RELATION KIT_THH

RELATION_KIT
LIQU_GAZ_ATM
HYDR_UTIL

Discretization in time: 20 steps of 0,5 hours time.

6.3 Results

The results are obviously the same one as for modeling B.

7 Bibliography

[1]
Project Alliances plan of qualification, notes ANDRA CNT-ASCS 02-075B
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/05/005/A

Author (S):
Key S. GRANET
:

Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.113

WTNP113 - Resaturation of an cell

Summary:

The test presented here makes it possible to check the correct operation of the operators used for the resolution of
equations of a flow in unsaturated medium. This test corresponds to test 3.2 of the plan of qualification of the project
ALLLIANCES [bib1].
It represents the evolution of water saturation of the medium around an cell of storage. Two phases are
takings into account, a phase of desaturation at the time of the exploitation of the underground work and a phase of

resaturation after the fill of gallery of the cells.

1
Problem of reference

1.1 Geometry

The studied field represents a cut of ground around an cell of storage.

D
C

O

WITH B

Co-ordinates of the points (m):

To 0
-500

C 10 -400
B 10 -500

D 0 -400
O 10 -450

Ray of the cell: 5.6 m

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (temperatures,…) who finally do not play any part in solution of the dealt with problem.

Liquid water
Density (kg.m-3)
1000
Viscosity
1
Parameters
Permeability K
10-18 m2
homogenized
Isotherm of sorption
S (P =
+
c)
0 15
.

0 85
.

[
8
.
1
1 + (6 5
. 10
.
P)
C
] 33.0
49
Relative permeability
Kr
=

W (PC)
3
S

Porosity
0,14
Storage
4. 10-10m-1
Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
HT-66/05/005/A

1.3
Initial conditions

The problem comprises two phases:

· First a 15 years phase of desaturation corresponding to the exploitation of the work underground
· One second phase of resaturation after the fill of the cell corresponding to exploitation (one initializes the saturation of the cell with 0,7).

The initial conditions are as follows:

For phase 1

· Alvéole P = 9,4.107 Pa (S = 0,49)
C

· Geological Barrière P = 1.105 Pa (S = 0,999)
C

For phase 2 (T > 15 years)

· Alvéole P = 3,015.107 Pa (S = 0,7)
C

1.4
Boundary conditions

They are expressed on the capillary pressure.

Phase 1:

On [AB] P = 1.105 Pa
C
On [CB] hydraulic Flow no one
On [CD] P = 1.105 Pa
C
On [A01] U [02D] hydraulic Flow no one

On the whole of the cell P =9,4.107 Pa (S=0,49).
C

Phase 2:

On [AB] P = 1.105 Pa
C
On [CB] hydraulic Flow no one
On [CD] P = 1.105 Pa
C
On [AD] hydraulic Flow no one

---

2 Modeling
With

2.1
Characteristics of modeling A

The results presented here result from modeling in plane deformations carried out with 2988 elements TRI3.

2.2 Functionalities
tested

Order Option

AFFE_MODELE D_PLAN_THHD

DEFI_MATERIAU THM_LIQU

THM_GAZ THM_DIFFU THM_INIT AFFE_CHAR_MECA DDL_IMPO PRE1

PRE2 TEMP STAT_NON_LINE COMP_INCR RELATION KIT_THH

RELATION_KIT LIQU_GAZ

HYDR_UTIL CREA_CHAMP OPERATION EXTR

CREA_CHAMP OPERATION AFFE

CREA_CHAMP OPERATION ADZE

STAT_NON_LINE COMP_INCR RELATION KIT_THH RECH_LINEAIRE

RELATION_KIT LIQU_GAZ

HYDR_UTIL

Discretization in time: 34 steps of time for a 10000 years simulation.

2.3 Results

One presents the profiles of capillary pressure and saturation on a horizontal cut (y = 450m) and verticals (X = 7m).

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HT-66/05/005/A

Capillary pressures Y = -450 m

1,00E+08

8,00E+07
7,5 years

15 years

has
) *6,00E+07*

P
50 years

(
100 years

4,00E+07
PC

200 years

2,00E+07
500 years

0,00E+00
1000 years

0
1
2
3
4
5
6
7
8
9 10
10000 years

X (m)

Appear 2.3-a: Profiles of capillary pressure Y = -450m

Saturation Y = -450m

1
7,5 years

15 years

0,9

50 years

0,8
100 years

200 years

***S** 0,7*

500 years

0,6
1000 years

0,5
10000 years

0,4

0
1
2
3
4
5
6
7
8
9
10

X (m)

Appear 2.3-b: Profiles of saturation Y = -450m

Author (S):
Key ***S. GRANET***
:

Capillary pressures X = 7m

1,00E+07

7,5 years

8,00E+06

15 years

6,00E+06

50 years

PC
100 years

4,00E+06

200 years

2,00E+06

500 years

0,00E+00
1000 years

-500
-480
-460
-440
-420
-400

10000 years

Y (m)

Appear 2.3-c: Profiles of capillary pressure X = 7 m

Saturations X = 7m

1

0,98
7,5 years

0,96
15 years

0,94
50 years

0,92
100 years

S
0,9

0,88
200 years

500 years

0,86

0,84
1000 years

0,82

10000 years

0,8

-500
-480
-460
-440
-420
-400

Y (m)

Appear 2.3-d: Profiles of saturation X = 7 m

2.4 Values tested

X (m)
Y (m)
Time (years)
PRE1 (Pa) Aster
5 -450
27
2.9E7
5 -450
10000 4.5E6
7 -450
27
4.2E6
7 -450
10000 4.5E6

These results are qualitatively in conformity with those which one finds in the literature of Alliances (isovaleurs).

---

3 Modeling
B

3.1
Characteristics of modeling B

It acts of the same modeling as above but with modeling THH2D (with a coefficient of infinite Henry). The awaited results must thus be exactly the same ones.

3.2 Functionalities
tested

Order Option

AFFE_MODELE
D_PLAN_THH2D

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_VAPE_GAZ
THM_AIR_DISS
THM_DIFFU
THM_INIT
AFFE_CHAR_MECA DDL_IMPO
PRE1

PRE2
TEMP
STAT_NON_LINE COMP_INCR RELATION KIT_THH

RELATION_KIT
*LIQU_AD_GAZ_*

VAPE
HYDR_UTIL
CREA_CHAMP OPERATION
EXTR

CREA_CHAMP OPERATION
AFFE

CREA_CHAMP OPERATION
ADZE

STAT_NON_LINE COMP_INCR RELATION KIT_THH
RECH_LINEAIRE

RELATION_KIT
*LIQU_AD_GAZ_*

VAPE
HYDR_UTIL

Discretization in time: 34 steps of time for a 10000 years simulation.

3.3 Values tested

X (m)
Y (m)
Time (years)
PRE1 (Pa) Aster
5 -450
27.2.9E7
5 -450
10000
4.5E6
7 -450
27.4.2E6

7 -450
10000
4.5E6

The values are well on the same ones as previously. The purpose of this modeling, heavier, is not to correspond to model the THM most complete as required by Alliances.

4 Bibliography

[1]
Project Alliances plan of qualification, notes ANDRA CNT-ASCS 02-075B

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
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Code_Aster ®
Version
7.3

Titrate:
WTNP113 - Resaturation of an cell

Date:
03/01/05
Author (S):
Key S. GRANET
:
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HT-66/05/005/A

Code_Aster ®
Version
8.1

Titrate:
WTNP115 - Désaturation of a porous environment without air

Date:
01/09/05
Author (S):
C. CHAVANT, Key S. GRANET
:
V7.32.115-A Page:
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Organization (S): EDF-R & D /AMA

Handbook of Validation
V7.32 booklet: Thermo-hydro-mechanics in porous environment unsaturated
Document: V7.32.115

WTNP115 Désaturation of a porous environment without air on unit cell

Summary:

One heats a porous environment whose pores are filled with a mixture of water and steam. Saturation initial in liquid is 50%, the loading is a uniform heat flux on the edges of the field.
modeling made by only one element corresponds to the modeling of a homogeneous problem in space.

The reference solution is an approximate analytical solution.

1
Problem of reference

1.1 Geometry

D

C

Y

X
With

B

Co-ordinates of the points (m):

To 0
0
C 100 100
B 100 -0
D 0
100

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (thermal conductivity, moduli of elasticity…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
103
Heat with constant pressure (J.K-1)
4180
thermal dilation coefficient of the liquid (K-1) 0.
Vapor
Heat-storage capacity (J.K-1)
1900
Initial enthalpy (latent heat of vaporization) 2,5E6.

Mass molar (kg.mol-1)
0,018
Skeleton
Heat-storage capacity with constant constraint (J.K-1) 1050
Initial State
Porosity
0,3
Temperature (K)
300
Pressure of liquid (Pa)
1E5
Steam pressure (Pa)
3700
Initial saturation in liquid
0,5
Constants
Constant of perfect gases
8,315
Coefficients
Homogenized density (kg.m-3)
2200
homogenized Isothermal of sorption
S (
=
- -
-
-
C
P)
12
0 5
.
10
(
0
0
C
P
vp
P
C
P)
With 0

vp
P = 3700
0
5
C
P = 10
-

1.3
Boundary conditions and loadings

On all the edges:
Heat flux
6
Q .n
ext.
= 10
Hydraulic flow no one

2
Reference solution

2.1
Method of calculation

2.1.1 Calculation of the steam pressure starting from the temperature

We suppose the linear curve of saturation. It is thus written:

S = S0 + S
CP
éq
2.1.1-1
[R7.01.11 éq 3.2.1-2] give then:
m

=
-0 0 0
lq
lq S
C
P
lq
Slq

éq
2.1.1-2
m

= - 0 0 1-
-
0
0
0
vp
(vp vp) (S) S vp CP

It is written that the total water mass is preserved (because there is no water flow at the edge) and one obtains:

mlq + mvp = 0

(
éq
2.1.1-3
lq - vp) S
PC + (

0
vp - vp) (1 - S0) = 0

[R7.01.11 éq 4.4-1] gives in addition

p
ol
vp M
= vp 1
ln
Plq +
0
p
RT
vp

lq
éq
2.1.1-4
M ol
vp (
ol
0
M
0
hvp - 0
hlq) 1
1
vp
p
p
T
T

- +
C
C
0
(vp - lq)

ln

+
-
0

1
R
T
T
R
T T

Coupling of the equations [éq 2.1.1-3] and [éq 2.1.1-4], for which it is necessary to add the equation of perfect gases
for the vapor, is a strongly nonlinear system which we will solve in small disturbance, it
who allows to linearize it.
All made calculations, one obtains:

ol
ol

1 S M
M
Pvp (lq - 0vp)
(- 0)

vp
S+
- (lq - 0
vp
T
S P
1 S p
0
vp)

lq = (0) 0

-

vp
2

RT

R
0
T

éq 2.1.1-5
P
M ol
M ol
vp -
vp
Plq = vp
T
H
H
0
0
(0vp - 0lq)

2

pvp
RT
R
0
lq
T

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C. CHAVANT, Key S. GRANET
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2.1.2 Calculation of the temperature

[R7.01.11 éq 3.2.4.3 - 1] gives:
Q
m
= - T p

+ C0
3
T

gz
vp

éq
2.1.2-1
(since the other dilation coefficients are null).
[éq 3.2.4.3 - 2] gives:
1-
m
(Slq)
=
gz

éq
2.1.2-2
T
3
One thus obtains:
Q
= - (
- S
+ 0
1

lq) p
C T
vp

éq
2.1.2-3

In this problem, Q
is anything else only the heat brought per unit of volume.
By calling Flight the total volume of the part and Surfing its side surface and T
the time of application
flows:

Surfing
Q
= T

Q
N
.
ext.
éq
2.1.2-4
Flight

2.1.3 System to be solved

1-
ol
S M
ol
M
(lq - 0vp)
(
0)
vp
S+
- (lq - 0
vp
S
S p
0

vp)

- (1 - 0) 0

vp
2
0
RT
RT

P
0
ol
ol
0
0
vp

1
M vp
M vp (vp
H - lq
H)

-
-
lq
P =
0

0
0
2

p
RT
R
0

vp
lq
T

Surfing

T
T
Q
N
.

0
- (
1 - S
C
Flight
lq)

0

ext.

éq 2.1.3-1

8.1

Titrate:
WTNP115 - Désaturation of a porous environment without air

Date:
01/09/05
Author (S):
C. CHAVANT, Key S. GRANET
:
V7.32.115-A Page:
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2.2
Results of reference

One gives the value of the temperature, the pressure of liquid and the steam pressure, solution system [éq 2.1.3-1] with the data summarized in the paragraphs [§1.2] and pointed out Ci below. For the calculation of the heat-storage capacities, one uses the following relations:

(0
1-)
0
0 0
= -
- -

S
0
R

lq Sl
(0
1 Sl) 0 0vp
C 0 = (1 -)
S
p
+

+ 1-

Sc
lq Sl C

S
C
lq
(
L)
p
vp
vp

0
0
C = C, this last relation being true because the dilation coefficient of the grains is null.

S

0
S
0
T
0
p

vp
0
vp
H
0
vp (calculated)
lq
5,00E-01 -1,00E-12 3,00E+02 3,70E+03 2,50E+06 2,67E-02 1,00E+03

0
R
0

S (calculated)
S

C
p
C
C
C
lq L
p
vp
0
(calculated)
2,20E+03 3,00E-01 2,93E+03 1,05E+03 4,18E+03 1,90E+03 2,78E+06

Q
N
.
ext.

T

Surfing
Flight

1,00E+06
1000
400
1,00E+04

After resolution, one obtains the following results:

vp
P

3.E+03
lq
P L
-1E+07

T

14

2.3 Uncertainties

Uncertainties are rather large because the analytical solution is an approximate solution of fact of the linearization of the equations.

---

3 Modeling With

3.1 Characteristics of modeling A

Modeling in plane deformations. A Q8 element

3.2 Functionalities tested

Order Option

AFFE_MODELE
D_PLAN_THVD

DEFI_MATERIAU
THM_LIQU

THM_VAPE_GAZ
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO
PRE1

TEMP
STAT_NON_LINE COMP_INCR
RELATION
KIT_THV

RELATION_KIT
ELAS
LIQU_VAPE

Discretization in time: only one step of time: 103 S.

3.3 Values
tested

Node
Type of value
Moment
Reference
Aster Difference
(S)
(analytical)
(%)
NO1
DEPL/TEMP
103 14 14,4 2.7%

NO1
DEPL/PRE1
103 -1.107 -1.3
107 30%

NO1
VARI_ELNO_ELGA/V4
3.

103 3.9
103 30%

One thus finds results relatively close to the analytical results. Uncertainty remaining enough broad because of linearization equations.

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Handbook of Validation
V7.33 booklet: Thermo-hydro-mechanics in porous environment of structures axisymmetric
Document: V7.33.102

WTNA102 - Diffusion of dissolved air (axi)

Summary:

Here a problem at temperature and saturation constants are considered. By boundary conditions adapted one imposes a water pressure and a steam pressure constants. A gas pressure is imposed on an edge of the field (null flows on other side). Only pressures of dry air and dissolved air connected by the law of Henry evolve/move. This problem is brought back in an equation for the pressure of dry air of type "equation of heat". The reference solution will be then a thermal calculation ASTER.

1
Problem of reference

1.1 Geometry

y
C

D

With
X

B

Co-ordinates of the points (m):

To 0 0
C
1 0,5
B
1
0
D
0
0,5

1.2
Properties of material

One gives here only the properties whose solution depends, knowing that the command file contains other data of material (thermal conductivity, moduli of elasticity…) who finally do not play any part in the solution of the dealt with problem.

Liquid water
Density (kg.m-3)
103
Specific heat with constant pressure (J.K-1)
0.
Dynamic viscosity of liquid water (Pa.s)
0.001
thermal dilation coefficient of the liquid (K-1)
0.
Permeability relating to water
Kr

W (S) = 0 5
.
Vapor
Specific heat (J.K-1)
0.
Mass molar (kg.mol-1)
0,01
Gas
Specific heat (J.K-1)
0.
Mass molar (kg.mol-1)
0,01
Permeability relating to gas
Kr

gz (S) = 0 5

.

Viscosity of the gas (kg.m-1.s-1)

0.001

Dissolved air

Specific heat (J.K-1)

0.

Constant of Henry (Pa.m3.mol-1)

50000

Initial State

Porosity

1

Temperature (K)

300

Gas pressure (Pa)

1.01E5

Steam pressure (Pa)

1000

Capillary pressure (Pa)

1.E6

Initial saturation in liquid

0,4

Constants

Constant of perfect gases

8,32

Coefficients

Homogenized density (kg.m-3)

2200

homogenized

Isotherm of sorption

S (P

c) =

.

0 4

Coefficient of Biot

0

Fick Vapor (m2.s-1)

FV=0

Fick dissolved air (m2.s-1)

FA=6. E-10

Intrinsic permeability (m2)

Kint = 1.E-19

1.3
Boundary conditions and loadings

On the whole of the field, one wants:

0
pw = cte = pw
1 = 0
0
W = cte =
K
W
W
0
pvp = cte = pvp
F

vp = 0
S (p)
C
= cte = S0
0
T = cte = T

= 1
ol
ol
ol
M
= M = M
have
vp
AD

On all the edges: Hydraulic flows and null thermics.

One now will linearize pvp according to pw.

Linear writing of pvp function of pw:

Section 4.2.3 of the reference document Aster [R7.01.11] gives us the relation
:
ol
dp
M
vp
vp dpw
=
. If this expression is linearized one obtains
:
p
RT
vp
W
0
ol
p M

0
ol
p M

vp
vp
p
p
0

vp
vp
0
p
p which one can write in the form:
vp =
W +
0
vp -
0
W
RT
RT
W

W

p = Ap + B

éq 1.3-1
vp
W

0
ol
p M
0
ol
p M
with
vp
vp
With =
and
0
vp

vp
0
B = p -
p
0
RT
vp
0
W
RT
W
W

On
:

AB
edge

p
= 115000
gz

PC = 10E6

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2
Reference solution

2.1
Method of calculation

2.1.1 Calculation of the conservation of the mass of air

The conservation of the gas mass is written:
to dmair + div (MR. M
éq
2.1.1-1
have +
)
AD
= 0
dt
It is written that the total water mass and the total mass of air are preserved (because there is no flow from gas water nor at the edge) and one obtains:

m
= m + m = S (
0
-) + 1
(- S) (
0
-)
air
have
AD
0
AD
AD
0
have
have
thus
D (m + m) = S D
+ -
éq

2.1.1-2
0
1
(
S) D
0

have
AD
AD
have
ol
M
ol
have
D
=
dP
M AD

have
have and D
=
dP
RT
AD
have
K H
DM

M ol
M ol dP
air = S
have

0.
+ 1
(- S
have
have
)
dt

K
0
RT dt

H

Calculation speeds:
Farmhouse = (- P)
éq
2.1.1-3
gz
have
have
since F
and P

vp = 0
vp = 0

and
M
with C
=
has
= (- P) - F C
D
AD
lq
lq
AD
AD
AD
AD

RT
Like P = P + P = P =
P
lq
W
AD
AD
have
K H

ol
RT
M AD
M

has
=
(- P) -.
. F P
D
AD
lq
have
AD
have
K
K
H
H

[éq 2.1.1-1] can then be simplified in the following form:

dPas
C
= Ldiv (P)
have
dt

ol
ol
M
M
C =
have
S .0
+ 1
(-
have
S)

K
0
RT
with

H

ol
0
RT
0
M have
L =

F
.
have
gz +
AD
lq +

AD
K
K
H
H

Equation of the heat whose one knows the result.
Handbook of Validation
V7.33 booklet: Thermo-hydro-mechanics in porous environment of axisymmetric structures
HT-66/04/005/A

2.2
Results of reference

With the preceding numerical values, one finds:

RT
P
P
P

have = 105
0
0
AD =
have = 4992
K H
ol
M
ol
M
0
have
0

P
and 0
AD
0

P

AD =
AD =
02
.
0
have =
have =
4
.
0
RT
RT

0
3

vp =
4.10-
vp =

The constants of the equation of heat are then:

6
C =,
2 4810-
16
L =,
1 4.10-

2.3 Uncertainties

Uncertainties are rather large because the analytical solution is an approximate solution of fact of the linearization of the equations.

---

3 Modeling

With

3.1
Characteristics of modeling A

Modeling in plane deformations. 20 elements QUAD8.

3.2 Functionalities
tested

Order Option

AFFE_MODELE
AXIS_THH2D

DEFI_MATERIAU
THM_LIQU

THM_GAZ
THM_VAPE_GAZ
THM_AIR_DISS
THM_DIFFU
THM_INIT
ELAS
AFFE_CHAR_MECA DDL_IMPO
PRE1

PRE2
TEMP
STAT_NON_LINE COMP_INCR
RELATION KIT_THH

RELATION_KIT
ELAS

LIQU_AD_GAZ_VAPE
HYDR_UTIL

Discretization in time: 100 steps of time of 5E7 S each one.

3.3 Results

X (m)
Time (S)
PRE2 Aster
Thermal PRE2 calculation
Relative error
0,2 3E9s 7.90E3
7.94E3 0.56%
0,2 5E9s 9.50E3
9.56E3 0.60%

Comparison pressure of dry air, thermal calculation
1,14E+05
1,12E+05
1,10E+05
Not; t=1E9
1,08E+05
Not; t=1E10s
S
Not; t=2E10s
1,06E+05
Pa
TEMP; t=2E9s
1,04E+05
TEMP; t=1E10s
1,02E+05
TEMP; t=2E10s
1,00E+05
9,80E+04
0
0,5
1
X
Handbook of Validation
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HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
WTNA102 - Diffusion of dissolved air (axi)

4
Summary of the results

The Aster results are in very good agreement with the analytical solution.

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Organization (S): EDF/IMA/MNN
Handbook of Validation
V7.90 booklet: Theoretical references of tests into thermomechanical
V7.90.02 document
HSNV100 - Elastoplasticity under thermal load
Summary:
To build the reference solution to test the treatment of the relation of behavior on a situation 0D (uniform field), in elastoplasticity under thermal load, with imposed displacement and temperature increasing. The elastic limit depends on the temperature. The modeling of the geometry can be:
· axisymmetric 2D or plane constraints,
· 3D.
This solution corresponds to test HSNV100 [V7.22.100].

Code_Aster ®
Version
3
Titrate:
HSNV100 - Elastoplasticity under thermal load
Date:
15/03/96
Author (S):
F. VOLDOIRE
Key:
V7.90.02-A
Page:
2/10

Contents

---

1 Presentation

The studied model problem is such as the solution is uniform in space, without any external effort given, so as to test only the treatment of the relation of behavior.

The following solid thus is considered:

· height
H,
· axisymmetric (of rays *has* and *b)*,
· or parallelepipedic (thickness *B* - *has*).

Z
H
0
R
has
B

It is placed between two lubricated rigid plates.

The material is thermoelastoplastic homogeneous (see hereafter) with isotropic work hardening and criterion of
Von Mises.

One supposes the uniform temperature spaces some, and increasing.

Code_Aster ®
Version
3
Titrate:
HSNV100 - Elastoplasticity under thermal load
Date:
15/03/96

2 Kinematics,
balance

2.1
Axisymmetric case (2D)

Fields of displacement:
U = *ur* (*R*) **er**
(blocking in *Z*)
U '0
0

R
R

Fields of deforamation: (**U**) = 0
0
0
according to *Z*

ur

0 0
R

0 0

0

R

Stress fields:
= 0 1 0 (cf boundary conditions)
L

according to

Z

0 0 0

2.2 Case
parallelepipedic
Fields of displacement:
U = *ux* (*X*) **ex** + *uy* (*y*) **ey**
(blocking in *Z*)
U '0 0

X
X

Fields of deforamation: (**U**) = 0
0
0
according to *Z*

0 0 *uy* '

y
0 0

0

X

Stress fields:
= 0 1 0 (cf boundary conditions)
L
according to

Z

0 0 0

y
The case could be studied in plane constraints and 3D.
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V7.90 booklet: Theoretical references of tests into thermomechanical
HI-75/96/014/A

---

3 Relation of behavior

Isotropic, linear work hardening (tangent *AND* constant module).
Criterion of Von Mises.
The elastic coefficients, *E* and, as well as the tangent module *AND* are invariants according to temperature.
The elastic limit varies *there* according to the temperature *T*:

O
O
y (*T*)
= *y* (1 - (*St* - *T*)
(for the temperature range studied, is positive *there*!).
The thermal dilation coefficient is constant.

AND
y
2µ =

E
1 +
E
3K =
E
1 - 2

The law of behavior is written (variable scalar intern *p*):
1
1

=
tr **Id** +
D + *p* +
O

(*T* - *T*) **Id**
9K
2µ

1
with: *D*
= - tr **Id**
(diverter of the constraints)

3

3
D
P

3

!
=
p!
, with
=
D D
2

éq
2
éq
p! =

0 if F (, *p*) =
-
éq
R (*p*) < 0
p!

0 if F (, *p*) = 0

R (*p*) indicates the function of work hardening:
E AND
R (*p*) = +
p
y
E - AND
The rate! *p* can be expressed, when F (, *p*) = 0. Indeed, of! *p* F identically no one, one draws:
! *p*! f+! *p* F = 0. Thus, when one is on the criterion (F =)
0, necessarily! F = 0. I.e.:
3D!
D

- R *T*!

,
T - R, *p*! *p* = 0
2
éq
3D!
D
E E

+ *O S*!
T
y
T -
! *p* = 0
2

E - *E*
éq
T
From where:
E - *E*
D
D

T
3 !

! *p*
O
=

+ *S*! *T*
y
if! *p* 0,

for
R
2

=
éq
(*p*)
E AND
éq

(criterion reached, in “load”)

4 Loading

thermics

Uniform temperature in space

T (*T*) = *T* + *To*, > 0

1

T [

,

0 *T fine*]; with *tfin* < *S*

T

To

T

Virgin initial State: *L* = 0; *p* = 0

---

5 Solution

The stress field being uniaxial, one a:

-1 0 0

D

L

=

0 2 0

3 0 0 - 1

As follows:

=
éq
L
and:
-1 0 0

P
! *p*
!
=
sgn (*L*) 0 2 0
2

0 0 - 1
The relation of behavior leads to:

! *p*
! *rr* =! = -
!
- sgn
L
(*L*) +! *T* = =

for the case of the parallelepiped
E
2
(! *xx*! *yy*
)

1
! *zz* = 0 =
!
L +

! *p* sgn (*L*) +! *T*

E
From where:

3
1 -
2
! *rr* =! =! *T* +
! *L*
2
2nd

! *p* = sgn (
L
L) -!
!
T -
0
if
L R (*p*)

E =
<

D
D
E - *E*

T
3 !

= max 0;

+ *O*!
y St

if not

E E
2

T

éq

I.e., in the case *L* = R (*p*) (criterion reached):
E - *E*

! *p*
Max 0;
T
O
=
+ *S T*
E E
(sgn (*L*)!
!
L
y
)

T

5.1 Phase
rubber band

At the beginning of the thermal loading, *L* being lower than *y*! *p* is null.
From where:
!
L = - *E*! *T*; ! *rr* =! =! *T* (1+).
As follows:

L = - *E T*
(compressionL <) 0

rr = = (1+) *T*

Validity of the elastic solution

The criterion is:

O
L (*T*) - *Y* (*T*)
= *E* = *T* - *y* (1 - *S T*) 0
The criterion is not crossed for *T* = [0, *ty*], with:
O

T
y
y
= (*E O*
+ *S*
y
)
y - *L*
OY
T
T y
At the moment *ty*:

E O

y
L (*ty*) = - *E* + *OY S*

5.2 Phase
elastoplastic

T ty. One is on the criterion. Then:

E - *E*

! *p*
Max 0;
T
O
=

+ *S T*
E E
(! sgn
L
(*L*)
!
y
)

T

By admitting that one is "charges some" (! *p* >)
0, then one eliminate! *p* to have:

E - *E*

!

= - *E*!
T
O
L
T T + sgn (*L*)

S y

E AND

then:
E - *E*

S O

y
! *p*
T
=
! *T* sgn

(*L*) +
E
E

With *T* = *ty*, *L* = - *E ty* < 0; one integrates then these expressions for *T T* (*T*
y! =):

E - *E*

T
O
L (*T*) = - *AND* (*T* - *ty*)
-
S y - *L T*

E E
(*y*)

T

(
E - *E*
p T)
T
=

2
[*E+soy*] (*t-ty*)

E
Maybe, after rearrangement, (*T ty*):

E
T

O
T

1
1

L (*T*)
= *y S T* - +
-

E
T

y

O

y (*E* - *AND*)
T
p (*T*) =
-
1

E2
T

y

Validity of this elastoplastic solution

It should be made sure that *L* (*T*) remains negative. Knowing that *S T* < 1, and that *T* > *ty*, the preceding result
confirm that *L* (*T*) < 0.

Lastly, it is noticed that:

1-
2
sgn (*L*)
! *p* +! *rr* = (1+)! *T*
2

---

from where:

1-
2
rr (*T*) = (*T*)

= (1+) *T* +
(
p T),
T

,
2
[*ty tfin*]
(since *L* (*T*) < 0).

6 Application

numerical
E = 200.000 *MPa*; = 0 3; = -
10 5 °C-1; = 10
. *s-1*

O

= 400 *MPa*; *To* = 0 °C; *S* = -
10 2 °C-1; *T*
< 100s
y
end

E
= 50.000 *MPa*
T

From where:
T

= 66 6666
.
S
y

133 333
.

L

(*ty*) = -
MPa

elastic phase

-
rr
(*ty*) = (*ty*) = 0866666
.
10 3
.

Then, elastoplastic phase:
with *T* =
S
80 :
L ()
80
= - 100 0
. *MPa*
(
p
)
80
=
-
0 3000
.
10 3
.

3
rr (
)
80
= ( )
80
=
-
1100
.
10
.
with *T* =
S
90 :
L ()
90
= - 7500
.
MPa
(

p
)
90
=
-
0 5250
.
10 3
.

3
rr (
)
90
= ( )
90
= 1275
.
10
.

Handbook of Validation
V7.90 booklet: Theoretical references of tests into thermomechanical
V7.90.03 document

HPLA100 - An analytical solution for the cylinder heavy thermoelastic hollow in uniform rotation

Summary:
One gives the analytical solution here axisymmetric 2D and in hull of the problem of the thin hollow roll thermoelastic weighing and in uniform rotation, subjected to a field of linear temperature in the thickness.
material is supposed characteristics independent of the temperature.
This solution corresponds to test HPLA100 [V7.01.100].

Contents

---

1 Uniform loading of rotation around OZ

1.1 Axisymmetric model 2D

The density of centrifugal force is: 2 *R* **er**.

One considers the boundary conditions following:

uz R
(, *Z*) = 0 in *Z* = 0 and *Z* = *L*

One postulates displacement in the form:

ur = *U R*
(); *uz* = *U* = 0

As follows:

U
rr = *u'*; =
;
R
zz = *rz* = *Z* = *R* = 0

Z
B1 B B2
L
!!
0
R
A1 A A2
H
R

The elastic constraints are expressed:

E

U

rr = (
1 - *u'*
+
1+)(1-
2) (
)

R

E

U

= (
1 -
+ '
1 +)(1-
2) (
)
U

R

E
U

zz =
'

(
+
1+)(1-
2)
U

R

The radial equilibrium equation is written:
(*R*) -
2

= - 2 *R*
rr R,
As follows:
(*Ru*) "

(1+)(1- 2)
2
R

éq 1.1-1
R
= -
(1) *E*
Note:
U
Ru
( )'
+ *u'* =
R

R
From where the general solution:
3
(
1+ 1 - 2
R
B
U R)
(
)(
)
= -
2
(

+
+
éq 1.1-2
1-)
Ar
E
8
R
The constraints are then:

3 -
2
r2
E
2

B

rr (*R*)
= -
.
+
With - 1 -
2
1-
8
(1+)(1-
2)

(
)

r2

1 +
2
r2
E
2

B

(*R*) = -
.
+
To + 1 -
2
éq 1.1-3
1 -
8
(1+)(1-
2)
(
)

r2

r2
2
2
E
zz (*R*) = -
.
+
With

1 -

2
(1+)(1-
2)

The boundary conditions in constraints are:
H
rr = 0 in *R* = *R* ± 2

One notes:
H
X = 2R
One obtains thanks to [éq 1.1-3]:
3
(- 2) 1(+)
B =
2 *R4* 1 - *x2*
() 2
8 1
(-) *E*
then:
(3 - 2) 1
(+) 1(- 2)
With =
2 *R2* 1 + *x2*
( )
4 1
(-) *E*

Numerical application:
R = 20 mm; *H* = 1 mm; = 8.106 kg/mm3; = 1 s1
E = 2.105 N/mm2; = 0.3.
From where: *To* = 7.13588.109; *B* = 3.561258.106 mm2
Note:
1
(+) 1 (- 2) 2 = 3.714286.10-12 mm2
1
(-) *E*
8
2 = 1.714286.10-6 MPa.mm-2
1-
2
As follows:
· in internal skin:
ur = 2.9424.10-7 mm;
zz = 0.99488.10-3 MPa
· in external skin:
ur = 2.8801.10-7 mm;
zz = 0.92631.10-3 MPa
1.2
Axisymmetric model hull
The centrifugal force is equivalent to a **pressure distributed**:

H2
p = 2 *H R* 1

+

12 *R2*
The solution is membranous, normal balance is written:
NR = *p R*

Author (S):
F. VOLDOIRE

W

The membrane deformation is: *E* =

, whereas *E*

R

zz = 0 = *K* = *Kzz*. In elasticity:

E H

NR =

E

1 - *v2*; *Nzz* = *v NR*; *M* = 0

From where the solution (arrow and circumferential normal effort):

1 - 2

() 2 *H2*

H2

W =

R3 1

+

; *NR*

E

12 *R2*

= 2R2 *H* 1 +

12 *R2*

Axial stress is worth:

H2

zz

= 2R2 1+

constant in L

(

'thickness)
12 *R2*

H2
If one does not take account of the correction of metric, term 1 should be removed

+
in
12R2
preceding expressions.
Numerical application (without correction of metric)**:**
p = 1,600000.104 MPa
W = 2,912000.107 mm
Nzz = 0,96000.103 N/mm
zz = 0,96000.103 MPa

2
Loading of gravity
2.1
Axisymmetric model 2D
The density of force is: - *G* **ez** (vertical gravity).
One considers the boundary conditions following:
uz R
(, *Z*) = 0 in *R* = *R* and *Z* = 0
(circle of support)
with uniform traction: *zz R*
(, *Z*) = *G L* in *Z* = *L*, balancing the weight.

One postulates the elastic solution of the type:

0 0

0

= 0 0 0

0 0 *zz*

so that:

rr = = - *zz* = - *uz*, *Z* = - *zz*;

E

rz = 0 = *R* = *Z*

One observes as follows:

ur, *R* = *ur* *U* () = - *A'* (*Z*) *R*

R

R *R*, *Z*

Then:

- *A'* (*Z*) =

( )

rr = - *zz*

uz, *Z* *R*, *Z* = *A'* *Z*

( )

U ()

( )

Z *R*, *Z* = *A* *Z* + *B* *R*

( )

From *rz* = 0, one draws:

B *R*

() - *R* *A* '' (*Z*) = 0

that is to say:

With *Z*

() = *cste* =;

B *R*

() = *R*

Boundary conditions in effort, one obtains:

G *z2*

G *r2*

With (*Z*) =

+; *B* *R*

( ) =

2nd

R2
Lastly, checks: = - *G* 2nd
As follows:

- *G Z R*
G
U

2
2
2
R (*R*, *Z*)
=
; *uz* (*R*, *Z*) =
Z + *R* - *R*

E
2nd (
(
)
éq 2.1-1

zz (*R*, *Z*) = *G Z*

Numerical application

G = 10 N/kg; = 8.10-6 kg/mm3; *R* = 20 mm; *L* = 10 mm
E = 2.105 N/mm2; = 0.3; *H* = 1 mm

· in internal skin:
U ()
R L = -2.34000.108 mm;
( )
zz L = 8.0000.104 MPa;
uz O
() = -1.185000.109 mm
· in external skin:
U ()
R L = -2.46000.108 mm;
( )
zz L = 8.0000.104 MPa;
uz O
() = 1.215000.109 mm

2.2

Axisymmetric model hull

A vertical traction is exerted in *Z* = *L*:
F = *G H L*
Gravity leads to a vertical force:
F = - *G H* **ez**
The boundary condition on the circle of support is: *uz Z*
() = 0 in *Z* = 0
The solution is membranous, vertical balance is written:
Nzz, *Z* = *G H*
Moreover: *NR* = 0. In elasticity, one deduces then:
- *NR*
G Z
G
E
zz
= *W* =
= -
; *E*
U () =
Z 2
R
E H
E
zz = *uz*, *Z* = *Nzz*
E H
Z Z
2nd
Axial stress is:

(
)
zz
= *G Z*
constant in the thickness
Numerical application:
F = 8.104 N/mm
W L
() = -2.4000.10-8 mm
Nzz (*L*) = 8.0000.104 N/mm
zz (*L*) = 8.0000.104 N/mm
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HI-75/96/014/A

---

3 Loading
thermomechanics
3.1
Axisymmetric model 2D
T + *T*
-
S
I
(*T T*
S
I)
T (*R*) - *T* (*R*) =
+
(*R* - *R*

réf
)
éq 3.1. - 1
2
H
Z
H
Ts
R
Ti
R
One postulates displacement in the form:
ur = *U R*
(); *uz* = *U* = 0
with the boundary conditions suitable. Thus, the elastic constraints are expressed:

E

U
E

rr = (
1 - *U* +
T - *T*
1 +)(1-
2) (
)
(*réf*)

R - 1 -

2

E

U

E

= (
1-
+ *U*
T - *T*
1 +)(1-

2) (
)
(*réf*)

R

- 1-
2

E
U

E

zz =

(
+ *U*
T - *T*
1 +)(1-
2)
(*réf*)

R

- 1-
2
The radial equilibrium equation *R*
( )
rr
-
, *R*
= 0 give:

(*Ru*)
(1+)

=
T - *T*

éq 3.1-2

R
1
(*réf*)
(-)

From where the general solution:
1+ (*T* - *T*
2
S
I)
(
R
B
U R)
(
)
=
(

+
+
éq 3.1-3
1-)
Ar
H

3
R
The constraints are then:

E (*S*
T - *I*
T) *R*
R

E T + *T*

S
I
rr (*R*)
=
-

H

1-
2

(
3 1-) - 1-
2
2

E

B

+

(
With - 1 -
2
1 +)(1-
2)
(
)

r2

E

(*St* - *iT*) *R*
2r

E T + *T*

S
I
(*R*) =

-
-

H
1-
2
(
3 1-) 1-
2
2

éq 3.1-4

E

B
+

(
To + 1 -
2
1 +)(1-
2)
(
)

r2

E (*S*
T - *I*
T) *R*

R
E T + *T*

S
I
zz (*R*)
=
-

H

1

-
2
1 - - 1 - 2
2

2nd

+

(

1 +) (1 - 2) *A*
H
H
The boundary conditions in efforts are: in *R* = *R* ±

. One obtains
2
rr = 0. One notes: *X* = 2R
thanks to [éq 3.1-4]:
T
(
)
B =
S - *Ti* (
) *R3* 1 - *x2*
() 2
6. 1
(-) 1+
then:

(*T* - *T*

S
I) *R*
T
2
+ *T*
With
(1)
S
I
=
+ -
3
1

2

6 (
- -
X
+
H 1 -) (
(
))

2

Numerical application:
R = 20 mm; *H* = 1 mm; = 10-5°C-1; *Ts* = - *Ti* = 0.5°C; = 0.3;
E = 2.105 N/mm2.
From where: *To* = -0.18569881.10-3; *B* = 0.02473096 mm2
Note:
1
(+) *Ts* - *Ti* = 0.61904762.10-5
1-
3 *H*
Handbook of Validation
V7.90 booklet: Theoretical references of tests into thermomechanical
HI-75/96/014/A

Code_Aster ®
Version

· in internal skin:
ur = 1.056145.106 mm;
zz = 1.4321427 MPa.
· in external skin:
ur = 1.110317.106 mm;
zz = -1.4250001 MPa.
If one takes *Ts* = +Ti = 0.1°C:
To = 0,00130000.10-3; *B* = 0,0 mm2
As follows:
· in internal skin:
ur = 25.350000.106 mm;
zz = -0.200000 MPa.
· in external skin:
ur = 26.650000.106 mm;
zz = -0.200000 MPa.

3.2
Axisymmetric model hull

For the field of temperature in the thickness given by [éq 3.1-1], one obtains the following expression law of behavior:

E H
E H T + *T*
T - *T*
S
I
S
I
H
NR
=
2 (*E*
+ *E*

zz) -
+

1 -
1 - 2
12
R

éq 3.2-1
E H
E H

T + *T*
T - *T*
S
I
S
I
H
Nzz =
2 (*E*
+ *E*

zz) -
+

1 -
1 - 2
12
R
and:

E h3
E H2 T + *T H*

M =

2

(
+

-
+
-
12 1 -) (*K*
K
S
I

zz)
(
12 1-)
T
T

2
R
S
I

éq 3.2-2

E h3
E H2 T + *T H*

M
S
I
zz
=

2
12 1
2

(

+
-
+
-
12 1 -) (*K*
K

zz)

(-)
T
T

R
S
I
H
According to these expressions, thermal terms in
are to be neglected if one does not consider
R
correction of metric in the thickness, i.e. in the case of usual models.
In our situation:
W
E =
; *E*
R
zz = 0
; *K* = *Kzz* = 0

Normal balance with the hull is written:
NR = 0
from where the arrow:
T
H
W = 1

(+) *T*
S + *Ti* + *S* - *Ti* *R*
2
12
R
and:
T
NR
S + *Ti*

zz
= *E H*
+ *Ts* - *Ti H*
2
12
R
M

zz
= - *E H2* (
) + *Ts* + *Ti H*
12 1
(-) *Ts* - *Ti*

2
R
As the second member of dilation does not take account of the correction of metric, terms out of *H*/*R* above are neglected.

Numerical application

R = 20 mm; *H* = 1 mm; = 10-5°C-1; *Ts* = - *Ti* = 0.5°C; = 0.3;
E = 2.105 N/mm2.
From where:
Mzz = -0.2380952 NR
in internal skin: *zz* = 1.449319 MPa *;
or
zz = 1.428571 MPa (without correction of metric)
If one takes *Ts* = +Ti = 0,1°C:
W = 26.00000.106 mm
Nzz = 0.2 N/mm
Mzz = 0.001190476 NR
in internal skin: *zz* = -0.2122466 MPa *;
or
zz = -0.200000 MPa (without correction of metric)

** The constraints in the thickness with correction of metric are given by:*

( )
H2

12 *x3*
zz x3
=
Nzz - *Mzz*/*R*
H 1 - *H2*/12 *R2*
(
) + *Mzz* - *Nzz*

12 *R h3* 1 - *H2*/12 *R2*
(
)

Handbook of Validation

V8.01 booklet: Fluid

V8.01.100 document

FDLV100 - Piston coupled to a column of fluid incompressible

Summary:

This test of the field of the fluids (coupling fluid-structure) validates the calculation of mass added on modal basis and
carry out, within the framework of a modal analysis, the calculation of the Eigen frequency of a system piston-arises
coupled to a column of incompressible fluid. To model the fluid, thermal elements are used
plans; to model the piston, one uses machine elements 2D in plane deformation and an element
discrete to model a spring. Lastly, the fluid interface/structure is modelled by linear elements
thermics modified to introduce a boundary condition of the type "acceleration" into the fluid. The case-test
comprise only one modeling, two-dimensional. The Eigen frequency of the coupled system is found
to 0.01% of the analytical result.

Key:
V8.01.100-A Page:
2/6

1 Problem of reference

1.1 Geometry

y
X
D
Piston
Fluid
With
B
L
L
Comes out from stiffness K

Steel piston connected to the solid mass by a spring and coupled to a column of incompressible fluid:
length:
L = 1.0 m
width:
D = 0.25 m
width AB of the piston:
0.05 m

X-coordinates of the points (in m):

With
B
L
X
0.05
0.
1.

1.2 Material properties

Fluid:

Water**:** *O* = 1000.0 Kg.m3

Solid:

Steel: *S* = 7800.0 Kg.m3; E = 2.E11 Pa; = 0.3

Arises connecting the piston to the solid mass:

Discrete element of type K_T_D_L: **K** = (1.E5, 1.E5, 1.E5) N/m

1.3 Boundary conditions and loading

One imposes a pressure (IE by analogy thermal a null temperature [R4.07.03]) in all them
nodes of the end of the fluid column.

One imposes the embedding of the spring on the solid mass and one imposes a displacement of the null piston according to
OY.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

Analytical calculation:

When the structure vibrates in the fluid, it modifies the field of pressure which obeys an equation of Laplace with boundary conditions of Von Neuman [R4.07.03].

In our case, taking into account symmetries of the problem, the field of pressure depends only on variable *X* and checks:

2p
p

=

0

X
N
2

F
S

X
X
= -

X 0
p

=
= *0 in X = L*
One notes as well as the field of pressure is a function closely connected of X-coordinate *X*. Both boundary conditions on the pressure imply: *p*
= **- xS N** (*X* - *L*
F
)
The compressive force which is exerted on the structure writes:
F
=
N *D*
=
L (**X N**) **N**
p (0)

S
D
F

As the problem is unidimensional, this force can be expressed in an algebraic way according to component of acceleration according to OX of the structure:
F = - *X L D* = - *L D X* = - *m X* with *m* = *L D*
F
F
has
has
F

It is the linear mass added of the fluid on the structure: it is noticed that it corresponds to the mass of fluid in the column, i.e. to the mass of fluid moved by the piston.
The equation of the movement of the piston projected on OX is written (free vibration not damped out taking into account
the presence of the fluid):
m X + *K X*

= *F* = - *m* *X* (*m* + *m*) *X* + *K* *X* =
has
has
0
The Eigen frequency of this immersed system is thus written:
1
K
F
= 2 *m*+*ma*
The effect of the fluid is thus to lower the Eigen frequency of the system in air.
Practically, in Aster, the matrix of added mass is given on the basis of modal
structure in the vacuum: To calculate the added mass given above, one restricts oneself with the calculation of
clean mode of the system piston-arises which corresponds to a translatory movement normalized with the unit
: one truncates consequently the modal base of the structure to only one mode in air (operator MODE_ITER_SIMULT option PLUS_PETITE). One determines thanks to this mode the mass added on the piston.
K
=
5
10 NR/m
m
= 200 kg/m
m
=
has
78 kg/m
The Eigen frequency of the system piston-arises immersed is thus *F*
= 3.018 Hz

2.2
Results of reference

Analytical

2.3 References
bibliographical

[1]
R.J GIBERT - Vibrations of the Structures - Interactions with fluids. Eyrolles (1988).

---

3 Modeling
With
3.1
Characteristics of modeling
Thermal formulation planes for fluid (QUAD4 and SEG2)
Plane deformation formulation and discrete for solid (QUAD4 and SEG2)
4 elements MEDPQU4
Fluid
80 elements THPLQU4
Piston
F
K
G
E
H
D
D
I
C
. . .
J
With
B
L
Comes out from stiffness K
4 elements of interface THPLSE2
1 element MECA_DIS_T_L
Cutting =
21 meshs QUAD4 according to the x axis
4 meshs QUAD4 according to the y axis
4 meshs SEG2 on the fluid interface/piston
1 mesh SEG2 representing the spring binding the piston to the solid mass
Boundary conditions:

DDL_IMPO: (GROUP_NO: noeupist DY: 0.)
DDL_IMPO: (GROUP_NO: embed DX: 0. DY: 0. DZ: 0.)
Name of the nodes:
GROUP_NO NOEUPIST is consisted of the ten nodes A, B, C, D, E, F,
G, H, I, J
The GROUP_NO EMBEDS is consisted of the node K

3.2
Characteristics of the grid

A number of nodes: 111 nodes
A number of meshs and types: 84 QUAD4, 5 SEG2

3.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
“THERMAL”
“PLANE”
[U4.22.01]
CALC_MASS_AJOU
MODE_MECA
[U4.??.??]
NUME_DDL_GENE
NUME_DDL_GENE
“FULL”
STORAGE
U4.55.07]
MODE_MECA
MODE_ITER_SIMULT
“BAND”
FREQ
U4.52.01]
concept “matr_asse_gene_r”
COMB_MATR_ASSE
COMB_R
[U4.53.01]
concept “matr_asse_gene_r”

---

4 Results of modeling A

4.1 Values tested

Identification	**Reference (Hz)**	**Aster (Hz)**	**% difference**
Order of the clean mode I: 1	3.018	3.01854	+0.018

4.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT OPTION: "PLUS_PETITE" NMAX_FREQ: 1.

4.3 Parameters of execution

Version: 3.05.24
Machine: CRAY C98
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
7.09 seconds

Titrate:
FDLV100 Piston coupled to a column of incompressible fluid
Date:
12/01/98
Author (S):
G. ROUSSEAU
Key:
V8.01.100-A Page:
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Handbook of Validation
V8.01 booklet: Fluid
HP-51/96/031 - Ind A

Code_Aster ®
Version
3
Titrate:
FDLV101 Two cylinders separated by an incompressible fluid
Date:
24/08/99
Author (S):
G. ROUSSEAU
Key:
V8.01.101-A Page:
1/8
Organization (S): EDF/EP/AMV
Handbook of Validation
V8.01 booklet: Fluid
V8.01.101 document
FDLV101 - Two cylinders separated by a fluid
incompressible

Summary:
This test of the field of the fluids (fluid coupling/structure) validates the calculation of matrix of mass added in
case where one has several structures immersed in the same fluid.
By a modal analysis, one thus determines the coupled modes of the two structures because of the mass of fluid which separates them. One adopts a modeling planes (thermal for the fluid, and deformation planes for
cylinders).
One finds the modes coupled of the system with less than 0.1% of the analytical result.
Handbook of Validation
V8.01 booklet: Fluid

---

1 Problem of reference

1.1 Geometry

N
R2
M
R *R*

X
R1

( )
1
( )
2

Two cylinders separated by incompressible fluid:
interior ray *R1* = 1.0 m external ray *R2* = 1.1 m

1.2 Material properties

Fluid:
Water: *O* = 1000.0 Kg.m3
Solid:
Steel: *S* = 7800.0 Kg.m-3; *E* = 2.E11 Pa; = 0.3
Arises connecting the piston to the solid mass:
One places a discrete element on mesh POI1 in the center of the cylinder 1 of *K1* stiffness and two discrete elements on mesh POI1 on cylinder 2 on the level of the axis OX whose stiffness is worth *K2*.
Discrete elements of type K_T_D_L:
K1= (1.E7, 1.E7, 1.E7) N/m
K2 = (5.E6, 5.E6, 5.E6) N/m

1.3
Boundary conditions and loading
One imposes a pressure (IE by analogy thermal a null temperature [R4.07.03]) in a node unspecified of the fluid.
One imposes a null displacement of the cylinders according to OY.
1.4 Conditions
initial
Without object for the calculation of added mass and the modal analysis.

2
Reference solution
2.1
Method of calculation used for the reference solution
Analytical calculation:
One will suppose that the movements of the cylinders and the fluid are primarily plane. Effects longitudinal will be neglected in front of the transverse effects. The problem is two-dimensional. Count held of symmetry, the reference mark used is a cylindrical reference mark (*R*,) related to the central cylinder (see figure
above). In this frame of reference and with this particular geometry, the normal derivative

is equal to the derivative
compared to *R*.
N
R
In all this part, the variable *p* indicates the hydrodynamic field of pressure in the fluid
created by the natural vibrations from the structures, **X1** or 2 indicates the clean modes of cylinder 1 or 2 respectively.

Clean modes of the hulls of border (

1) and (2) in the absence of fluid is form (*N*
indicate the order of the mode):
cos

N
or
sin *N*
0

1n
X
(**R**)
and
X2 N (**R**)
0
cos *N*
or
sin *N*

is the azimuth angle. These modes are uncoupled of course. The 1st component corresponds to
normal displacement of the interior hull, 2nd with that of the external hull. In volume
fluid, one has thus two problems to solve:
cos *N*

p
p

1n
1n
p

= 0

= - or

= 0
éq 2.1-1
1n
F

N
N
sin *N*

1
2
and:
cos *N*
p

p

2n
2
p

= 0

= 0
N

= or
éq 2.1-2
2n
F
N
N

1
2
sin *N*

The field *p N*
1 corresponds to the field of pressure generated in the fluid if the central hull 1 vibrates only, the field *p2n* is that created by the external hull 2 if it only vibrates. The linearity of the equation of Laplace makes it possible to solve independently each problem and then of to superimpose to find the field of pressure total.
The solution of the problem [éq 2.1-1] is, in polar co-ordinates, of the type [bib1]:
cos

N
N

1

p (*R*,)
N
=
+
or
1n
Ar
B
R

sin *N*

One must have *N* 0, bus if not one with the not-conservation of the volume of the fluid.

Constant A and B are determined by the boundary conditions:
cos

N

p

p

1n
1n

= - or
and

= 0
F
N
N
sin

1
R
N
2
R

It is found whereas the field of pressure for each of the two problems is written:
N
N
N
N

R1
1
+
F
(*R R*) (*R2 R*) 1 (*R R*
2

) cos

p (*R*,)
=
or
2

1n
N
(
N
R2 R)
1
- 1
sin *N*

and:
N
N
N
N

R2
2
1
1
+
F
(*R R*) (*R R*) (*R R*
2
) cos

p
(*R*,)
=
or
2

2 N
N
(
N
R2 R)

1
- 1
sin *N*

With
The modal coefficients of added mass *mijnm* are calculated starting from the following formula [R4.07.03] if *I* = 1 or 2, *J* = 1 or 2, (*N*, *m*) belongs to ¦2.
m With
=
p
X

im (**R**)

N
jn
(**J**) *D*
ijnm
J
J
The indexing is a little more complex here than in the formula presented in [R4.07.03]: indices I and J refer to hulls 1 and 2, and indices *m* and *N* are associated the modes of hull. One
notice that there is coupling of the modes of the various hulls, external and intern.
It is noticed, on the one hand, that the fluid does not couple the modes of different indices *N* bus them integrals
cos *N* cos *m D*

cancel themselves; in addition, the fluid does not couple either the modes

cos *N* and sin *N* bus
cos *N* sin *N D* =

0. The only existing coupling is a coupling between
()
two hulls for the modes of comparable nature.
With each mode *N*, one associates a matrix of order 4 symmetrical. A submatrix corresponding to projection on mode *N* is written:
With
With
m
m

With

11nn
12nn
1
M
= *A*
With
m21nn m22nn
With

1
M
0
The total matrix is written:
With
With

with **M** = **M**
With
1
2
0
M

2
cos *N*
2

with
With
=
p

or

11
m nn
L 1
R
,
1 (1
R
)

D
0

sin *N*

That is to say:
2n

R R
+ 1
With
2
(2) 1
=

11
m nn
R L
éq 2.1-3
F
1
N
(*R R*) 2n -
2
1
1

---

one will obtain:
2n

R R
+ 1
With
2
(2) 1
m
=

22nn
R L
éq 2.1-4
F
2
N
(*R R*) 2n -
2
1
1
and:
N

R R
With
With
(2 2) 1
m
=
= -
21nn

12
m nn
éq 2.1-5
F
1
R
2
R L
N
(*R R*) 2n -
2
1
1

L indicates here the height of the hulls cylinders in the longitudinal direction.

In our case, one considers only the modes of order *N* = 1 of the hulls: they correspond respectively with the modes of translation of each hull along an axis passing by the center central tube: one takes those arbitrarily corresponding to axis OX: coefficients of mass added linear are written:

2
R R
+ 1
With
2 (2
) 1
=
11
m
R
F
1 (*R R*) 2 -
2
1
1
2
R R
+ 1
With
2 (2
) 1
m
=
22
R

F
2 (*R R*) 2 -
2
1
1
R R
With
With
(2 2) 1
m
=
= -
21
12
m
R R
F
1
2 (*R R*) 2 -
2
1
1
The equation of the generalized movement of the two coupled hulls is written:
m
0 *X K*
0 *X*
m
m X
1
1
1
1
11
12
1

+
= -

0 *m X* 0 *K X*
m
m X
2

2
2
2
12
22
2
The own pulsations of the coupled system are given by the equation of degree 4:

m + *m*
m

K

1
11
12
0
det
2
1

-
= 0
m
m + *m*
0 *K*

12
2
22
2

Numerical application:

$K1$ = 107 N/m $K2$ = 107 N/m
$m11$ = 33.060 kg/m
$m22$ = 40.004 kg/m
$m12$ = 36.200 kg/m

One obtains two Eigen frequencies:

$f1$ = 1.696 Hz $f2$ = 4.128 Hz

2.2
Results of reference

Analytical

2.3 References
bibliographical

[1]
R.J GIBERT. Vibrations of the Structures. Interactions with fluids. Eyrolles (1988).

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3 Modeling

With

3.1

Characteristics of modeling

Thermal formulation planes for fluid (QUAD4 and SEG2)
Plane and discrete deformation formulation for solid (TRIA3, QUAD4 and POI1)
This modeling is designed to determine the modes of order N = 1 of the cylinders. Modes of hulls of a higher nature cannot be simulated by this type of model, but by one modeling of the type COQUE_CYL [U4.22.01].

Cutting =
64 meshs QUAD4 on the circumference of the cylinders
64 meshs TRIA3 on the interior of the interior cylinder
64 meshs SEG2 on the fluid interface/cylinders
2 meshs QUAD4 following the thickness of the fluid
2 meshs QUAD4 following the thickness of the external cylinder

Boundary conditions:
DDL_IMPO: (Group_no: HANG DY: 0.)
DDL_IMPO: (Group_no: ACCREXT DY: 0.)
TEMP_IMPO: (Group_no: TEMPIMPO TEMP: 0.)

3.2
Characteristics of the grid

A number of nodes: 356 QUAD4
A number of meshs and types: 64 TRIA3, 128 SEG2, 3 POI1

3.3 Functionalities
tested

Orders
Keys

AFFE_MODELE
"THERMAL"
"PLANE"
[U4.22.01]
CALC_MASS_AJOU
MODE_MECA
[U4.??.??]
NUME_DDL_GENE
NUME_DDL_GENE
"FULL"
STORAGE
[U4.55.07]
MODE_MECA
MODE_ITER_SIMULT
"BAND"
FREQ
[U4.52.01]
concept
"matr_asse_gene_R"
COMB_MATR_ASSE
COMB_R
[U4.53.01]
concept
"matr_asse_gene_R"

4

Results of modeling A
4.1 Values
tested
Identification
Reference (Hz)
Aster (Hz)
% difference
Order of the clean mode I: 1
1.696
1.695808
0.011
Order of the clean mode I: 2
4.128
4.12473
0.079
4.2 Remarks
Calculations of modes carried out by:
MODE_ITER_SIMULT OPTION: “PLUS_PETITE” NMAX_FREQ: 2.
4.3 Parameters
of execution
Version: 3.05.24
Machine: CRAY C98
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
10.28 seconds
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V8.01 booklet: Fluid
V8.01.102 document

FDLV102 - Mass added calculated on a model generalized

Summary:

This test belongs to the field of the fluid interaction/structure, in its aspect inertial coupling: it is about to calculate a matrix of added mass, starting from a generalized model resulting from a calculation by under-structuring dynamics. One carries out a modal analysis on the fluid coupled system/structure starting from a calculation by under structuring, and one compares the result with a modal calculation in direct fluid. One tests thus, for a problem two-dimensional fluid, the possibility of calculating the terms of added car-mass and mass added of coupling between substructures deduced between them by rotation and translation (these "deduced" substructures not being with a grid).

There is currently only one modeling, which consists in assigning to the fluid grid thermal elements plans.

Version
3
Titrate:
FDLV102 Masses added, calculated on a generalized model
Date:
21/07/99
Author (S):
G. ROUSSEAU
Key:
V8.01.102-A Page:
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1
Problem of reference
1.1 Geometry
D
With
F
B
K2
I
K1
K1
K2
K2
K1
L
L
O1
O2
R
R
E
H
J
y
K
K2
K1
O
X
D
G
C

L

Line of cylinders with circular section connected by springs to a fixed solid mass:

length:

L = lx = 2.0 m

width

L = ly = 1.0 m

ray of the cylinders:

R= 0.25 m

outdistance between centers of the tubes:

D = 1.0 m

Co-ordinates of the points (in m):

O1

O2

With

B

C

D

X

0.

1.00

0.50

1.50

1.50

0.50

y

0.

0.

0.50

0.50

0.50

0.50

E

F

G

H

I

J

K

L

X

-0.50

0.

0.

0.25
0.
0.25
0.
0.50
y
0.
0.50
-0.50
0.
0.25
0.
0.25
0.

1.2
Properties of materials

Fluid: Water
O = 1000.0 Kg.m3
Solid: Steel
S = 7800.0 Kg.m3 E = 2.E11 Pa = 0.3

Springs connecting the cylinder (substructure n°1 with a grid) to the solid mass:

Discrete element of type K_T_D_L:
K1 = (1.E7 1. 1.E7) N/m
K2 = (1. 1.E8 1.E8) N/m

1.3
Boundary conditions and loading

Without object for the calculation of added mass.

1.4 Conditions
initial

Without object for the calculation of added mass.

Handbook of Validation
V8.01 booklet: Fluid
HP-51/96/031 - Ind A

Code_Aster ®
Version
3
Titrate:
FDLV102 Masses added, calculated on a generalized model
Date:
21/07/99
Author (S):
G. ROUSSEAU

2
Reference solution

2.1
Method of calculation used for the reference solution

Direct modal calculation (without dynamic under-structuring)

Calculation of the clean modes in air:

One calculates with the option BANDAGES of operator MODE_ITER_SIMULT the first 4 frequencies clean of the system in air (system mass-arises):

mode 1:
vibration of the two cylinders in phase according to OX
mode 2:
vibration of the cylinder n°2 according to OY (on the right)
mode 3:
vibration of the two cylinders in opposition of phase according to OX
mode 4:
vibration of the cylinder n°1 according to OY (on the left)

These modes can be analytically given [bib1].

Calculation ASTER provides for the Eigen frequencies in air:

mode 1:
f1 = 17.3555 Hz
mode 2:
f2 = 18.2034 Hz
mode 3:
f3 = 42.6760 Hz
mode 4:
f4 = 57.5418 Hz

Calculation of the matrix of mass added on modal basis:

On this modal basis, one calculates the matrix of added mass of order 4 with the operator CALC_MATR_AJOU [U4.55.10] option "MASS_AJOU" key word MODE_MECA (terms of the triangular one
inferiors):

m11 = 300.67 kg/m
m12 = 0.001 kg/m
m13 = 269.98 kg/m
m14 = 0.009 kg/m
m22 = 269.98 kg/m
m23 = 0.009 kg/m
m24 = 31.05 kg/m
m33 = 301.71 kg/m
m34 = 0.011 kg/m

m44 = 269.86 kg/m
Addition of this matrix to the matrix of generalized mass:
One adds the matrix thus determined to the matrix of generalized mass (operator COMB_MATR_ASSE [U4.53.01]) then one calculates the Eigen frequencies of the structure immersed with
operator MODE_ITER_SIMULT option PLUS_PETITE [U4.52.01].
Calculation finds the Eigen frequencies following:
mode 1:
f'1 = 15.8782 Hz
mode 2:
f'2 = 16.7811 Hz
mode 3:
f'3 = 39.0389 Hz
mode 4:
f'4 = 53.0488 Hz

2.2
Results of reference

Eigen frequencies determined by ASTER in a direct calculation.

2.3 References
bibliographical

[1]
R.J GIBERT - Vibrations of the Structures. Interactions with fluids. Eyrolles (1988).

---

3 Modeling
With

3.1
Characteristics of modeling

Thermal formulation planes for fluid (TRIA3 and SEG2)

Plane and discrete deformation formulation for solid (TRIA3 and SEG2)
Cutting =
40 meshs TRIA3 according to the x axis
20 meshs TRIA3 according to the y axis
120 meshs SEG2 on the contour of the two cylinders
4 meshs SEG2 on the contour of the two cylinders representing them
meshs of the springs
Boundary conditions:
DDL_IMPO: (GROUP_NO: PBLOC1 DX: 0. DY: 0. DZ: 0.)
DDL_IMPO: (GROUP_NO: PBLOC2 DX: 0. DY: 0. DZ: 0.)
DDL_IMPO: (GROUP_NO: PBLOC3 DX: 0. DY: 0. DZ: 0.)
DDL_IMPO: (GROUP_NO: PBLOC4 DX: 0. DY: 0. DZ: 0.)
Name of the nodes:
E = PBLOC1
L = PBLOC2
F = PBLOC3
G = PBLOC4

3.2

Characteristics of the grid

A number of nodes: 1 881
A number of meshs and types: 3.580 TRIA3, 124 SEG2

3.3 Functionalities
tested

Orders
Keys

AFFE_MODELE
“THERMAL”
“PLANE”
[U4.22.01]
CALC_MATR_AJOU
OPTION “MASS_AJOU”
MODELE_GENE
[U4.55.10]
DIST_REFE
NUME_DDL_GENE
“FULL”
STORAGE
[U4.55.07]
MODE_ITER_SIMULT
“BAND”
FREQ
[U4.52.01]
concept matr_asse_gene_r

COMB_MATR_ASSE
COMB_R
[U4.53.01]
concept matr_asse_gene_r
Handbook of Validation
V8.01 booklet: Fluid
HP-51/96/031 - Ind A

Code_Aster ®
Version
3
Titrate:
FDLV102 Masses added, calculated on a generalized model
Date:
21/07/99
Author (S):
G. ROUSSEAU
Key:
V8.01.102-A Page:
5/6
4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
direct calculation
calculation with
under-structuring
Order of the clean mode I: 1
15.8782
15.8782
+0.0000
Order of the clean mode I: 2
16.7811
16.7815
+0.00002
Order of the clean mode I: 3
39.0389
39.0289
0.0002

Order of the clean mode I: 4
53.0488
53.0586
0.0002

4.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT option: “band” List_freq: (2. 70.)

4.3 Parameters
of execution

Version: 3.05.24
Machine: CRAY C98
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
22 seconds
Handbook of Validation
V8.01 booklet: Fluid
HP-51/96/031 - Ind A

---

5 Recall

Course of the calculation of mass added by modal synthesis

· Calcul of the clean modes of substructure 1 (cylinder of left with a grid) with interfaces blocked by MODE_ITER_SIMULT [U4.52.02]
· Définition of two dynamic interfaces type CRAIG-BAMPTON (displacement unit imposed):
“EAST”: to the point PBLOC2 = L corresponds
“CUS”: to the point PBLOC4 = G corresponds
· Définitions of 2 modal bases associated these interfaces: operator DEFI_INTERF_DYNA [U4.55.03]:

BAMO1:
two dynamic modes and a constrained mode: unit displacement
on PBLOC2 = L
BAMO2:
two dynamic modes and a constrained mode: unit displacement
on PBLOC4 = G
· Définitions of 2 macronutrients associated with these modal bases: operator
MACR_ELEM_DYNA
[U4.55.05]
· Définition of the generalized model: operator DEFI_MODELE_GENE [U4.55.06]:
Sous_structure_1: “CYLINDR0”: corresponds to the cylinder of left (with a grid)
Sous_structure_2: “CYLINDR1”: corresponds to the cylinder of right-hand side (nonwith a grid)
This second substructure is deduced from the first by rotation of -90°.
ANGL_NAUT: (- 90. , 0. , 0.)
Connection: “IS” and “CUS”
This definition of the two substructures makes it possible DEFI_MODELE_GENE to calculate
translation enters the two substructures.
· Création of a profile line of full sky starting from the definite generalized model: operator
NUME_DDL_GENE [U4.55.07]
· Assemblage of the matrices of generalized stiffness and mass: operator
ASSE_MATR_GENE [U4.55.08]
· Calcul of the matrix of mass added starting from the definite Generalized Model:
The modal bases attached to each of the two substructures define
fields with the nodes of displacement to the site of the 1st substructure in
grid. Operator CALC_MATR_AJOU [U4.55.10] transports the field to the nodes
corresponding to the modal base of the second substructure via the translation and
rotation defined higher to assign it to the site of the second substructure
in the grid. The calculation of the added mass is thus carried out following this displacement
of field to the nodes: one can thus calculate the mass added on the 1st substructure,
mass added on the second substructure as well as the term of coupling between
two substructures, taking into account the fluid environment of each one of under
structures.
· Sommation of the matrix of assembled mass generalized with the matrix of added mass:
COMB_MATR_ASSE [U4.53.01]
· Calcul of the clean modes of the immersed total structure: MODE_ITER_SIMULT
[U4.52.02].

Organization (S): EDF/EP/AMV
Handbook of Validation
V8.01 booklet: Fluid
V8.01.103 document

FDLV103 - Separate concentric spheres by an incompressible fluid

Summary:
This test relates to the field of the fluids in the aspect inertial coupling. One carries out a modal analysis of one rigid sphere connected to the solid mass by springs and diving in an incompressible volume of fluid of form spherical.
The test validates the calculation of mass added in 3D as well as modal calculation for a system fluid-structure coupled in 3D.

1
Problem of reference
1.1 Geometry
P1
K
The interior sphere has one
( )
Z
S1
ray = 0.35 Mr.
R1
R

1
( )
X
The external sphere has one
( )
S1
S2
ray = 0.45 Mr.
y
R2
R2

1

2
K
( )
S2
P2
1.2
Material properties
The interior sphere (*S1*) is out of steel:
S: 7.800 kg/m3
E: 2.1 1011 Pa
: 0.3
The fluid filling out the volume ranging between (*S1*) and (*S2*) is water of density *F*: 1.000 kg
(equivalent thermal characteristics: = 1, *F*

C = 1.000).
One passes to model the fluid by a thermal modeling 3D.
1.3

Boundary conditions and loadings
One supposes a null temperature in a point of the fluid grid.
One embeds the springs on the level of the solid mass at the points *P1* and *P2*.

2
Reference solution
2.1
Method of calculation used for the reference solution
One bases oneself on an analytical result [bib1]:
In the case of two concentric spheres immersed in the same fluid, it is shown that the mass added induced by the fluid confined on the internal sphere (*S1*) is worth:

3
R
1+ 2 1
2

R2
m
=
R3

has
F

3

3 1

R
1- 1

R2

If it is supposed that the sphere has one degree of freedom according to OZ, clean mode of translation sphere (*S1*) according to OZ is given by:
1
2K
F
= 2 *m*+*ma*
5
Numerical application:
K = 10 NR/m, *m* = 12,00 kg, *m* = 329,17 kg
has
F = 3.8534 Hz

2.2 References
bibliographical

[1]
R.D. BLEVINS, “Formulated for natural frequency and mode shape”, ED. KRIEGER

---

3 Modeling
With
3.1
Characteristics of modeling

Modeling includes/understands:
· side structure:

2 discrete elements of type K_TR_L
(mesh SEG2)
1316 elements of hulls of the type DKT
(mesh TRIA3)
· fluid side:
1316 thermal elements of face of the type 3D
(mesh TRIA3)
14454 thermal elements of volume of the type 3D
(mesh TETRA4)
The nodes of the hull interns are blocked according to all their degrees of freedom of rotation, like their two d.d.l of translation DX and DY (GROUP_NO: NOINT).
The springs are embedded with the solid mass at the points P1 and P2 (GROUP_NO: ENCAST).
The hulls are thickness 1 Misters.

3.2
Characteristics of the grid

A number of meshs and types: 2632 TRIA3, 2 SEG2, 14454 TETRA4.

3.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
"THERMAL"
"3D"
[U4.22.01]
CALC_MATR_AJOU
OPTION "MASS_AJOU"
[U4.55.10]
MODE_MECA
NUME_DDL_GENE
NUME_DDL_GENE
"FULL"
STORAGE
[U4.55.07]
Handbook of Validation
V8.01 booklet: Fluid
HP-51/96/031 - Ind A

Code_Aster ®
Version
4.0
Titrate:
Concentric FDLV103 Spheres separated by a fluid
Date:

4 Results of modeling A

4.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
Order of the clean mode: 1	3.8534	3.8983	+1.15%

4.2 Parameters of execution

Version: 3.05.24
Machine: CRAY C98
Obstruction memory:
30 MW
Time CPU To use:
212.86 seconds

5

Summary of the results
One finds the values of the analytical results well.
The small variation observed on the added mass can come:
· of a discretization not rather fine of the surface of the sphere,
· or of a discretization not fine enough of fluid volume.

Handbook of Validation
V8.01 booklet: Fluid
V8.01.104 document
FDLV104 - Calculation of mass added on model
generalized 3D
Summary:
This test of the field of the fluids (fluid coupling/structure) validates the calculation of mass added on a model
generalized of type 3D, namely two spheres coupled by an incompressible fluid.
By a modal analysis carried out by dynamic under-structuring, one obtains the coupled modes of both
spheres because of the presence of the fluid. The Eigen frequencies are compared with those determined by one
direct calculation.
One obtains the Eigen frequencies with a margin of less than 3%.

Titrate:
FDLV104 Masses added on model generalized 3D
Date:
12/01/98
Author (S):
G. ROUSSEAU
Key:
V8.01.104-A Page:
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1
Problem of reference

1.1 Geometry

Sphere 1
Sphere 2
K1
K3
K2
K2
K3
K1
K3
K1
H
0
Y
K3
X
R
K1
K2
L
Z
L
Length:
L = 4 m
width:
L = 2 m
height:
H = 2 m
Thickness of the hulls:
E = 103 m
Ray of the spheres:
R = 0.5 m

1.2
Properties of materials
Structure: steel - material elastic
E = 2.1011 Pa
= 0.3
S = 7800 kg/m3
The springs have as respective stiffnesses:
K1 = 106 N/m
K2 = 105 N/m
K3 = 107 N/m
Fluid: water - thermal material are equivalent
= 1.
the specific heat plays the part of density of the fluid: *F* = 1000 kg/m3
1.3
Boundary conditions and loadings
Side structure: the ddl of rotation DRX, DRY, DRZ of sphere 1 are blocked:
DRX: 0.0
DRY: 0.0
DRZ: 0.0
Fluid side: one imposes a pressure (i.e temperature) null in a node of the fluid grid.

2
Reference solution
2.1
Method of calculation used for the reference solution
One uses a direct modal calculation to obtain the Eigen frequencies modified by the fluid around spheres.
The two spheres result by a translation from vector from components (2, 0. , 0.) and for one

rotation of nautical analyses (90. , 0. , 90.) what makes it possible to plan to build a model generalized on the 1st sphere. One will be able to carry out same modal calculation with coupling fluid/structure by using the dynamic under-structuring. **Direct** calculation with taking into account of mass added leads to the Eigen frequencies of the immersed system following:

f1 =
3.1172 Hz
f2 =
3.1183 Hz
f3 =
9.2727 Hz
f4 =
9.8267 Hz
f5 =
22.4400 Hz
f6 =
30.3295 Hz

2.2
Results of reference

Direct modal calculation by Code_Aster.

2.3
Uncertainty on the solution

Uncertainties on the solution are related to the discretization of the fluid interface/structure and on the invariance of the grid by rotation of nautical angles (90°, 0°, 90°).

---

3 Modeling
With

3.1
Characteristics of modeling

Modeling includes/understands:
· side structure:
336 elements of hulls DKT modelling sphere 1,
6 discrete elements of type K_TR_L (modeling DIS_TR) modelling the six springs connecting sphere 1 with the solid mass,
· fluid side:
672 THER_FACE3 thermal elements modelling the fluid interface/structure,
39.445 Thermal THER_TETRA4 elements modelling the fluid.

3.2
Characteristics of the grid

A number of meshs and types: 672 meshs TRIA3, 39.445 TETRA4, 6 SEG2

3.3 Functionalities
tested

Orders
Keys
CALC_MATR_AJOU
MODELE_GENE
[U4.55.10]
OPTION
“MASS_AJOU”

---

4 Results of modeling A

4.1 Values tested

Identification	Reference	Aster	% difference
	Hz	Hz	
N°1 mode	3.1172	3.1189	+0.056%
N°2 mode	3.1183	3.1321	+0.44%
N°3 mode	9.2727	9.3144	+0.45%
N°4 mode	9.8267	9.8533	+0.27%
N°5 mode	22.4400	23.1291	+3.1%
N°6 mode			

30.3295
31.1779
+2.8%

4.2 Remarks

The variation on the two last Eigen frequencies is explained by a not-symmetry of the grid of the fluid interface/structure (thermal) compared to that of the first. **Grid** of the interface fluid/structure (thermal elements) of the second sphere does not result exactly from that from the first by rotation of nautical angles of 90°, 0°, 90°.

4.3 Parameters of execution

Version: NEW 3.5.24
Machine: CRAY C90
Obstruction memory:
30 MW
Time CPU to use:
161.3 seconds

5
Summary of the results

The results obtained by calculation by dynamic under-structuring show perfect agreement with direct calculation. Nevertheless, to have this agreement, it should be taken care that them grids of the interfaces fluid/structure (thermal elements) of the substructures which are repeated with the interior of the fluid grid result perfectly by rotations of nautical angle defined in DEFI_MODELE_GENE.

Code_Aster ®
Version
6.4

Titrate:
FDLV105 - Mass added on axisymmetric piston

Date:
16/07/03
Author (S):
***NR. GREFFET** Key*
:
V8.01.105-B Page:
1/4

Organization (S): EDF-R & D /AMA

Handbook of Validation
V8.01 booklet: Fluid
V8.01.105 document

FDLV105 - Mass added on axisymmetric piston coupled to a column of incompressible fluid

Summary:

This test of the field of the fluids implements a modal analysis on a system coupled fluid structure incompressible of type piston column of fluid with free face. The piston and the fluid are modelled respectively by machine elements and thermal axisymmetric. One validates the calculation thus of mass added in axisymmetric configuration.

Handbook of Validation
V8.01 booklet: Fluid HT-66/03/008/A

Code_Aster ®
Version
6.4

Titrate:
FDLV105 - Mass added on axisymmetric piston

Date:
16/07/03
Author (S):
NR. GREFFET Key
:
V8.01.105-B Page:
2/4

1
Problem of reference

1.1 Geometry

arises
piston
L = 1 m
Free face
Y
0
E = 0.03 m
X
H = 0.025 m
fluid

The system consists of a circular piston vibrating in contact with an annular column of fluid finished by a free face:

Length: 1 m
width: 0.03 m
height: 0.025 m

the axis of revolution is axis OY of the reference mark. OX indicates the radial axis.

1.2
Properties of materials

Structure: steel - material elastic

E = 2.1013 Pa
= 0.3
S = 7800 kg/m3

105
The spring has a stiffness by radian of K = 2 N/m/rad

Fluid: thermal material are equivalent

= 1.

C = 1000 kg/m3
F
p

1.3
Boundary conditions and loadings

Side structure: ddl DX of all the nodes of the structure is blocked: DX: 0.0

Fluid side: one imposes a pressure (i.e temperature) null on the nodes of the free face.

Titrate:
FDLV105 - Mass added on axisymmetric piston

Date:
16/07/03
Author (S):
NR. GREFFET Key
:
V8.01.105-B Page:
3/4

2
Reference solution

2.1
Method of calculation used for the reference solution

One solves the analytically following coupled problem:

F forces hydrodynamic pressure on the piston
m y& + K y = F

2

p
p pressure hydrodynamic in the fluid

= -0
with

y
2

m, K

: mass and stiffness of the piston respectively
p

= y

y
F &

by radian

The hydrodynamic field of pressure in the fluid is written:

p = - y& (y - L
F
)

from where the compressive force being exerted on the piston:

E

e2
F =
p R D R = -
y L
F

N
& 2
0

e2
the mass added by radian is worth: m = L
has
F

2

1
K
the clean mode of the coupled system is worth: F =
=
2
27.25Hz
m + my

2.2
Results of reference

Analytical.

2.3 References
bibliographical

[1]
GIBERT R.J. : Vibrations of the structures, Eyrolles (1988).

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3 Modeling
With

3.1
Characteristics of modeling

· Côté structure:

8 machine elements axisymmetric MEAXQU4,

1 specific element of type K_T_N modelling the spring,

· fluid side:

380 thermal elements axisymmetric THAXQU4 modelling the fluid,

8 thermal elements axisymmetric THAXSE2 modelling the fluid interface/structure.

3.2
Characteristics of the grid

Side structure:
8 meshs QUAD4
Fluid side:
8 meshs SEG2
1maille POI1
320 meshs QUAD4
A number of meshs:
337

3.3 Functionalities
tested

Orders

AFFE_MODELE "AXIS"
THERMICS

CALC_MATR_AJOU OPTION
"MASS_AJOU"

4
Results of modeling A

4.1 Values
tested

Identification Hz
Hz
% difference
Reference

Aster
N°1 mode
27.25
27.37
0.469

5
Summary of the results

The calculation of mass added on axisymmetric elements is very well carried out. One will note however that the calculated quantities are masses added by radian (divided by 2).

Organization (S): EDF/EP/AMV
Handbook of Validation
V8.01 booklet: Fluid
V8.01.106 document
FDLV106 - Calculation of added damping
in annular flow
Summary:
This test of the fluid field/structure implements the calculation of mass and damping added on one cylindrical structure subjected to an annular flow which one supposes potential. One calculates in a first
times mass and damping added by the flow on the structure for various speeds upstream (4 m/s, 4.24 m/s and 6 m/s), this on a model 3D for the fluid and hull for the structure. The structure has one displacement of rotation around a pivot located at the downstream end of the cylinder compared to the flow.

The determined coefficients, one assigns them to a discrete model are equivalent to 1 ddl mass-arise-shock absorber,
on which one carries out a modal analysis, in order to determine the complex Eigen frequencies of the system
for the various rates of flow:
4 m/s: damping,
4.24 m/s: critical engine failure speed, null damping,
6 m/s: negative damping, undulation.

1
Problem of reference
1.1 Geometry
L
V0
Z
entry
N
IH
N left
y
R
X
E
C
X
not
swivelling
roll fixed intern

fluid
external cylinder
mobile in rotation around the pivot C
L = 50 m
IH = 1 m
Re = 1.1 m
C: not pivot of the external structure
1.2
Properties of materials
Fluid: density G = 1000 kg/m3 (water).
Structure: S = 7800 kg/m3; E = 2.1011 Pa; = 0.3 (steel).
1.3
Boundary conditions and loadings
Fluid:
· to simulate the permanent flow, one imposes on the face of entry of the fluid a speed normal of 4 m/s (by thermal analysis, one imposes a normal heat flow equivalent of -4),
· to calculate the fluid disturbance brought by the movement of the external cylinder Dirichlet in a node of the fluid.
Structure:
&
L
&
one imposes on the external cylinder a displacement of the type X =
- y Z
I

with the nodes of
2
grid of this cylinder.

2
Reference solution

2.1
Method of calculation used for the reference solution

For the calculation of the added coefficients:

it is shown [bib1] that the coefficients of mass and added depreciation depend on permanent potential fluid speeds as well as two fluctuating potentials 1 and 2: these potentials are in the case of written the rotational movement of the external cylinder around the pivot C [bib1]:

= V y

0

R2

R2

L
L
1 =
E
R + I y +
sin

with X
y Z

2
2
I
R
2
2
E - IH
R

=
-

R2 V

R2

0
2 =
E
R + I sin

R2
2
E - IH
R

However the added modal coefficients projected on this mode of rotation are written:
M =
X. N dS

has
1
I
external cylinder
C =

2 +

.
has
(
1) (Xi. N) dS
external cylinder
that is to say:
V Re
2
0

3
R
C = -
R
I
+
L2
has
2
E
Re2 - R
R
I
E
R3

R2 L
3
M
E
= +
R
I
+

has
2
2
E
R - R
R 3
E
I
E

For the system with 1 degree of freedom are equivalent:
It is about a system mass-arise-shock absorber representing the rotational movement of roll around the pivot C downstream.

J
C

· the inertia of the mechanical system subjected to the flow is written: J = I + My
where I is the inertia of the external cylinder swivelling compared to axis Cx (cf appears below) in air.

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It is shown [bib2] that this inertia is worth:
m
I =
(3R2 +2 L2
E
)
6
where m is the mass of the cylinder:
m = 2 R E L
S
E
where E is the thickness of the cylinder, L its overall length.
S is the density of the cylinder.
Z
C
0
y
X
X
m
R3

R2 L3
2
2
E
I
thus J =
(3R +2 L +

+

E
)
R
2
2
E
6
R - R
R 3
E
I
E
· the damping of the mechanical system subjected to the flow is written: = A + Ca
where A is the damping of the mechanical system in air. Usually, A is equal to some
% of damping criticizes system: TO = 2 IK.
where I is the inertia of the cylinder in air calculated above and K the rigidity of the spring at the point of
swivelling C. One takes reduced damping equal to 1%.
Thus, the total damping of the system under flow is written:
R3
2
E

R
= IK - V
R
I
2
0
2
2
E +
L
Re - IH
Re
· the rigidity of the mechanical system subjected to flow is written: K = K + Ka
where K is the rigidity of the spring in air. Ka is the rigidity added by the flow. One shows [bib1] that this one is null on this mode of rotation.
K =
has
0

Thus the overall rigidity of the system is independent of the vitessse of flow.

K = K

· One calculates then the complex modes of this mechanical system under flow (vibrations free deadened):

J

+

+ C = 0

The complex Eigen frequencies of this system are written [bib3]:

R
2
= - ± -
1
2
I
1
or

K
K
with =
and
=
=
2
J
J
I + *My*
: reduced damping of the system
: own pulsation.

· Numerical Applications:

One made three calculations of damping added correspondent to three rates of flow which three involve behavior vibratory of the structure:

speed to 4 m/s
speed to 4.24 m/s
speed to 6 m/s

The values of the mechanical system are:

-
E = 2 1

. 0 2 *m*
L = 50 *m*
R = 1 *m*
R2 = 11
, *m*
I
I = 4 5
. 107 *kg m2*
8
-
To = 4 2
. 4 10 *N.m rad S*
1
13
-
K = 10
N.m rad 1
The added mass and damping brought by the flow are worth:
I = 16
. 6 1010 *kg m2*
has
(independent of the value rate of flow)
According to the speed of entry of the fluid, one a:
-
V = 4 *m/s*
C
8
= -4 00
.
10 *N.m rad S*
1
0
has
-
V = 4 2
. 4 *m/s*
C
8
= -4 24
.
10 *N.m rad S*
1
0

has
-
V = 6 *m/s*
C
8
= -594
.
10 *N.m rad S*
1
0
has
Depreciation of the fluid system/structure is written:
·
8
1
with *V* = 4 *m S*
=
-
/
:
0 24
.
10 *N.m rad S*
0
The flow does not amplify the vibrations. Structural damping interns is sufficient important to dissipate the energy brought by the flow to the structure.
The system is still deadened.
· with *V* =.
m/s:
0
4 24
0 (rate of flow criticizes)
The damping of the system is cancelled.
·
8
1
with *V* = 6 *m S*
= -
-
/
:
15
. 10 *N.m rad S*

0
(the flow amplifies the vibrations)
The damping of the system at this last speed is negative: the system enters then in **instability of undulation**.

Corresponding reduced depreciation is written:

-
V = 4 *m/s*
4
=
0
11
. 10
= 0 (in theory)
V = 4 2
. 4 *m/s*
0
5
=
-
1 380
.
10 (with the errors rounding)
-
V = 6 *m/s*
4
= -
0

6.6
. 10
The own pulsation remains as for it unchanged: = 12 5
. *Hz*.

2.2
Results of reference

Analytical result.

2.3 References
bibliographical

[1]
ROUSSEAU G., LUU H.T. : Mass, damping and stiffness added for a structure
vibrating placed in a potential flow - Bibliography and establishment in
Code_Aster - HP-61/95/064
[2]
BLEVINS R.D: Formulated for natural frequency and shape mode. ED. Krieger 1984
[3]
SELIGMANN D, MICHEL R: Algorithms of resolution for the quadratic problem
[R5.01.02], Handbook of Reference Aster.

---

3 Modeling
With

3.1
Characteristics of modeling

For the system 3D on which one calculates the added coefficients:
For the fluid:
480 meshs QUAD4
elements of hulls MEDKQU4
For the solid:

480 meshs QUAD4
elements thermics THER_FACE4
on cylindrical surfaces
360 meshs QUAD4
thermal elements THER_FACE4
on the faces of entry and exit of fluid volume
720 meshs HEXA8
thermal elements THER_HEXA8
in fluid annular volume

3.2 Functionalities
tested

Orders
Keys

CALC_MATR_AJOU
OPTION
"MASS_AJOU"
[U4.55.10]
"AMOR_AJOU"
POTENTIAL
MODE_ITER_INV
CALC_FREQ
FREQ
[U4.52.01]
MODE_ITER_SIMULT
APPROACH
"REAL"
[U4.52.02]

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
N°1 mode
with *V* = *m/s*
12.5 Hz
12.388
0.889
0
4
frequency
0.445
reduced damping
1.1 104
1.095 104
N°1 mode
with *V* =.
m/s
12.5 Hz
12.388
0.889
0
4 24
frequency
+0.895
reduced damping
1.380 105
1.392 105
N°1 mode
with *V* = *m/s*
12.5 Hz
12.388
0.889
0
6
frequency
0.740
reduced damping

6.60 104
6.649 104

4.2 Parameters of execution

Version: 3.06.08
Machine: CRAY C98
Obstruction memory:
80 MW
Time CPU to use:
51.7 seconds

5 Summary of the results

The computational tool of damping under flow (potential assumption) was validated on the mode of rotation of a cylindrical structure subjected to an annular flow. It is however necessary to note [bib1] that the very good agreement enters the semi-analytical model suggested for comparison and calculation numerical is obtained only if the cylinder is sufficiently long.
Indeed, the semi-analytical model is in fact only one approximate solution of the problem arising.

Handbook of Validation
V8.01 booklet: Fluid
Document: V8.01.107

FDLV107 - Rigidities added under flow
annular

Summary:

This test of the field of the interaction fluid-structure, validates the calculation of rigidity added on a circular cylinder
excited on its first mode of inflection rotulé-rotulé and subjected to annular flows the different ones speeds.

One calculates the rigidity added (function speed) on the first mode of inflection of the cylinder. One checks
decrease of the Eigen frequency of the mode, up to zero value for a critical engine failure speed flow of fluid.

Handbook of Validation
V8.01 booklet: Fluid HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
FDLV107 - Rigidities added under annular flow

Date:
01/03/04
Author (S):

1
Problem of reference

1.1 Geometry

fluid
U

U
Z
R

E
R I
y
X
With
B
L

The system represented on the diagram above is composed of two coaxial cylinders and a fluid in flow at the speed U in annular space enters the two cylinders. Dimensions are:

- *interior ray: IH = 1 m;*
- *external ray: Re = 1.05 m;*
- *length: L = 100 Mr.*

1.2
Properties of materials

Structure:

Young modulus: E = 2.1011 Pa;

Poisson's ratio: = 0.3;
density: S = 7800 kg/m3.

Fluid:

density: = 1000 kg/m3.

1.3
Boundary conditions and loadings

Structure:

blocking of the nodes of the interior cylinder;
kneecap at points A and B of the external cylinder.

Fluid:

one imposes various speeds in entry of the fluid field with equal normal heat fluxes
to 4 m/s, 0.5 m/s, 1.5 m/s, 2 m/s, 2.2 m/s and 2.688 m/s (critical engine failure speed).

1.4 Conditions
initial

Without object.

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is an approximate analytical solution. Analytical fluctuating potentials approached to calculate added rigidity are written [bib1]:

2
2

R

R
y L
+

E
I
2

1 (R, y)
(
)
=
R +
sin sin
2
2

R - R
R
L
E
I

2
2

R

R
y L

+

E
I
2

2 (R, y)
(
)
=
R +
sin cos

2
2
R - R
R
L

E
I

The rigidity added on the first mode of inflection of the external cylinder considered as a beam rotulé-rotulé is written [bib1]:

V 2 3R3
R2
K
0
E
I

With = -

2 (
R +
R2 - R
E
2

E
I) L

Re

This rigidity, calculated on a cylindrical geometry, is then assigned to a model with a degree of freedom are equivalent.

The system with 1 ddl equivalent is a system mass-arises equivalent to which one affects a mass equalize with the mass of the system increased by the mass added by the fluid and a rigidity equalizes with
rigidity of the system increased by the rigidity added by the flow for various speeds.

The mass of the system in air is of:

M = 10292 kg

for an external cylindrical hull thickness:

C = 2.103 m

For equivalent rigidity in air of the system "external hull", one takes the rigidity of a subjected beam with a force distributed over all its length:

F
d3e
K = 384EI
= 1.649 10-3 m
5L3
with
I =
8

thus K = 2.533.104
.
NR/m

The equivalent system coupled with the flow is represented by the following diagram:

m
K

with m = M + M
K = K + K
With
With

The own pulsation of the coupled system evolves/moves according to the square rate of flow. If one call V c0 the critical engine failure speed of flow for which rigidity K is cancelled:

2nd
R - I
R lK
0
V, K + K A (0
V)
2
(2 2)
= 0 with 0
V
=

C
C
C
2

I
R
3 3

+

E
R
E
R

E
R
Handbook of Validation
V8.01 booklet: Fluid HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
FDLV107 - Rigidities added under annular flow

then it is shown that:

(V
2
0) = ( )
0
1 - X
E

where one posed:

E
(0)
K
=

(
rest

with

fluid

in

system

clean

pulsation
)
M + MR. A

V
X = 0
(

of

reduced

speed
flow)
V0c

The pulsation of the fluid at rest is worth: = 0.085 rad/s.

2.2
Results of reference

One calculates for various rates of flow the Eigen frequency of the system.

V (m S)
0
/

0.5 1.5 2. 2.2
2.688
Mr. A (kg)
3.486E6 3.486E6 3.486E6 3.486E6
3.486E6
KA (N/m)
-876.5 -7888.50
-14023.95
-16968.98
-25330
Mtotal (kg)
3.491E+6 =
=
= =
Ktotal (N/m)
24453.5 17441.5 11306.05
8361.00 0.
F (V
1.318 1.112 0.896 0.772
0.

0) X 102 (Hz)

2.3 Uncertainty on the solution

Semi-analytical solution.

2.4 References bibliographical

[1]
ROUSSEAU G., LUU H.T. - Mass, damping and stiffness added for a structure vibrating placed in a potential flow - internal Note EDF/DER, HP-61/95/064/A (1995).

---

3 Modeling With

3.1 Characteristics of modeling

For the geometry on which one evaluates the added coefficients:

Fluid: *1800 thermal elements THER_HEXA8 1560 thermal elements THER_FACE4 of interface;*

Structure: *1200 elements of hull QUAD4 modeling "DKT".*

For the system with 1 ddl equivalent: 2 discrete finite elements modeling "DIS_T".

3.2 Characteristics of the grid

Grid 1 (hulls cylinders):
1800 meshs HEXA8 1560 meshs QUAD4

Grid 2 (discrete system):
1 mesh SEG2 1 nets POI1

3.3 Functionalities tested

Orders

CALC_MATR_AJOU OPTION
"RIGI_AJOU"

POTENTIAL

CHAM_NO

4 Results of modeling A

4.1 Values tested

Identification Reference

Aster
% difference
X 102
X 102
frequency to 0.5 m/s
1.318
1.332
+1
frequency to 1.5 m/s
1.112
1.130
+1.6
frequency to 2 m/s
0.896
0.917
+2.3
frequency to 2.2 m/s
0.772
0.795
+2.9
frequency to 2.688 m/s
0.
0.192

---

5 Summary of the results

The variation on the Eigen frequencies increases owing to the fact that when one is close the critical engine failure speed buckling, the rigidity of the equivalent system must tend towards zero. However, with the errors of round (since one assigns "to the hand" the values of rigidity added calculated by the operator to one discrete model) do not make it possible to obtain an own pulsation of the system null at the speed critical.
Variations on the added values of rigidity also remain because the reference solution is built on an semi-analytical solution which leaves the approximation according to which the separation of the variables between the dimension y and the co-ordinates orthoradiales is possible. It will be noticed that the selected potentials to describe the disturbance generated by the vibration of the structure in the fluid do not check the equation of Laplace compète but only in one transverse section of the fluid in co-ordinates orthoradiales. This approximation carried out on the reference solution can explain certain variations with numerical calculation.

Handbook of Validation
V8.01 booklet: Fluid HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
FDLV108 - Calculation of damping added in annular flow
Date:
01/03/04
Author (S):
NR. GREFFET, *G. Key ROUSSEAU*
:
V8.01.108-A Page:
1/6

Organization (S): EDF-R & D /AMA, EDF-DPN/UTO

Handbook of Validation
V8.01 booklet: Fluid
Document: V8.01.108

FDLV108 - Calculation of damping added in annular flow (variable density)

Summary:

This test of the fluid-structure field implements the calculation of mass and damping added on one cylindrical structure subjected to an annular flow which one supposes potential. One calculates mass

and
damping added by the flow on the structure for a speed upstream of 4 m.s1, on a model 3D
for the fluid and hull for the structure. The structure has a displacement of rotation around a pivot located at
the downstream end of the cylinder compared to the flow. The interest of the test lies in the taking into account of one
fluid field of nonhomogeneous density.

---

1 *Problem of reference*

1.1 Geometry

L
V 0
Z
nentrée
R I
1
2
nso rtie
y
R E

O
C
X
roll fixed intern
fluid
external cylinder
mobile in rotation compared to axis Cx

L = 50 m

R = 1 m
I

R = 1.1 m
E

C: not pivot of the external structure (swivelling around Cx)

1.2
Properties of materials

fluid: density 1 = 1000 kg.m3; 2 = 750 kg.m3;

Structure: S = 7800 kg/m3; E = 2.1 1011 Pa; = 0.3 (steel).

1.3
Boundary conditions and loadings

Fluid:

· to simulate the permanent flow, one imposes on the face of entry of the fluid a speed normal of 4 m/s (by thermal analysis, one imposes a normal heat flow equivalent from 4);
· to model the variation of density, one imposes a condition of continuity of flow with the interface;
· to calculate the fluid disturbance brought by the movement of the external cylinder one imposes a boundary condition of Dirichlet in a node of the fluid.

Structure:

L

· one imposes on the external cylinder a displacement of the type X =
- y Z
I

with the nodes of
2
grid of this cylinder.

2
Reference solution

2.1
Method of calculation used for the reference solution

For the calculation of the added coefficients:

one shows [bib1] that the coefficients of mass and added depreciation depend, in each area where is constant, of the permanent potential fluid speeds as well as two fluctuating potentials and: these potentials are written the movement in the case of of
1
2
rotation of the external cylinder around the pivot C [bib1]:

= V y

0
R2

R2

E
I

L
L

For the area relative to

R

1
=
+
y
sin
:
with X
y
1
Z
2
2
I

R - R
2
2
E
I
R
+

=
-

R2 V

R2

=
E
0
R + I sin
2
R2 - R2
E
I
R

V
= 1 0 y

2
2
R

2
R

E
I

L
L

For the area relative to

R

2
=

+
y
sin
:
1
with X
y
I
Z

2
R - 2
R
E
I
R
+

2
=
-

2

1
2
R V

2
R

=
E
0
R + I sin
2

2
2
2 R - R
E
I
R

However the added modal coefficients projected on this mode of rotation are written:

M =
X. N dS
has

1 I
external cylinder

Ca =
(+ .
2
1) (Xi. N) dS
external cylinder

maybe by separating the integral on two half-cylinders:

V R2
C
0
E
2
2
2
has = -
+
1
E
2 (R
R
E
I) L
R - R
2
I

R2
L
3
M
E
2

2
has = (7 +
1
2)
+
E
2 (R
R
E
I)
R - R
3
2
I

· Numerical Applications:

One made a calculation of added damping which corresponds for the speed given to one deadened vibratory behavior of the structure:

V0 speed to 4 m.s1

The values of the mechanical system are:

E =
-2 m

L =
m
R = m
R =
m
With =
8 NR m rad -
2 10
50
1
11
4 24 10
1
.
,
.
.
S
I
2

The added mass brought by the flow is worth:

M
kg m
has = 1.614.109
2
.
(independent of the value rate of flow)

Added damping is worth with V0 = 4 m.s1 (it is independent of the change of mass voluminal):

C
NR m rad S
has = -
-
0.399.109
1
.
.

Knowing that the damping of the mechanical system is worth A =
NR m rad -
4 24 108
1
.
.
S,
the total damping of the fluid system/structure is written:

· with V =
m S
8
= -
NR m rad 1
4
15 10
-
/
:
.
.
S
0

The flow does not amplify the vibrations. Structural damping interns is sufficient important to dissipate the energy brought by the flow to the structure. The system is still deadened.

2.2
Results of reference

Analytical result.

2.3 References
bibliographical

[1]
ROUSSEAU G., LUU H.T. : Mass, damping and stiffness added for a structure vibrating placed in a potential flow - Bibliography and establishment in Code_Aster - HP-61/95/064

Handbook of Validation

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3 Modeling
With

3.1
Characteristics of modeling

For the system 3D on which one calculates the added coefficients:

For the solid:
240 meshs QUAD4
elements of hulls MEDKQU4

For the fluid:
240 meshs QUAD4

thermal elements THER_FACE4

on cylindrical surfaces

540 meshs QUAD4

thermal elements THER_FACE4

on the faces of entry, of exit and interface *fluid volume*

720 meshs HEXA8

thermal elements THER_HEXA8

in fluid annular volume

3.2 Functionalities
tested

Orders

CALC_MATR_AJOU OPTION
“MASS_AJOU”

“AMOR_AJOU”

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster error
(%)
Added coefficients

mass:
1.614 109
1.608 109
0.3
damping
-0.399 109

-0.393 109
0.15

5
Summary of the results

The computational tool of damping under flow (potential assumption) was validated on the mode of rotation of a cylindrical structure subjected to an annular flow with density variable. It should however be noted [bib1] that the very good agreement enters the semi-analytical model proposed for comparison and numerical calculation is obtained only if the cylinder is sufficiently length, the semi-analytical model being makes of it only one approximate solution of the problem arising.

NR. GREFFET, G. Key ROUSSEAU

Organization (S): EDF-R & D /AMA, EDF-DPN/UTO

FDLV109 - Calculation of coefficients added in plane flow

Summary:

This test of the fluid field/structure implements the calculation of mass, rigidity and damping added on
a plane structure subjected to a confined flow which one supposes potential. These added coefficients are
calculated for a speed upstream of 4 m.s1, on a model 3D for the fluid and hull for the structure.
structure is subjected to an imposed displacement of inflection.

HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
FDLV109 - Calculation of coefficients added in plane flow
Date:
01/03/04
Author (S):
NR. GREFFET, G. Key ROUSSEAU
:
V8.01.109-A Page:
2/6

1 Problem of reference

1.1 Geometry

L
V0
X
Z
y
N
nsortie
entry
O
L
E
fluid

L = 50 m

I = 5 m

thickness of fluid E = 0.5 m

thickness of the plate H = 0.5 m

E
the Oxyz reference mark is at a distance from
plate
2

1.2
Properties of materials

Fluid: density = 1000 kg.m3 (water).

Structure: = 7800 kg/m3; E = 2.1 1011 Pa; = 0.3 (steel).
S

1.3
Boundary conditions and loadings

Fluid:

· to simulate the permanent flow, one imposes on the face of entry of the fluid a speed
normal of 4 m/s (by thermal analysis, one imposes a normal heat flow equivalent
from 4),
· to calculate the fluid disturbance brought by the movement of the external cylinder one imposes
a boundary condition of Dirichlet in a node of the fluid.
E
· one imposes in X =
the condition = = which corresponds to a null flow through
2
1
2
0
higher fluid wall.

Structure:

· the plate is subjected to a displacement corresponding to its first two modes of
inflection [bib2]:

y
2y
X = sin
; X
1
= sin

2
Reference solution

2.1
Method of calculation used for the reference solution

For the calculation of the added coefficients:

it is shown [bib1] that the coefficients of mass and added depreciation depend on permanent potential fluid speeds as well as two fluctuating potentials and
1
2: these
potentials are in the case of written the movement of inflection of the plate [bib1]:

( )
1 =

V y
0
( )1
E

y
For the first mode:

= X -
sin

1

2

L
() V
E
y
1
0

2 =
X -
cos
L
2

L

(2)

=

V y
0
(2)
E
2y
For the second mode:

= X -

sin

1

2

L
(2)
V
2
E
2 y

0

2 =
X -
cos
L
2

L

However the added modal coefficients projected on these modes of inflection are written:

has
(I)
M =
X. N dS
ij

1
J
external cylinder
has
(I)
(I)
(I)
Cij =

.
.

external cylinder (
+

2

1) (X J N) dS
has
(I)
(I)
Kij =

.
.
external cylinder (
2) (X J N) dS

that is to say:

L
M has = M has = el
; M has
11
22
12 = 0
2
8
Ca = Ca = 0; Ca = Ca = - elV
11
22
12
21
0

3
2
L
2
2 L
K has = - eV 2
; K has = - eV 2
; K has
11
0
= 0
2L
22
0
L

· Numerical Applications:

One made a calculation of added damping which corresponds for the speed given to one deadened vibratory behavior of the structure:

V0 speed to 4 m.s1

The values of the mechanical system are:

E = H =
-
510 1
.
m
L = 50m
L = 5 m

The added mass brought by the flow is worth:

M has
5
= 0 625
.
10

kg
11
M has
5
= 0 625
.
10

kg
22

M a12 = 0

Added damping is worth with V0 = 4 m.s1:

Ca11 = 0
Ca22 = 0

Ca
5
= 0 266
.
10 N.m 1
-
12

The added stiffness is worth with V0 = 4 m.s1:

K has
4
= 0
- 3943
.
10 N.m 1
- rad 2
11
K has
5
= -01577
.
10 N.m 1
- rad 2
22

K a12 = 0

2.2
Results of reference

Analytical result.

2.3 References
bibliographical

[1]
ROUSSEAU G., LUU H.T. : Mass, damping and stiffness added for a structure vibrating placed in a potential flow - Bibliography and establishment in Code_Aster - HP-61/95/064
[2]
BLEVINS R.D: Formulated for natural frequency and shape mode. ED. Krieger 1984

---

3 Modeling
With

3.1
Characteristics of modeling

For the system 3D on which one calculates the added coefficients:

For the solid:
160 meshs QUAD4
elements of hulls MEDKQU4

For the fluid:
160 meshs QUAD4

elements thermics THER_FACE4

on the plane surface

184 meshs QUAD4

thermal elements THER_FACE4

on the faces of entry and exit of fluid volume

480 meshs HEXA8

thermal elements THER_HEXA8

in fluid volume

3.2 Functionalities tested

Orders

CALC_MATR_AJOU OPTION “MASS_AJOU”

MACRO_MATR_AJOU OPTION MATR_AMOR_AJOU

MATR_RIGI_AJOU

MODE_ITER_SIMULT OPTION “BAND”

4 Results of modeling A

4.1 Values tested

Identification Reference Aster** % **difference
M has
0.625 105 0.624
105 0.1
11
M has
0.625 105 0.621

105 0.6
22
M has
0 0.6
10-6 -
12
Ca
0 -0.81
10-6 -
11
Ca
0 -0.68
10-6 -
22
Ca
0.266 105 0.265
105 0.3
12
K has
-0.394 104 -0.394
104 0.0
11
K has
-0.157 105 -0.157
105 0.0
22
K has
0 -0.134
10-5 -
12
Handbook of Validation
V8.01 booklet: Fluid
HT-66/04/005/A

Code_Aster ®
Version
7.2

Titrate:
FDLV109 - Calculation of coefficients added in plane flow
Date:
01/03/04
Author (S):

5
Summary of the results

The computational tool of coefficients added under flow (potential assumption) was validated on
the first two modes of inflection of a plane structure. It should however be noted [bib1] that the very maid
agreement between the semi-analytical model suggested for comparison and numerical calculation is not
obtained that if the plate is sufficiently long, the semi-analytical model being does only one of them
approximate solution of the problem arising.

Handbook of Validation
V8.01 booklet: Fluid
Document: V8.01.110

FDLV110 - Calculation of mass added on modes obtained by under-structuring

Summary:

This test of the field of the modal analysis and the interaction fluid-structure implements the calculation of mass
added on a structure made up of three concentric cylinders separated by two rings from fluid (water) which one supposes the behavior governed by the potential theory (fluid true, incompressible at rest). model is three-dimensional for water. The structure is represented by elements of the mean hull type in modeling A (the structure is rigid in the reference solution). This one is characterized by two clean modes evaluated by dynamic under-structuring, with interface of the type CRAIG-BAMPTON. The interest of the test lies in the use of the functionality `NOEUD_DOUBLE `of the operator `CALC_MATR_AJOU `.
This functionality makes it possible to calculate the effects of added mass of a structure represented by a grid
surface (without thickness) which is bathed in a fluid. The fluids chosen in this case-test are of densities different on both sides from the intermediate cylinder (water at different temperatures).

1
Problem of reference

1.1 Geometry

L
surface fluid
k2
Z
IH
R
y
F
X
Re
springs
fluid
k1
roll medium
external cylinder

5
L=50m; Rf=1m; Ri= m; R
3
e=3m; k1=109 N.m1; k2=0.5 107 N.m1; fluide=1000 kg.m3;
s=7800 kg.m3; thickness of the hull: 50 cm.

1.2
Properties of materials

Fluid: density 1 = 1000 kg.m3; 2 = 750 kg.m3.

Structure: = 7800 kg/m3; E = 2.1 1011 Pa; = 0.3 (steel).
S

1.3
Boundary conditions and loadings

The external cylinder on the one hand is connected to a fixed frame via the four springs of unit stiffness k1,
connected in addition to the cylinder medium by four springs of unit stiffness k2. The two structures are
rigid in this reference solution.

2
Reference solution

One calculates the clean modes of the system after having checked those of each substructure. One evaluate then the mass added on the modes in air.

2.1
Decomposition in substructures

First substructure: roll intermediate

The first substructure is consisted of the intermediate cylinder and four springs of stiffness k2 = 107 N.m1. These springs are embedded with the interface with the external cylinder which constitutes
second substructure (interface of the type CRAIG-BAMPTON).

IH
k2

Mass cylinder 1: m1 = 2.041 106 kg

The cylinder being rigid, its movement can be modelled by a system mass-arises with a degree of freedom:

m1

Achacune of its ends, the cylinder is connected to two springs in parallel: equivalent stiffness of each one = 2k2 is k'

1
2k
1
4k
The Eigen frequency is worth then:
2
F =
=
, that is to say: F = 0 705
.
Hz
2
1
m
2
1
m

Second substructure: roll external

The second substructure is the external cylinder connected on the one hand to the interface by the same ones
springs, in addition with a fixed frame:

Re
k1
K

Mass cylinder 2: m2=3,674 106 kg
Handbook of Validation
V8.01 booklet: Fluid
HT-66/04/005/A

Equivalent stiffness of a fastener of this cylinder by the system of springs in series k1 and k2 being worth
9,9.106 N.m1 (four fasteners of the same type connect in parallel the cylinder to an embedding), Eigen frequency is given by:

1
4k2 1
K (k2 + 1
K)
F =
, that is to say: F =.
0.522Hz
2
1
m

N.B.: the third cylinder (interior cylinder) was not modelled in our case because it agint of one fixed cylinder. It thus constitutes a fixed wall of the fluid field.

Modes in air of the structure supplements (intermediate cylinder and external cylinder)

It is a system with two degrees of freedom:

m2
m1
k3=4k1
k4=4k2

The Eigen frequencies of this system are given by the exact formula [bib2]:

1
K
K
K
K
K
K 2
K K
F =
3 + 4 + 4 ± 3 + 4 + 4 - 4 3 4
,
I
32
m
m
m

2
2
1
m
m
m
2
2
1
m m
2
1
2

that is to say

F = 0.497

and

Hz
F = 5.
Hz
263
1
2
.

The two clean modes admit, for numerical value:

X

X
3
1

-
.

1
1
- 9 10

=
and
=

.
X
-3

5. 10
X
2

1

1

2 2

2.2 Calculation of the matrix of added mass

Fluid potentials

Beginning again [bib1], it is established that:

2
R + 2
2
2
R

2
2
( )
1
2 I
F
R +
E
I
R
= R
+
I
R
E
R
1
;
I
(-3
5.e)
2
+

×

R

2
2
2
2
E
2
2

R - R
R - R
R -
I
F
E
I
E
I
R
and

2
R + 2
2
2
R

2
2
(2)

=
I
F
E
R
I
R
I
R
E
R
1
(- -3

9.e)
2
+
2
+

× I
R
+
; R
2
2
2
2nd
2
2

R - R
R - R
R -
I
F
E
I
E
I
R

The shape of the matrix of added mass, in this configuration, is:

11
12
M
M
M =
has
has
has

21
22
M has
M has

With:

2
2

2
2
R + R

11
2 I
F
R +
I
E
R
M
=
has
L
R
+

I
= 753
,
1
.106 kg,
2
2
2
2

R - R
R -
I
F
E
I
R

2
2
R + R
22
2
I
E

M
=
has
L
R

E
= 676
,
2
10
. 6 kg,

2
2

R -
E
I
R

2
2

2
2
R + R

2
2
-
I
F
R + R

I
E
-
R + R
12

I
E

M
=
has
L
5
(10
.
3)
2
× R
+

- 9
(10
.
3)
2
× R

I
E
= 15318
-
kg.
2
2
2
2
2
2

R - R
R -
I
F
E
I
R
R -
E
I
R

The coefficient of inertial coupling
12
M A is regarded as negligible in front of the coefficients of added car-mass
11
M has and 22
M A. the Eigen frequencies of the system do not depend, in first approximation, that from these two dernièrs coefficients.

2.3
Results of reference

Analytical result.

2.4 References
bibliographical

[1]
ROUSSEAU G., LUU H.T. : Mass, damping and stiffness added for a structure vibrating placed in a potential flow - Bibliography and establishment in Code_Aster - HP-61/95/064
[2]
BLEVINS R.D.: Formulated for Natural frequency and shape mode, ED. Krieger
Handbook of Validation
V8.01 booklet: Fluid
HT-66/04/005/A

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3 Modeling
With

3.1
Characteristics of modeling

For the system 3D on which one calculates the added coefficients:

Roll:
2400 meshs QUAD4
elements of hulls MEDKQU4

12 meshs SEG2
elements springs MECA_DIS_T_L

Fluid:
3600 meshs QUAD4

thermal elements THER_FACE4

on cylindrical surfaces

7200 meshs HEXA8

thermal elements THER_HEXA8

in fluid annular volume

3.2 Functionalities tested

Orders

CALC_MATR_AJOU OPTION “NOEUD_DOUBLE”

“MASS_AJOU”

4
Results of modeling A

4.1 Values
tested

Frequencies analytical
Calculated frequencies
Variation (%)
in air (Hz)
in air by Aster (Hz)

First mode in air
0.497 0.496
0.2
Second mode in air
5.263 5.147
0.2

Mass added theoretical calculated added Masse
Variation (%)
(kg)
(kg)

M11
1.753 106 1.741
106 0.6
M22
2.675 106 2.567
106 4.0

Frequencies analytical
Water frequencies
Variation (%)
modes out of water (Hz) calculated by Aster (Hz)

First mode out of water
0.365
0.364
0.2
Second mode out of water
4.004 4.061
1.0

5
Summary of the results

The calculation of mass added on modes estimated by under-structuring is satisfactory. This has licence to validate option "NOEUD_DOUBLE" of order "CALC_MATR_AJOU". The variation observed on
the second coefficient of added mass is explained by the discretization of the second cylinder.
a many elements are a little insufficient to calculate in an exact way the integral of the field of pressure on the structure.

Handbook of Validation
V8.01 booklet: Fluid
Document: V8.01.111

FDLV111 - Absorption of a wave of pressure in a fluid column

Summary:

One tests the fluid paraxial elements of order 1 intended to apply conditions absorbing to the border

of a grid finite elements to simulate the infinite one in direct transitory calculations.
Are used they to model an infinite fluid column, in 3D or 2D, in which one creates a wave of pressure using a piston. One is interested in nonthe reflexion of the wave at the "infinite" end of the column.
One tests successively the two direct transitory operators of Code_Aster, namely DYNA_LINE_TRAN and
DYNA_NON_LINE.
Handbook of Validation
V8.01 booklet: Fluid HT-62/01/012/A

1
Problem of reference

1.1 Geometry

The system considered in the case 3D is that of a column of fluid with square section and of a piston of the same section animated of a rigid movement of body according to the axis of the column. Side surface
column consists of a motionless rigid guide. One places the elements absorbents on the face opposed to the piston to simulate the infinite character of the column in this direction. In the case 2D, the principle is identical with a very broad supposed column and a piston which one does not model that a vertical section (see diagram).

Z

X

Piston
Acoustic fluid
Surface absorbing

Section case 3D:
Section case 2D:

Z

y

1.2
Properties of materials

Piston: concrete

Acoustic fluid: water

Density:
2400 kg.m3
Density:
1000 kg.m3
Young modulus:
3,6.1010 Pa
Celerity:
1500 m.s1
Poisson's ratio: 0,48

1.3
Boundary conditions and loadings

One has on side surface of the column the elements fluid-structure which one blocks the ddl displacements with zero to reproduce the condition of rigid wall.
One imposes on all the nodes of the face of the piston in contact with the fluid a displacement according to X
with the function of following temporal excitation:
Displacement of the piston according to X
1,00E+00
9,00E-01
8,00E-01
)
m 7,00E-01
6,00E-01
5,00E-01
4,00E-01
3,00E-01
Displacement (2,00E-01
1,00E-01
0,00E+00
-0,1
0,1
0,3
0,5
0,7
0,9
1,1
1,3
1,5

Time (S)

1.4 Conditions initial

The displacement of the piston is null at the initial moment and the fluid is at rest.

2 Reference solution

The solution must show the absorption of an acoustic wave by absorbing surface. The movement piston is a uniform translation according to the x axis. Taking into account the symmetry of the problem around this axis, one will obtain an identical field of pressure in all the plans X = Cte. Moreover, the absorbing border is orthogonal with this axis. One thus studies the absorption of waves of pressure plane under normal incidence. The theory [bib1] known as that with a fluid paraxial border of order 1, this absorption is perfect. It is what one must check with this reference solution.

One thus goes, by observing the evolution of the pressure in a given point of the grid, to stick to to find in the signal obtained the duration of excitation and the return at rest after the passage of the wave, characteristic of its absorption.

4/10

2.1
Results of reference

One gives in this paragraph the results obtained with Code_Aster in this configuration. One check that they are satisfactory and one takes them as reference for the future.
They concern, for the case 3D, the evolution of pressure in a point of the fluid located at 150 m of the piston in direction X and in the center of the section in the yz plan. For the case 2D, the point is located at 40 m piston according to X and in the middle of the section in the direction y (in 2D, one takes a shorter grid and refined).
Pressure in the fluid - case 3D
8,00E+03
6,00E+03
4,00E+03
2,00E+03
0,00E+00
0,00E+00
5,00E-01
1,00E+00
1,50E+00
2,00E+00
2,50E+00
-2,00E+03
Pressure (Pa)
-4,00E+03
-6,00E+03
-8,00E+03
Time (S)

Pressure in the fluid - case 2D
5,00E+03
4,00E+03
3,00E+03
2,00E+03
1,00E+03
0,00E+00
-1,00E+03
0,00E+00

5,00E-01
1,00E+00
1,50E+00
2,00E+00
2,50E+00
Pressure (Pa) -2,00E+03
-3,00E+03
-4,00E+03
-5,00E+03
Time (S)

As envisaged, the width of the signal measured in both cases is identical to that of the function of excitation. Physically, one observes well compression due to advanced piston, then depression corresponding to its retreat to return to its initial position. One notes also clearly the return at rest immediately after the passage of the wave and the absence of signal thought of the end of the grid.

2.2 Uncertainties

It is about a numerical result of the study. The qualitative forecasts are found. Values numerical are related to the precision of calculation. Only the return at rest is clearly given by analysis.

2.3 References bibliographical

[1]
B. ENGQUIST, A. MAJDA "Absorbing boundary conditions for the numerical simulation of waves. "Mathematics of Computation (1977).

3
Modeling a: case 3D

3.1
Characteristics of modeling

Piston: PHENOMENON: "MECHANICAL"
MODELING: "3D"

Fluid: PHENOMENON: "MECHANICAL"

MODELING: "3D_FLUIDE"

3.2
Characteristics of the grid

A number of nodes: 54
A number of meshs and types: 20 HEXA8
40 QUA4 (faces of HEXA8)
Node 47
201 m
Node 16
50 m

Node 18

3.3 Functionalities tested

Orders

AFFE_MODELE AFFE MODELING 3D_FLUI_ABSO DYNA_LINE_TRAN

DYNA_NON_LINE

3.4 Values tested

One tests the values of the pressure to nodes 16, 18 and 47 (see grid). For node 16, one tests the two maximum ones (compression and depression) and the return at rest. For nodes 18 and 47, one tests the maximum in compression.

.

DYNA_LINE_TRAN:

Node
Moment (S)
Calculation with
Results of
Variations reference -
Code_Aster
reference
calculation with
(Pa Pressure)
(Pa Pressure
Code_Aster (%)
N16 4.71250D01 7.13737D+03
NON_REGRESSION
NON_REGRESSION
7.27500D01
7.08305D+03
NON_REGRESSION
NON_REGRESSION
1.27375D+00 0.182
0.
0.182
ABSOLUTE
N18 4.71250D01 7.13737D+03
NON_REGRESSION
NON_REGRESSION
N47 3.72500E01 7.09321E+03
NON_REGRESSION NON_REGRESSION

.
DYNA_NON_LINE:

Node
Moment (S)
Calculation with
Results of
Variations reference -
Code_Aster
reference
calculation with
(Pa Pressure)
(Pa Pressure
Code_Aster (%)

N16 4.71000E01 7.11473E+03
NON_REGRESSION NON_REGRESSION
7.26000E01
7.00022E+03
NON_REGRESSION NON_REGRESSION
1.20000E+00 37.5
0.
37.5
ABSOLUTE
N18 4.71000E01 7.11473E+03
NON_REGRESSION NON_REGRESSION
N47 3.72000E01 7.08110E+03
NON_REGRESSION NON_REGRESSION

3.5 Parameters
of execution

Version: 5.2.16

Machine: SGI ORIGIN 2000 (claster)

Time CPU: 300
Memory: 64 Mo

4
Modeling b: case 2D

4.1
Characteristics of modeling

Piston: PHENOMENON: "MECHANICAL"
MODELING: "D_PLAN"

Fluid: PHENOMENON: "MECHANICAL"

MODELING: "2D_FLUIDE"

4.2
Characteristics of the grid

25 m

51 m
Node 7
Node 10

A number of nodes: 35

A number of meshs and types: 24 QUA4

18 SEG2 (faces of QUA4)

4.3 Functionalities
tested

Orders

AFFE_MODELE AFFE
MODELING
2D_FLUI_ABSO
DYNA_LINE_TRAN

4.4 Values
tested

One tests the values of the pressure to nodes 7 and 10 (see grid). For node 10, one tests them two maximum (compression and depression) and the return at rest. For node 7, one tests the maximum
in compression.

.
DYNA_LINE_TRAN:

Node
Moment (S)
Calculation with
Results of
Variations reference -
Code_Aster
reference
calculation with
(Pa Pressure)
(Pa Pressure
Code_Aster (%)
N10 3.86000E01 4.88962E+03

NON_REGRESSION NON_REGRESSION
6.37000E01
4.93961E+03
NON_REGRESSION NON_REGRESSION
1.15600E+00 0.434
0.
0.434
ABSOLUTE
N7 3.86000E01
4.89074E+03
NON_REGRESSION NON_REGRESSION

.
DYNA_NON_LINE:

Node
Moment (S)
Calculation with
Results of
Variations reference -
Code_Aster
reference
calculation with
(Pa Pressure)
(Pa Pressure
Code_Aster (%)
N10 3.84000E01 4.87451E+03
NON_REGRESSION NON_REGRESSION
6.44000E01
4.88583E+03
NON_REGRESSION NON_REGRESSION
1.09400E+00
3.1
0.
3.1
ABSOLUTE
N7 3.84000E01 4.88877E+03
NON_REGRESSION NON_REGRESSION

4.5 Parameters
of execution

Version: 5.2.16

Machine: SGI ORIGIN 2000

Time CPU: 500
Memory: 64 Mo

5
Summary of the results

One finds by calculation with two modelings qualitatively, the maximum ones of pressure with good moments and the return at rest after the passage of the wave.
The results obtained with operators DYNA_LINE_TRAN and DYNA_NON_LINE are very close.
The difference comes from obtaining to each step in time from the state from balance from the efforts from the second
member with operator DYNA_NON_LINE. This difference remains however tiny because the step of time used with DYNA_LINE_TRAN is sufficiently small.

Code_Aster ®
Version
6.4

Titrate:
FDLV112 - Calculation of stopping with reserve under seismic request
Date:
23/06/03
Author (S):
***G. DEVESA**, D. NUNEZ Key*
:
V8.01.112-A Page:
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Organization (S): EDF-R & D /AMA, CS IF

Handbook of Validation
V8.01 booklet: Fluid
Document: V8.01.112

FDLV112 - Calculation of stopping with reserve under seismic request

Summary:

The goal of this case test is to validate the functionalities of calculation coupled fluid-structure of stopping with reserve

under seismic request by taking of account the assumption of incompressibility, therefore of mass added for
reserve like that of forces added to model the movement of drive of this reserve due
with the seismic excitation.
Calculation is linear, transitory on modal basis.

1
Problem of reference

1.1 Geometry

The geometry consists of 2 subsets: the arch dam [Figure 1.1-a] and reserve [Figure 1.1-b].

Appear 1.1-a: Arch dam

Appear 1.1-b: Reserve

1.2
Properties of materials

The stopping consists of concrete:

E 36000
MPa

0.2

2400 Kg/m3

Reserve consists of water (= 1000 Kg/m3)

1.3
Boundary conditions and loadings mechanical

One blocks the N130 node at the base of the stopping and one imposes on the group of nodes BARFOND, which
constitute the bottom of the stopping in contact with the foundation, a uniform displacement in all them
directions. The N130 node interdependent of all group BARFOND is subjected to a seismic excitation in the 3 directions of space. The 3 accélérogrammes are represented on the figures
[Figure 1.3-a], [Figure 1.3-b], [Figure 1.3-c] below.

Appear 1.3-a: Acceleration in X

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Appear 1.3-b: Acceleration in Y

Appear 1.3-c: Acceleration in Z
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23/06/03
Author (S):
G. DEVESA, D. NUNEZ Key
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2
Reference solution

2.1
Method of calculation used for the reference solution

The data of this test are draw from a general study implementing the functionalities from Code_Aster to deal with the problems of seismic analysis of the concrete dams [bib1]. Results obtained were confronted with those obtained with software EACD dedicated to this kind of

calculation.
However, there no were precise statements of value with this software. This is why one directs oneself towards
a numerical solution and results of nonregression obtained exclusively with
Code_Aster.

2.2
Results of reference

One tests in m/s2 maximum acceleration according to the 3 directions and the spectrum of response of oscillator
corresponding (SRO) for a damping of 5% to the N1909 node, medium of the higher edge of stopping.

2.3
Uncertainty on the solution

Numerical solution.

2.4 References
bibliographical

[1]
E. CHAMPAIN: "Seismic Analysis of the concrete dams with Code_Aster" -
NT HT-62/01/023/B
Handbook of Validation
V8.01 booklet: Fluid
HT-66/03/008/A

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3 Modeling With

3.1 Characteristics of modeling

Modeling A relates to the incompressible fluids with added masses. One thus does not model that the water stopping and not reserve. The latter is taken into account only in macro-order MACRO_MATR_AJOU.

3.2 Characteristics of the grid

The grid includes/understands 80 meshs of the type PENTA15 and 696 meshs of the type HEXA20. The stopping is modelled in 3D.

3.3 Functionalities tested

Orders
MACRO_MATR_AJOU MASS_AJOU
FORC_AJOU

4 Results of modeling A

4.1 Values tested

Identification	Reference (m/s2)	Aster (m/s2)	Difference
ACCEX (T = 1.0 S)	5.85886	5.85886	0
SROX (F = 9.0 Hz)	17.6053	17.6053	0
ACCEY (T = 1.0 S)	2.80757	2.80757	0
SROY (F = 9.0 Hz)	9.7625	9.7625	0

ACCEZ (T = 1.02 S)
-0.77467 -0.77467 0
SROZ (F = 17.4 Hz)
3.81459 3.81459 0

5
Summary of the results

The results obtained were confronted with those obtained with software EACD dedicated to this kind of
calculation. Although there no were precise statements of value with this software, the study [bib1] concluded with
a good agreement with Code_Aster. However, one refers in this test with results of
not regression obtained exclusively with Code_Aster.

Handbook of Validation
V8.03 booklet: Nonlinear fluid
Document: V8.03.100

FDNV100 - Shaking of a water tank with
elastic deformable wall

Summary:

This test, of the fluid-structure field, proposes the implementation of a transitory dynamic calculation (operator
DYNA_NON_LINE) with taking into account of a free face. Being given the absence of values of reference
adapted, it is about a case-test of nonregression.

1
Problem of reference

This case-test, based on the model of the article [bib1], aims to test the correct taking into account of a free face in a calculation fluid-structure coupled with operator DYNA_NON_LINE.

1.1 Geometry

One considers a parallelepipedic tank, filled with water, whose external walls are indeformable. This rigid tank comprises a deformable internal plate, named. It is embedded at its base at the bottom of the tank, its sides vertical being free. This flexible wall exceeds free face a 12,9 cm height:

Deformable plate
Q
Z
free face
12,9cm

free face
N3119
N145
fluid field
FONDP
: segment of right-hand side
intersection of the bottom (FUNDS) and of
z=18,2cm
the vertical deformable plate
y
x=19,1cm

X
MELT: bottom of
r=23,1cm
fluid field
y=10cm
X

1.2
Properties of materials

The fluid (water) contents in the tank has as characteristics:

density:
F = 1000 kg/m3
speed of sound:
C = 1500 m/s

The deformable wall is elastic linear (duralumin):

density:
S = 2787 kg/m3
Young modulus:
E = 62,43 Gpa
Poisson's ratio:
= 0,35

1.3
Boundary conditions and loading

1.3.1 Conditions of Dirichlet

The loading defined here is of the displacement type imposed on a surface. More precisely, one consider that the bottom of the tank can move only according to direction X.

According to this direction X, one will request the system by imposing on the bottom of the tank a displacement
sinusoidal in time, of frequency 1,7704 Hz and amplitude 0,001 Mr.

This imposed displacement can be compared to a request of the mono-support type applied by base tank (seismic application).

1.3.2 Conditions of Neumann

In superposition in the surface condition of Dirichlet previously defined, one subjects also it model with the field of gravity (imposed voluminal effort).

Lastly, the upper surface of the fluid field is seen characterized by conditions of the type surfaces free.

2
Reference solution

2.1
Method of calculation used for the reference solution

The only results of the literature [bib1] are modal types: Eigen frequencies and paces of certain modes.

Being given the need for testing operator DYNA_NON_LINE, and being given relative complexity model which is 3D, it is not possible to find the Eigen frequencies by transitory analysis in a reasonable time CPU.
For information, this type of analysis carried out with a random loading corresponding to a noise

white requires, for reasons of probabilistic convergence, a calculation for a physical time of loading of 250 S, which corresponds to a time CPU of a few hours.

In order to have a computing time about a few minutes, it is obligatory to calculate the evolution over a time runs (a few seconds). This restrictive framework does not make it possible to find precisely and in a way compatible with a postprocessing automated the results of modal analysis.
The validation brought by this test can thus be only of the type not regression of the solution numerical.
As the functionalities of calculation coupled fluid-structure are the subject already of a certain number of
tests of validation in addition, this limitation with nonthe regression for this particular case-test is not crippling.

As complementary validation, complete calculation with signal of 250 S.A. carried out.
spectra at the points of observations indeed showed a good agreement with the results of modal analysis of [bib1].

2.2 Results of reference

One tests values of displacements at various moments, according to direction X, for two points of grid: N145 and N3119. These points are on the free face, on both sides of the wall deformable, as one can see it on the diagram of the paragraph [§1.1].

2.3 Uncertainty on the solution

Numerical solution (calculated with version 7.03.06 of the code).

2.4 Reference bibliographical

[1]
BERMUDEZ A., RODRIGUEZ R., SANTAMARINA D.: "Finite element computation of sloshing modes in containers with elastic baffle punts ", Int. J. Numer. Meth. In Engrg., Flight. 56, 447-467, 2003
Handbook of Validation
V8.03 booklet: Nonlinear fluid
HT-66/04/005/A

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3 Modeling With

3.1 Characteristics of modeling

Modeling 2D_FLUI_PESA

Modeling

DIST_TR

Q
Modeling
solid 3D
On each immersed side
deformable plate:
modeling FLUI_STRU
Modeling
3D_FLUIDE
GRID CASE TEST 2D_FLUI_PESA

· The total grid comprises 8163 nodes, that is to say approximately 125000 ddls,
· The specific element Q (modeling DIS_TR) makes it possible to represent one simply accelerometer present in the model of the article [bib1],
· The deformable plate is modelled by 5120 elements of massive solid (modeling 3D) pentaedric with 6 nodes (10 layers in the thickness for a good approximation of

behavior in inflection in spite of the linearity of the elements),
· the free face is modelled by 512 elements MEFP_FACE3 (modeling 2D_FLUI_PESA)
triangles with 3 nodes,
· fluid volume is modelled by 24576 elements of fluid (modeling 3D_FLUIDE)
tetraedric with 4 nodes.

3.2
Writing of the boundary conditions

The bottom of the tank can move only according to direction X:

```
CONDLIM=AFFE_CHAR_MECA (
MODELE=MODELE,
DDL_IMPO= (_F (
GROUP_NO= ("FUNDS", "FONDP",),
DY=0.0,
DZ=0.0,),),);
```

According to this direction X, one imposes on the bottom of the tank a sinusoidal displacement in time, of
frequency 1,7704 Hz and of amplitude 0,001 m:

```
FREQ
=
1.7704;
LFONC=DEFI_LIST_REEL (DEBUT=0.0,
INTERVALLE=_F (
```

JUSQU_A=10.0,

PAS=0.01,),);

FONC = FORMULA (REAL = '" (REAL: INST) =
*(0.001) *SIN (2*PI*FREQ*INST) "');*
DEPLX=CALC_FONC_INTERP (
FONCTION=FONC,
NOM_PARA=' INST',
LIST_PARA=LFONC,);
CHARG_SE=AFFE_CHAR_MECA_F (
MODELE=MODELE,
DDL_IMPO=_F (
GROUP_NO= ("FUNDS", "FONDP",), DX=DEPLX,),);

The voluminal loading of gravity is defined as follows:

PESA=AFFE_CHAR_MECA (
MODELE=MODELE,
GRAVITY
:
(9.81,
0.,
0.,
-1.));

3.3
Characteristics of the grid

The grid contains:
24575 TETRA4
5120
PENTA6
4096
TRIA3

3.4 Functionalities
tested

Orders

AFFE_MODELE MODELING
“FLUI_STRU”
AFFE_MODELE MODELING
“2D_FLUI_PESA”

AFFE_CHAR_MECA GRAVITY

DYNA_NON_LINE

4

Results of modeling A

4.1 Values tested

The tests are done on the value of displacement following X (noted DX) for various moments and for nodes N145 and N3119.

Identification	***Reference***	***Aster***	*% difference*
DX (N145, t=0,8 S)	*5.1624169321991e-04*	*5.1624169321991e-04*	*2.10e-14*
DX (N145, t=1,4 S)	*1.4970110314375e-04*	*1.4970110314375e-04*	*-2.63e-12*
DX (N145, t=2,0 S)	*-2.3927413131721e-04*	*-2.3927413131721e-04*	*-2.32e-12*
DX (N3119, t=1,0 S)	*-9.9736272860105e-04*	*-9.9736285773823e-04*	*-1.74e-13*
DX (N3119, t=1,6 S)	*-8.7855056121762e-04*	*-8.7855056121762e-04*	*1.73e-13*
DX (N3119, t=2,0 S)	*-2.3929161952584e-04*	*-2.3929161952584e-04*	*4.98e-13*

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Organization (S): EDF/EP/AMV
Handbook of Validation
V8.21 booklet: Modal accoustics
Document: V8.21.100

ADLV100 - Piston coupled to a column of fluid

Summary:
Calculation in fluid coupling accoustics-structure of the first mode of a system fluide1 - piston fluid 2.
One tests the matrices of rigidity and mass of the elements of the fluid type and type coupling fluid-structure.
One tests also the boundary condition of the free face type.
Fourteen modelings are tested.

1
Problem of reference

1.1 Geometry

y
Fluid 1: air
Solid
Z
Q3
P3
M3
Q4
M4

P4
Fluid 2: water
has
M
Q2
M2
P
P2
With
Q
P1
M1
1
X

Ls

= the 0.075, Ls = 0.025, It = 0.05 m
constant square section, has = 0.05 m
or circular section (in the axisymmetric case) constant of ray R = has = 0.05 Mr.

1.2
Properties of materials

solid: E = 2 1011Pa
S = 7800 Kg/m3
= 0.3
air: Ca = 340 m/s
= 1.2 Kg/m3 has
water: this = 1400 m/s
E = 1000 Kg/m3
C = speed of sound
C = speed of sound in the fluid

1.3
Boundary conditions and loading

· For all the points M of the face (M1 m2 m3 M4) pressure and potential of displacement are null (condition of the free face type),
· for the points P of the solid, one blocks all the ddl except the translation in X so that this solid comprise like a piston according to axis X.

Titrate:
ADLV100 Piston coupled to a column of fluid
Date:
14/10/98
Author (S):
***F. STIFKENS**, G. ROUSSEAU*
Key:
V8.21.100-B Page:
3/32

2
Reference solution
2.1
Method of calculation used for the reference solution

At the low frequencies, the wavelengths acoustic of the movements considered are large compared to dimension characteristic of fluid volume (L/C <<)
1. The problem is thus
monodimensional according to axis X.
It is shown [bib1] that a light fluid as the air primarily acts like an added stiffness tandis that a heavy fluid behaves only like one added mass. One can thus calculate
first Eigen frequency of the system:

S
K
K = K
2
air =
=
C
has has
with
L
m
has
m = ms + me = L S
S
S
+ L S
E
E
Maybe,
c2
=
has has
(the L

S S + L
E E)
Note:
The first own pulsation of the system checks L/C well << 1.

2.2 References
bibliographical

[1]
GIBERT - Vibrations of the Structures. Interactions with the fluids. Sources of excitation random - Collection of the Management of the Studies and Research of EDF.

---

3 Modeling
With
3.1
Characteristics of modeling

Elements MECA_HEXA8, MEFL_HEXA8, MEFS_QUAD4
Z
M3
M4
y
M2
With
M1
X
MEFS_QUAD4
MEFL_HEXA8
MECA_HEXA8
Boundary conditions:
in all the nodes of the face M

DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0. DZ: 0.)

3.2 Functionalities
tested

Orders
Keys

AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“3D_FLUIDE”
GROUP_MA
[U4.22.01]
“FLUI_STRU”
“3D”
MODE_ITER_SIMULT
“BAND”
FREQ
[U4.52.01]

3.3
Characteristics of the grid

A number of nodes:
63
A number of meshs and types:
24 HEXA8, 8 QUAD4

4
Results of modeling A

4.1 Values tested

Frequency (Hz)		
Reference	***Aster***	***Error (%)***
13.8285	*13.8277*	*< 0.01*

4.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
OPTION: "BAND"
LIST_FREQ (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

4.3 Parameters of execution

Version: 3.05
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
5.7 seconds

---

5 Modeling
B
5.1
Characteristics of modeling

Elements MEDPQU4, MEFLQU4, MEFSSE2

y
MEDPQU4
M3
M2
With
M1
X
MEFLQU4
MEFSSE2

Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)

5.2 Functionalities
tested

Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]

FLUID
AFFE_MODELE
“MECHANICAL”
“2D_FLUIDE”
GROUP_MA
[U4.22.01]
“2D_FLUI_STRU”
“D_PLAN”
MODE_ITER_SIMULT
“BAND”
[U4.52.01]

5.3
Characteristics of the grid

A number of nodes:
21
A number of meshs and types:
12 QUAD4, 4 SEG2

---

6 Results of modeling B

6.1 Values tested

Frequency (Hz)	Reference	Aster	Error (%)
	13.8285	13.8277	< 0.01

6.2 Remarks

Calculations carried out by:
MODE_ITER_SIMULT
OPTION: "BAND"
Freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

6.3 Parameters of execution

Version: 3.00.10
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
2.9 seconds

---

7 Modeling
C

7.1
Characteristics of modeling

Elements MEAXQU4, MEAXFLQ4, MEAXFSS2
MEAXQU4
M1
Y
With
M2
M3
MEAXFLQ4
X
MEAXFSS2
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)
Not M1 --> N019, m2 --> N020, m3 --> N021, A --> N01

7.2 Functionalities
tested
Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO

GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“AXIS_FLUIDE”
GROUP_MA
[U4.22.01]
“AXIS_FLUI_STRU”
“AXIS”
MODE_ITER_SIMULT
“BAND”
[U4.52.01]

7.3
Characteristics of the grid

A number of nodes:
21
A number of meshs and types:
12 QUAD4, 4 SEG2

8
Results of modeling C

8.1 Values
tested
Frequency (Hz)

Reference
Aster
Error (%)
13.8285
13.8277
< 0.01

8.2 Remarks

Calculations carried out by:
MODE_ITER_SIMULT
OPTION: “BAND”
FREQ (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

8.3 Parameters
of execution

Version: 3.02.04
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
4 megawords
Time CPU to use:
4.6 seconds

---

9 Modeling
D
9.1

Characteristics of modeling
Elements MECA_HEXA20, MEFL_HEXA20, MESF_QUAD8
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0. DZ: 0.)

9.2 Functionalities
tested
Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
"MECHANICAL"
"3D_FLUIDE"
GROUP_MA
[U4.22.01]
"FLUI_STRU"
"3D"
MODE_ITER_INV
"ADJUSTS"
FREQ
[U4.52.01]

9.3
Characteristics of the grid
A number of nodes:
201
A number of meshs and types:
24 HEXA20, 8 QUAD8
Handbook of Validation
V8.21 booklet: Modal accoustics
HX-XX/98/XXX - Ind X

---

10 Results of modeling D

10.1 Values tested

Frequency (Hz)	Reference	Aster	Error (%)
	13.8285	13.8277	-0.006

10.2 Remarks

Calculations of modes carried out by:
MODE_ITER_INV
option: "ADJUSTS"
List_freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

10.3 Parameters of execution

Version .3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
9.2 seconds

---

11 Modeling E

11.1 Characteristics of modeling

Elements MECA_PENTA15, MEFL_PENTA15, MESF_TRIA6

Boundary conditions:

in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0. DZ: 0.)

11.2 Functionalities tested

Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“3D_FLUIDE”
GROUP_MA
[U4.22.01]

"FLUI_STRU"
"3D"
MODE_ITER_INV
"ADJUSTS"
FREQ
[U4.52.01]

11.3 Characteristics of the grid

A number of nodes:
331
A number of meshs and types:
84 PENTA15, 28 TRIA6

12
Results of modeling E

12.1 Values tested

Frequency (Hz)	**Reference**	**Aster**	**Error (%)**
	13.8285	13.8277	-0.006

12.2 Remarks

Calculations of modes carried out by:
MODE_ITER_INV
option: "ADJUSTS"
List_freq (10. , 20.)

One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

12.3 Parameters
of execution

Version .3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
18.1 seconds
Handbook of Validation
V8.21 booklet: Modal accoustics
HX-XX/98/XXX - Ind X

---

13 Modeling
F

13.1 Characteristics of modeling

Elements MECA_PENTA6, MEFL_PENTA6, MESF_TRIA3
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0. DZ: 0.)

13.2 Functionalities
tested

Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
"MECHANICAL"
"3D_FLUIDE"
GROUP_MA
[U4.22.01]
"FLUI_STRU"
"3D"
MODE_ITER_INV
"ADJUSTS"
FREQ
[U4.52.01]

13.3 Characteristics of the grid

A number of nodes:
84
A number of meshs and types:
84 PENTA6, 28 TRIA3

14

Results of modeling F

14.1 Values tested

Frequency (Hz)	Reference	Aster	Error (%)
	13.8285	13.8277	-0.006

14.2 Remarks

Calculations of modes carried out by:
MODE_ITER_INV
option: "ADJUSTS"
List_freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

14.3 Parameters of execution

Version .3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
6.1 seconds

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15 Modeling

G

15.1 Characteristics of modeling

Elements MECA_TETRA10, MEFL_TETRA10, MESF_TRIA6

Boundary conditions:

in all the nodes of the face M

DDL_IMPO:

(GROUP_NO: noeusurf

NEAR: 0. PHI: 0.)

in all the nodes of the piston

(GROUP_NO: noeupist

DY: 0. DZ: 0.)

15.2 Functionalities

tested

Orders

Keys

AFFE_CHAR_MECA

DDL_IMPO

GROUP_NO

[U4.25.01]

DEFI_MATERIAU

ELAS

[U4.23.01]

FLUID

AFFE_MODELE

“MECHANICAL”

“3D_FLUIDE”

GROUP_MA

[U4.22.01]

“FLUI_STRU”

“3D”

MODE_ITER_INV

“ADJUSTS”

FREQ

[U4.52.01]

15.3 Characteristics of the grid

A number of nodes:

366

A number of meshs and types:

173 TETRA10, 16 TRIA6

HX-XX/98/XXX - Ind X

16 Results of modeling G

16.1 Values tested

Frequency (Hz)	**Reference**	**Aster**	**Error (%)**
	13.8285	13.8277	-0.006

16.2 Remarks

Calculations of modes carried out by:
MODE_ITER_INV
option: “ADJUSTS”
List_freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

16.3 Parameters of execution

Version .3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
19.0 seconds

---

17 Modeling
H

17.1 Characteristics of modeling

Elements MECA_TETRA4, MEFL_TETRA4, MESF_TRIA3
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0. DZ: 0.)

17.2 Functionalities
tested
Orders
Keys

AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“3D_FLUIDE”
GROUP_MA
[U4.22.01]

“FLUI_STRU”
“3D”
MODE_ITER_INV
“ADJUSTS”
FREQ
[U4.52.01]

17.3 Characteristics of the grid

A number of nodes:
69
A number of meshs and types:
173 TETRA4, 16 TRIA3

18
Results of modeling H

18.1 Values tested

Frequency (Hz)	**Reference**	**Aster**	**Error (%)**
	13.8285	13.8277	-0.006

18.2 Remarks

Calculations of modes carried out by:
MODE_ITER_INV
option: “ADJUSTS”
List_freq (10. , 20.)

One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

18.3 Parameters
of execution

Version .3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
5.5 seconds
Handbook of Validation
V8.21 booklet: Modal accoustics
HX-XX/98/XXX - Ind X

---

19 Modeling
I

19.1 Characteristics of modeling

Elements MEDPQU8, MEFLQU8, MEFSSE3
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)

19.2 Functionalities
tested

Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“2D_FLUIDE”
GROUP_MA
[U4.22.01]
“2D_FLUI_STRU”
“D_PLAN”
MODE_ITER_INV
“ADJUSTS”
[U4.52.01]

19.3 Characteristics of the grid

A number of nodes:
53
A number of meshs and types:
12 QUAD8, 4 SEG3

20
Results of modeling I

20.1 Values
tested

Frequency (Hz)	Reference	Aster	Error (%)
	13.8285	13.8277	-0.006

20.2 Remarks

Calculations carried out by:
MODE_ITER_INV
option: “ADJUSTS”
Freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

20.3 Parameters
of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
4.7 seconds

---

21 Modeling
J
21.1 Characteristics of modeling
Elements MEDPTR6, MEFLTR6, MEFSSE3
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)
21.2 Functionalities
tested
Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“2D_FLUIDE”
GROUP_MA
[U4.22.01]
“2D_FLUI_STRU”
“D_PLAN”
MODE_ITER_INV
“ADJUSTS”
[U4.52.01]
21.3 Characteristics of the grid
A number of nodes:
65
A number of meshs and types:
24 TRIA6, 4 SEG3

---

22 Results of modeling J

22.1 Values tested

Frequency (Hz)	**Reference**	**Aster**	**Error (%)**
	13.8285	13.8277	-0.006

22.2 Remarks

Calculations carried out by:
MODE_ITER_INV
option: "ADJUSTS"
Freq (10. , 20.)

One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

22.3 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
4.9 seconds

---

23 Modeling
K

23.1 Characteristics of modeling

Elements MEDPTR3, MEFLT3, MEFSSE2
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)

23.2 Functionalities
tested

Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
"MECHANICAL"
"2D_FLUIDE"
GROUP_MA
[U4.22.01]

"2D_FLUI_STRU"
"D_PLAN"
MODE_ITER_INV
"ADJUSTS"
[U4.52.01]

23.3 Characteristics of the grid

A number of nodes:
65
A number of meshs and types:
24 TRIA3, 4 SEG2

24
Results of modeling K

24.1 Values
tested

Frequency (Hz)	Reference	Aster	Error (%)
	13.8285	13.8277	-0.006

24.2 Remarks

Calculations carried out by:
MODE_ITER_INV
option: "ADJUSTS"
Freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:
Value of the first Eigen frequency of vibration of the coupled system.

24.3 Parameters
of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU to use:
4.4 seconds

---

25 Modeling
L

25.1 Characteristics of modeling

Elements MEAXQU8, MEAXFLQU8, MEAXFSSE3
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)

25.2 Functionalities
tested

Orders

Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
"MECHANICAL"
"AXIS_FLUIDE"
GROUP_MA
[U4.22.01]
"AXIS_FLUI_STRU"
"AXIS"
MODE_ITER_INV
"ADJUSTS"
[U4.52.01]

25.3 Characteristics of the grid

A number of nodes:
53
A number of meshs and types:
12 QUAD8, 4 SEG3

---

26 Results of modeling L

26.1 Values tested

Frequency (Hz)	**Reference**	**Aster**	**Error (%)**
	13.8285	13.8277	-0.006

26.2 Remarks

MODE_ITER_INV
option: "ADJUSTS"
Freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:
Value of the first Eigen frequency of vibration of the coupled system.

26.3 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
4 megawords
Time CPU to use:
4.7 seconds

27 Modeling
M

27.1 Characteristics of modeling

Elements MEAXTR6, MEAXFLTR6, MEAXFSSE3
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)

27.2 Functionalities
tested

Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO
GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“AXIS_FLUIDE”
GROUP_MA
[U4.22.01]
“AXIS_FLUI_STRU”
“AXIS”

MODE_ITER_INV
"ADJUSTS"
[U4.52.01]

27.3 Characteristics of the grid

A number of nodes:
65
A number of meshs and types:
24 TRIA6, 4 SEG3

28
Results of modeling M

28.1 Values
tested

Frequency (Hz)	Reference	Aster	Error (%)
	13.8285	13.8277	-0.006

28.2 Remarks

MODE_ITER_INV
option: "ADJUSTS"
Freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

28.3 Parameters

of execution
Version: 3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
4 megawords
Time CPU to use:
4.9 seconds
Handbook of Validation
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HX-XX/98/XXX - Ind X

---

29 Modeling
NR
29.1 Characteristics of modeling
Elements MEAXTR3, MEAXFLTR3, MEAXFSSE2
Boundary conditions:
in all the nodes of the face M
DDL_IMPO:
(GROUP_NO: noeusurf
NEAR: 0. PHI: 0.)
in all the nodes of the piston
(GROUP_NO: noeupist
DY: 0.)
29.2 Functionalities
tested
Orders
Keys
AFFE_CHAR_MECA
DDL_IMPO

GROUP_NO
[U4.25.01]
DEFI_MATERIAU
ELAS
[U4.23.01]
FLUID
AFFE_MODELE
“MECHANICAL”
“AXIS_FLUIDE”
GROUP_MA
[U4.22.01]
“AXIS_FLUI_STRU”
“AXIS”
MODE_ITER_INV
“ADJUSTS”
[U4.52.01]

29.3 Characteristics of the grid

A number of nodes:
21
A number of meshs and types:
24 TRIA6, 4 SEG3

30
Results of modeling NR

30.1 Values
tested
Frequency (Hz)
Reference

Aster
Error (%)
13.8285
13.8277
-0.006

30.2 Remarks

MODE_ITER_INV
option: “ADJUSTS”
Freq (10. , 20.)
One did not connait the analytical solution of the first clean vector.

Contents of the file results:

Value of the first Eigen frequency of vibration of the coupled system.

30.3 Parameters
of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
4 megawords
Time CPU to use:
4.4 seconds

31
Summary of the results

The value of the modal frequency obtained with Code_Aster is satisfactory since, with one moderated discretization, it is equal to 0,01% close with the theoretical solution, whatever the type of modeling.

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Document: V8.21.101

ADLV101 - Modes of shaking of a tank filled of water

Summary:

This test, of the acoustic and fluid field, relates to the research of the Eigen frequencies of a tank rectangular filled of a fluid including/understanding a free face. The modal analysis determines the first thus
modes of shaking of the surface of the fluid filling the tank. The first three Eigen frequencies are found with less than 1% of the analytically calculated frequencies.

1
Problem of reference
1.1 Geometry
free face
H
L
L
dimensions of the tank:
height: H = 0.3 m
length: L = 0.8 m
width: L = 0.1 m

1.2
Properties of materials
The modelled material is the fluid contained in the tank:
density: *C* = 1000 kg/m3
speed of sound: *C* = 1400 m/s

1.3
Boundary conditions and loading
One imposes the field of gravity on the whole of the fluid model
charge = AFFE_CHAR_MECA
(
...
GRAVITY: (9.81, 0. , 0. , 1.));

2
Reference solution
2.1

Method of calculation used for the reference solution

The reference [bib3] provides the general formula of the modes of shaking in a tank parallelepipedic:

2
2

2
2
1
I
J
I
J

F =
G
+
HT H
+
ij
2
L2
l2

L2
L

2

where *I* and *J* are the orders of the longitudinal and transverse modes (a number of nodal lines in each direction).

In the particular case or - *L* is large, the formula is simplified for the longitudinal modes [bib1],
L
[bib2].

2.2

Results of reference

L
For
= 8. and *H* = 0 3
. the first four modes are at frequencies 0.898, 1.384, 1.709 and 1.975.
L

2.3 References
bibliographical

[1]
WAECKEL F., LEPOUTERE C. Note internal EDF/DER “Effect of gravity on surface
free of a fluid coupled to a structure ", HP-61/93/139.
[2]
MUTO, KASA, NAKAHARA, Experimental ISHIDA “tests one sloshing response of has toilets pool
with submerged blocks " - ASME, flight PVP 98, (1985).
[3]
BLEVINS R.D. Formulated for natural frequency and shape mode. ED Krieger

---

3 Modeling
With

3.1
Characteristics of modeling

L
MEFP_FACE4
L
MEFL_QUAD4
H

· the free face is modelled by 57 elements MEFP_FACE4 (modeling 2D_FLUI_PESA)
quadrangle with 4 nodes,
· fluid volume is modelled by 513 elements of fluid (modeling 3D_FLUIDE) cubic
with 8 nodes.

3.2
Characteristics of the grid

The grid contains:
513 HEXA8

57 QUAD4

3.3 Functionalities tested

Orders

Keys

AFFE_CHAR_MECA
GRAVITY
[U4.25.01]
AFFE_MODELE
MODELING
“2D_FLUI_PESA”
[U4.22.01]

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HP-51/99/011 - Ind A

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4 Results of modeling A

4.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
mode1	8.98250e-01	8.99460e-01	0.135
mode 2	1.38452e+00	1.39010e+00	0.403
mode 3	1.70952e+00	1.72406e+00	0.851
mode 4	1.97551e+00	2.00526e+00	1.506

4.2 Parameters of execution

Version: 5.02
Machine: Origin 2000
Obstruction memory:
8 MW
Time CPU to use:

---

5 Modeling
B

5.1
Characteristics of modeling

This modeling differs from modeling A only by the type of free element of face and by type of element of fluid:

· the free face is modelled by 57 elements MEFP_FACE8 (modeling 2D_FLUI_PESA) quadrangle with 8 nodes,
· fluid volume is modelled by 513 elements of fluid (modeling 3D_FLUIDE) cubic with 20 nodes.

5.2
Characteristics of the grid

the grid contains:
513 HEXA20
57 QUAD8

5.3 Functionalities
tested

Orders
Key word factor
Key word
Argument
Keys
AFFE_CHAR_MECA
GRAVITY
[U4.25.01]
AFFE_MODELE

AFFE
MODELING
“2D_FLUI_PESA”
[U4.22.01]
AFFE
MODELING
“3D_FLUIDE”
MODE_ITER_INV
CALC_FREQ
OPTION
“NEAR”
[U4.52.01]

6 Results of modeling B

6.1 Values tested

Identification	Reference	Aster	% difference
mode1	8.98250e-01	8.98252e-01	0.000
mode 2	1.38452e+00	1.38452e+00	0.000
mode 3	1.70952e+00	1.70958e+00	0.003
mode 4	1.97551e+00	1.97569e+00	0.009

6.2 Parameters of execution

Version: 5.02
Machine: Origin 2000
Obstruction memory:
8 MW
Time CPU to use:

---

7 Modeling
C

7.1
Characteristics of modeling

This modeling differs from modeling A only by the type of free element of face and by type of element of fluid:

· the free face is modelled by 57 elements MEFP_FACE9 (modeling 2D_FLUI_PESA) quadrangle with 9 nodes,
· fluid volume is modelled by 513 elements of fluid (modeling 3D_FLUIDE) cubic with 27 nodes.

7.2
Characteristics of the grid

the grid contains:
513 HEXA27
57 QUAD9

7.3 Functionalities
tested

Orders
Key word factor
Key word
Argument
Keys
AFFE_CHAR_MECA
GRAVITY
[U4.25.01]
AFFE_MODELE

AFFE
MODELING
“2D_FLUI_PESA”
[U4.22.01]
AFFE
MODELING
“3D_FLUIDE”
MODE_ITER_INV
CALC_FREQ
OPTION
“NEAR”
[U4.52.01]

8 Results of modeling C

8.1 Values tested

Identification	Reference	Aster	% difference
mode1	8.98250e-01	8.98252e-01	0.000
mode 2	1.38452e+00	1.38452e+00	0.000
mode 3	1.70952e+00	1.70957e+00	0.003
mode 4	1.97551e+00	1.97569e+00	0.009

8.2 Parameters of execution

Version: 5.02
Machine: Origin 2000
Obstruction memory:
8 MW
Time CPU to use:

---

9 Modeling D

9.1 Characteristics of modeling

This modeling differs from modeling A by the type of element used. Each mesh of modeling A is cut into two by a vertical plane.

· the free face is modelled by 114 elements MEFP_FACE3 (modeling 2D_FLUI_PESA) triangle with 3 nodes,

· fluid volume is modelled by 1026 elements of fluid (modeling 3D_FLUIDE) pentaedric with 6 nodes.

9.2 Characteristics of the grid

the grid contains:
1026 PENTA6
114 TRIA3

9.3 Functionalities tested

Orders	**Key word factor**	**Key word**	**Argument**	**Keys**
AFFE_CHAR_MECA	GRAVITY			[U4.25.01]
AFFE_MODELE				

AFFE
MODELING
“2D_FLUI_PESA”
[U4.22.01]
AFFE
MODELING
“3D_FLUIDE”
MODE_ITER_INV
CALC_FREQ
OPTION
“NEAR”
[U4.52.01]

10
Results of modeling D

10.1 Values
tested

Identification	Reference	Aster	% difference
mode 1	8.98250e-01	8.99450e-01	0.134
mode 2	1.38452e+00	1.39004e+00	0.399
mode 3	1.70952e+00	1.72387e+00	0.839
mode 4	1.97551e+00	2.00473e+00	1.479

10.2 Parameters
of execution

Version: 5.02
Machine: Origin 2000
Obstruction memory:
8 MW
Time CPU to use:

---

11 Modeling E

11.1 Characteristics of modeling

This modeling differs from modeling B by the type of element used. Each mesh of modeling B is cut by a vertical plane.

· the free face is modelled by 114 elements MEFP_FACE6 (modeling 2D_FLUI_PESA) triangle with 6 nodes,

· fluid volume is modelled by 1026 elements of fluid (modeling 3D_FLUIDE) pentaedric with 15 nodes.

11.2 Characteristics of the grid

the grid contains:
1026 PENTA15
114 TRIA6

11.3 Functionalities tested

Orders	**Key word factor**	**Key word**	**Argument**	**Keys**
AFFE_CHAR_MECA	GRAVITY			[U4.25.01]
AFFE_MODELE	AFFE	MODELING		

“2D_FLUI_PESA”
[U4.22.01]
AFFE
MODELING
“3D_FLUIDE”
MODE_ITER_INV
CALC_FREQ
OPTION
“NEAR”
[U4.52.01]

12 Results of modeling E

12.1 Values tested

Identification	Reference	Aster	% difference
mode 1	8.98250e-01	8.98252e-01	0.000
mode 2	1.38452e+00	1.38452e+00	0.000
mode 3	1.70952e+00	1.70957e+00	0.003
mode 4	1.97551e+00	1.97569e+00	0.009

12.2 Parameters of execution

Version: 5.02
Machine: Origin 2000
Obstruction memory:
8 MW
Time CPU to use:
44.17 seconds
Handbook of Validation

---

13 Summary of the results

Modeling A implements elements of fluid of the type HEXA8 and elements of surface free of type QUAD4. The result obtained reveals a maximum error of 1.52% compared to analytical solution.

Modeling B utilizes elements of fluid of the type HEXA20 and elements of surface free of type QUAD8. The results correlate perfectly with the analytical solution.

Elements fluid of the type HEXA27 and fluid weighing of type QUAD9 are used for modeling C. the results obtained are identical to the reference solution.

Modeling D makes it possible to validate elements fluid of the type PENTA6 and elements of surface free of type TRIA3. The results obtained reveal a relative error of 1.479% compared to the reference solution.

Modeling E makes it possible to validate the elements of free face of type TRIA6. They are connected to elements of fluid of the type PENTA15. There is perfect coincidence of the results with the solution analytical.

Generally, it is observed that the results obtained by elements with interpolation quadratic (HEXA20, HEXA27) are in excellent agreement with the analytical results. Nevertheless the elements with linear interpolation have an acceptable precision on the results.

Date
:

06/08/03
Author (S):
***G. DEVESA**, F. STIFKENS Key*
:
V8.21.102-A Page:
1/10

Organization (S): EDF-R & D /AMA

Handbook of Validation
V8.21 booklet: Accoustics
Document: V8.21.102

ADLS102 - Meridian oscillator fluidelastic

Summary:

The objective is to calculate the displacement of the piston of a "oscillator meridian fluid-rubber band".
It is about piston-arises coupled with a fluid contained in a channel with rigid and fixed walls; the channel is crossed by a wave of depressurisation.

One considers the plane problem of this meridian model. This two-dimensional problem is brought back to a problem
monodimensional by considering by approximation that rates of transverse flow induced by movement of the piston are transmitted instantaneously in axial speeds.

Only one modeling is used. The calculation of the modes is in formulation U, p.
Elements 2D are thus used; these elements are based on meshs QUAD4 for the fluid and for piston, on meshs SEG2 for the interface between fluid and piston to take into account the fluid interaction
structure (PHENOMENE= `MECANIQUE', MODELISATION='2D_FLUI_STRU').

The boundary conditions of nonreturn of the wave are carried out by modelling a piston shock absorber with each
end; the excitation is carried out by applying a depression to the piston of entry.

The fluid which one considers is water (hot), the model schematizing the interaction fluid-structure in annular space between tank and envelope of heart during a fast depressurisation.

An exact analytical solution exists. Its comparison with the results produced by *Code_Aster* allows to validate the taking into account of the fluid coupling structure in 2D.

---

1 Problem of reference

1.1 Geometry

One describes below the model of meridian oscillator fluidelastic schematizing the interaction fluid-structure in annular space tank-envelope of heart.
The meridian elastic fluid oscillator is a model of annular space tank-envelope of heart of engine; it consists of an oscillator (piston side-arises appearing a mobile wall) coupled with a compressible fluid contained in a channel with rigid and fixed walls.
The channel is crossed by a wave of depressurisation.
The figure [Figure 1.1-a] below illustrates the model described.
H
Z
E
D X

Appear 1.1-a: Total diagram of the oscillator meridian fluid-rubber band

The channel is of section rectangular of dimensions E × H the rigid side piston moves according to Z perpendicular to a wall.
A wave of depressurisation arrives by the left; while moving towards the line (without possibility of return) this wave aspires the piston which, by its resulting displacement, generates waves propagating towards the ends of the conduit, supposed infinitely long so that there is no reflexion.

One conceives a two-dimensional modeling of this system, represented with the figure [Figure 1.1-b] below:
K
2L
M
Z
- L
L
X
E
V
V
O
dx
(D)

Appear 1.1-b: Theoretical two-dimensional mechanical representation
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Code_Aster ®
Version
7.0

Its geometrical characteristics are as follows:

length piston of wall 2L = 5,0 m,
height of fluid
E = 0,5 m,
width of fluid
H = 1,0 m,
section of fluid
S =

E H
.

1.2
Properties of materials

The physical characteristics of fluid material (hot water) in the tube are as follows:
density
3
3
= 0,7510 kg/m,
F
C speed of sound = 1,0 103

m/s.
F

Physical characteristics of materials constituting the piston of wall and the pistons of end have only one formal role in the calculation of Code_Aster.

These physical material characteristics are as follows:
Young modulus E = 2,0 1012

Pa,
Poisson's ratio = 0,3,
density
3
= 0 kg/m.
S

1.3
Characteristics of the springs, masses and shock absorbers

The characteristics of the piston of wall as an oscillator are as follows:
Stiffness
K = 5,0 1010

N/m,
Mass
M = 200,0 103

kg.
Damping A = 0 Ns/m
The characteristics of the pistons of end as oscillators are as follows:
Stiffness
K = 0 N/m,
Mass
m = 0 kg,

Damping has = C S = 37,5 104

NR s/m.
F
F

1.4
Boundary conditions and loadings

Infinitely rigid piston of wall and with displacement only according to the vertical axis.

Infinite length of fluid thus not of reflexion of end of the waves: this C.L is simulated in model by a piston at each end, of null mass, moving only according to the x axis *and provided with a shock absorber with adequate damping; these pistons are moreover more infinitely rigid.*

Total reflexion of the waves on infinitely rigid walls of the tube of fluid: realized simply in omitting to model the wall by elements of structure.

2
Reference solution

2.1
Method of calculation used for the reference solution

The goal is to determine temporal displacement Z (T) of the piston of wall.
One considers the plane problem of this meridian model of which geometrical characteristics, mechanics and fluids are described on the figure [Figure 1.1-a]; the side piston is length 2L.
The two-dimensional problem is brought back to a monodimensional problem while considering by approximation that rates of transverse flow z& induced by the movement of the piston transmit instantaneously in axial speeds in the channel.
In the volume of control D = edx of wide dx under the piston of wall one can write:
D (V) = 1 dxd
2nd
&z
In the fluid variation speed and variation of pressure in adiabatic evolution are connected by:
P = cV
The pressure at the moment T in a point of X-coordinate X results from the superposition of the

propagation from
all elementary sources distributed on the piston:
The coupling thus consists of this: the movement of the piston of acceleration &z (T) induced in the channel one
field of pressure P (X, T) whose effort resulting on the extent from the piston itself acts as return on dynamics of the oscillator.

The geometrical, mechanical characteristics and fluids of the model are presented on the figure [Figure 1.1-b].
It is considered initially that the piston and the fluid are at rest and one carries out to release oscillator with
the moment T = 0 by imposing an initial speed to him.

The expression of the pressure P (X, T) in a point of the channel develops:
C T X
X - U
+ L
U - X

P (X, T) =
-
+
-

2nd 0
&z (
) of the &z (
) of D

- L
C
X
C

However there is Z ()
0 = 0 and Z (T) = 0 for T negative, and
L - X
Z (-
) = 0 since upstream of the piston (X ranging between - L and L) the quantity enters
C
L + X
bracket is always negative; for the same reason there is Z (-
) = 0 .

C
Finally it comes:
c2
L - X
L + X
P (X, T) =
2 Z (T) - Z (T -
) - Z (T -
)
2nd
C
C

One integrates this expression on X in order to obtain the resultant of the compressive forces on the piston:
+ L
L
R (T) = - H
P (X, T) dx = -2H P (X, T) dx

:
- L
0
Indeed P (X, T) is even in X; it is thus enough to integrate on half of the piston.
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From where the expression of the resultant of the compressive forces on the piston on the assumption of small
movements:
Hc2
T

R (T) = -
2L Z (T) - C
Z (U) of
E
2

T
L

- C

The movement of the oscillator thus obeys the equation:
2HLc2
2HLc2
T
M &z+ K z+
Z
C
Z (U) of =

0

E
E
T 2 L
- C
or:
M &z- F - blow
F
int
L = 0
if one poses:
2HL c2

2HLc2
T
F
K Z
Z
int = -
-
and F
C
U
Z () of
coupl =

E
T 2L
E
C

One now considers the case of the propagation of a wave of decompression to stiff face of P0 amplitude along the conduit. At the moment T = 0, this wave still attack the piston of wall with rest, creating on this piston a force of excitation such as:

2L
Hct P

if T
0
<

F
C
excit =

2L
2HL P

if T
0

C
The equation of the movement is written then:

M &z = F + coupl
F
+ excit
F
int

This equation is solved numerically with the Matlab software for the characteristics presented meridian oscillator.

2.2 Result of reference

Displacement Z (T) of the piston of wall.

2.3 Uncertainty of the solution

Analytical solution.

2.4 References bibliographical

[1]
F. STIFKENS: "Transitory Calculation in Code_Aster with the vibroacoustic elements". Note intern R & D HP-51/97/026/A.
[2]
F. TEPHANY, A. HANIFI, C. LEHAUT: "Elements of analysis of the interaction fluid-structure in annular space tank-envelope of heart in the event of APRP" - internal Note SEPTEN ENTMS/94.057.

3 Modeling

3.1
Characteristics of modeling

3.1.1 System
vibroacoustic equivalent to be modelled

In order to avoid the waves of return coming from the ends of a modeling inevitably of dimension finished one provides these ends with systems "piston-shock absorber" as on the figure [Figure 3.1.1-a].
The channel is modelled over an overall length of 28 m sufficient to obtain with certainty, at least the two first extrema of the curve of displacement of the piston without disturbance of a wave of reflexion at the ends.
piston
wall
piston
piston
discharger
stiffness
K
anechoic
mass
M
5 m
P

0
0,5 m

fluid

=

0
m =
m
=Sc
=Sc
density

celerity
C
28 m
rigid wall
fluid

Appear 3.1.1-a: Vibroacoustic system are equivalent

3.1.2 Modeling
numerical in finite elements of Code_Aster

One chose to model in 2D.

For the fluid: modeling is in formulation p.
It is carried out by the assignment on meshs of the type QUAD4 (quadrilateral with 4 nodes) of elements
PHENOMENON = ' MECANIQUE', MODELING = ' 2D_FLUIDE'.

For the structures: modeling is in formulation U.
It is carried out by the assignment on meshs of the type QUAD4 (quadrilateral with 4 nodes) of elements
PHENOMENON = ' MECANIQUE', MODELING = ' D_PLAN'.
For the discrete elements of oscillators: modeling is in formulation U.
It is carried out by the assignment on meshs of the specific type POI1 of elements
PHENOMENON = ' MECANIQUE', MODELING = ' DIS_T'.

For the interfaces fluid-structure: modeling is in formulation U, p.
It is carried out by the assignment on meshs of the type SEG2 (segments with 2 nodes) of elements
PHENOMENON = ' MECANIQUE', MODELING = ' 2D_FLUIDE_STRU'.

3.2
Characteristics of the grid
10 élém. 2D of structure
10 élém. 1D of structure
10 élém. 1D flui-stru
10 élém. 2D of structure
10 élém. 1D flui-stru
50 elements of structure
50 élém. 1D flui-stru
560 X 10 elements 2D of fluid
specific element stiffness
specific element shock absorber

Appear 3.2-a: Two-dimensional grid of the model of oscillator fluidelastic

One gathered in the table hereafter, the data characterizing this modeling.

Type of mesh
Numbers
QUAD4
SEG2
POI1
total

A number of elements
2870
80
3
2953

A number of generated nodes
3164
0
0
3164

Table 3.2-1: Characteristics of the two-dimensional grid of the oscillator fluidelastic

3.3 Calculation

One wishes to validate the elements of interaction fluid-structure in transient state by a loading of excitation.
One carries out the calculation of the displacement of the piston of wall with operator DYNA_LINE_TRAN.

3.4 Functionalities tested

Orders Key word factor
Key word
MECHANICAL AFFE_MODELE
D_PLAN
2D_DIS_T
2D_FLUIDE
2D_FLUI_STRU
FLUID DEFI_MATERIAU
RHO, CELE_R,
ELAS
E, NAKED,…
AFFE_CARA_ELEM

AFFE_CHAR_MECA DDL_IMPO
DX, DY…
LIAISON_SOLIDE

PRES_REP
CALC_MATR_ELEM

CALC_VECT_ELEM

ASSE_MATRICE

ASSE_VECTEUR

DYNA_LINE_TRAN

:

06/08/03
Author (S):
G. DEVESA, F. STIFKENS Key
:
V8.21.102-A Page:
9/10

4
Result of modeling

4.1 Values
tested

The results of calculation with Code_Aster are presented graphically on [Figure 4.1-a] in superposition with the "analytical" reference solution.
The curve of Code_Aster appears very close to the reference during the first 4 oscillations but the differences, at the same time in amplitude and phase, are increasingly perceptible when T increases.
EDF
Acoustic department and vibratory Mechanics
Electricity
Subjected meridian oscillator fluidelastic has depressurisation
from France
-3
X 10
0.0
-0
Displacements compare piston of
wall, between calculation by Aster and
-0.2
analytical calculation
-0.4
-0.6
Aster
-0.8
analytical
depl. balance
displacement (m)
-1.0
-1.2
-0.00136

-3
0
20
40
4
60
6
80
100
X 10
time (S)
agraf 22/12/97 (c) EDF/DER 1992

Appear 4.1-a: Comparison between Code_Aster calculation and analytical semi reference

The test relates to the displacement of the piston of wall in two moments given close to both first extrema.
The table presents comparative of the 2 first extrema curve of displacement of the piston between analytical points and points calculated by Code_Aster.
The values obtained of the moments of extrema in one and the other case are estimated values extracted without interpolation from the rough computed values: they do not correspond exactly enters
the analytical curve and the curve of Code_Aster.
One estimates the tolerance of variation relating compared to the analytical value to 1.%.

Reference
Code_Aster
Relative variation
analytical

Inst. (ms) Dépl. (mm)
Inst. (ms)
Dépl. (mm)
%
1st Extremum
20,13
-1,3530
20,15
-1,3536
0,05
2me Extremum
26,05
-0,4210
26,05

-0,42071
0,07

Test of nonregression of the code:
the tolerance of relative variation compared to the reference is worth 0,1%.
Handbook of Validation
V8.21 booklet: Accoustics HT-66/03/008/A

4.2 Notice

The values of reference finally selected are those obtained by Code_Aster at the time of restitution of the case-test, which will thus make it possible to check nonthe later regression of the code to the course of its evolution.

5
Summary of the results

Good precision over the first periods then light error in amplitude and phase due to

1
1
the influence of integration in numerical time Newmark =, =.

4

Code_Aster ®
Version
6.4

Titrate:
FDLL200 - Piping embedded and free by beam fluid-structure
Date:
08/07/03
Author (S):
F. STIFKENS, G. DEVESA Key
:
V8.21.200-A Page:
1/6

Organization (S): EDF-R & D /AMA

Handbook of Validation
V8.21 booklet: Accoustics
Document: V8.21.200

FDLL200 - Piping embedded and free by beam
fluid-structure

Summary:

The objective is to calculate the low frequency behavior of a piping filled with water. Piping has a circular section; it is embedded at an end and free other side.

One uses the elements of beam élasto-accoustics available in Code_Aster which take into account the fluid interaction structure (PHENOMENON = "MECHANICAL", MODELING = "FLUI_STRU").

The boundary conditions are mechanical to simulate the embedding of the structure, and accoustics for to simulate the condition of tank of the fluid in this point (boundary conditions of null pressure and potential of fluid displacement no one).

The fluid which one considers is a heavy fluid in order to put forward the phenomenon of coupling enters the column of fluid and the structure constitutive of piping. Properties of the fluid and material of structure are selected so that the celerity of a wave being propagated in the fluid is the same one as celerity of a mechanical wave being propagated in piping. Under these conditions, first mode of structure resounds at the same frequency as the column of fluid.

An exact analytical solution exists which provides the first Eigen frequency. Its comparison with results produced by Code_Aster (search for eigenvalues) makes it possible to validate the taking into account of fluid coupling structure in the longitudinal direction, the transverse effects being non-existent in this model.
One tests thus partially the matrix of stiffness and that of mass.

1
Problem of reference

1.1 Geometry

Piping is a hollow roll with circular section, filled with fluid.

Characteristics of piping:

length: L = 1,0 m
external diameter: D = 0,1 m
thickness: ep = 0,01 m

1.2
Properties of materials

The physical characteristics of material constituting the tube are as follows:

Young modulus: E = 1,0 · 1010 Pa
Poisson's ratio: = 0,3
density: S = 1,0 · 104 kg/m3
E
celerity longitudinal wave: Cs =
= 1,0 · 103 m/s
S

The physical characteristics of fluid material in the tube are as follows:

density: F = 1,0 · 103 kg/m3
speed of sound: cf = 1,0 · 103 m/s

1.3
Boundary conditions and loading

Displacement only according to the x axis.
Embedding of piping in end A.
Free piping in the end B.
For the fluid condition of tank in end A.
Handbook of Validation
V8.21 booklet: Accoustics HT-66/03/008/A

2
Reference solution

2.1
Method of calculation used for the reference solution

One studies the vibratory behavior of a piping filled with fluid. Piping is embedded with one of its ends and free at the other end. The section of piping is circular. One be interested in the low frequencies of the longitudinal behavior of piping.

One defines:

length of the tube:
L,
Young modulus of the pipe:
E,
diameter external of the pipe:
D,
thickness of the walls:
ep,
surface of the solid section:
Ss,
surface of the fluid section:
Sf
celerity in the pipe (structure):
Cs,
celerity in the fluid:
cf,

One chose the characteristics of the fluid and the pipe in order to have the following relation:

E
C = C =
= C = 1000 m/s
F
S

S

In this particular case of equality of celerities, one shows [bib2] that the first Eigen frequency of coupled problem is such as:

L

Ss
E
tg
=
.

2
C
S
S
F
C
F

It is worth in this case: F = 157,94 Hz

2.2
Results of reference

Only one modeling is used. The calculation of the modes is in formulation U, p.

2.3
Uncertainty of the solution

Analytical solution.

2.4 References
bibliographical

[1]
WAECKEL F., DUVAL C.: Note principle and of use of the pipes implemented in Code_Aster. Note intern R & D HP-61/92.138
[2]
DUVAL C.: Dynamic response under random excitation in Code_Aster. Note intern R & D HP-61/92.148

---

3 Modeling
With

3.1
Characteristics of modeling

The modeling of the beams élasto-acoustics is in formulation U, p.
It is carried out by the assignment on meshs of the type SEG2 (segments with 2 nodes) of elements PHENOMENON = "MECHANICAL", MODELING = "FLUI_STRU".

One assigns to the elements the characteristics of circular section:
external ray
Rext = 0,100 m

thickness

ep = 0,010 m
cf [§1.1]

One also assigns to these elements a mixed material of behavior at the same time ELAS:
Young modulus
E = 1,0.1010 Pa

Poisson's ratio
= 0,3

density
S = 1000 kg/m3

and FLUID:
celerity
C = 1000 m/s

density
F = 1000 kg/m3
cf [§1.2]

Degrees of freedom (DDL) of translation in y and Z (DY and DZ) and all DDL of rotation (DRX, DRY and
DRZ) of all the nodes are blocked.
In order to embed end A of piping, one also blocks the DDL of translation in X (DX) of
node NO1.
For the fluid the condition of tank at end A is imposed by NEAR: 0. and PHI: 0. with
node NO1.

3.2
Characteristics of the grid

The total number of nodes used for this grid is 26.
The meshs are 25 and of type SEG2.
The file of grid is with the format ASTER.

3.3 Calculation

One wishes to validate the elements of beam élasto-accoustics.
One carries out the calculation of the frequency of the first axial mode coupled with the operator MODE_ITER_SIMULT.

3.4 Functionalities tested

Orders

MECHANICAL AFFE_MODELE FLUI_STRU

FLUID DEFI_MATERIAU RHO, CELE_R

ELAS AFFE_CHAR_MECA DDL_IMPO DX, DY…

NEAR, PHI MODE_ITER_SIMULT

Handbook of Validation V8.21 booklet: Accoustics HT-66/03/008/A

4
Results of modeling A

4.1 Values
tested

The test relates to the frequency of the first coupled axial mode of piping containing a fluid.
The tolerance of relative variation compared to the analytical value is worth 0,1%.

Number of the mode
Analytical value
Computed value
Relative variation
1 157,93981
Hz
157,94539 Hz
+0,004 %
Value not regression

Test of nonregression of the code:
the tolerance of relative variation compared to the reference is worth 0,1%

4.2 Notice

The values of reference are at the same time the analytical values and also those obtained by
Code_Aster during the restitution of the case-test, which will thus make it possible to check nonthe

regression
later of the code during its evolution.

5
Summary of the results

It is noted that the computed value of the frequency of the first coupled axial mode reproduced very exactly the analytical value with a relative precision of 0.004%.

Code_Aster ®
Version
4.0
Titrate:
AHLV100 Guides wave at anechoic exit
Date:
13/10/98
Author (S):
***F. STIFKENS**, G. ROUSSEAU*
Key:
V8.22.100-B Page:
1/30
Organization (S): EDF/EP/AMV
Handbook of Validation
V8.22 booklet: Harmonic accoustics
Document: V8.22.100

AHLV100 - Guide wave at anechoic exit
Summary:
A rectilinear guide of wave at anechoic exit, with rigid walls, whose propagation medium is air "normal", is excited by a harmonically vibrating piston.
One calculates by an acoustic formulation the acoustic field of pressure of the harmonic response for 13 different modelings. The results are tested in 2 points at the entry and 2 points at the exit.
They make it possible to validate the matrices of rigidity, mass, damping (impedance), the vector source (imposed normal speed) as well as the operators of postprocessings.
The results of reference come from an analytical calculation.
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

1
Problem of reference
1.1 Geometry
y
wave
plane
exit
B
D
anechoic
O
X
With
C
surface side rigid
Z
Tube with rectangular section:
length:

L = lx = 1.0 m
height:
H = ly = 0.1 m
width:
L = lz = 0.2 m
Co-ordinates of the points (in m):
With
B
C
D
X
0.
0.
1.00
1.00
y
0.
0.05
0.
0.05
Z
0.20
0.10
0.20
0.10

1.2
Properties of materials

Air:
O = 1.3 kg. m3
Co = 343. m.s1

1.3
Boundary conditions and loading

Normal speed at the entry
*V = Vn*exp (it) with Vn = 0.014 m.s1*
F = 500 Hz
Impedance at the end CD
Z = O. Co = 445.9 Kg.m2s1

2
Reference solution
2.1
Method of calculation used for the reference solution

The general analytical solution for a guide of wave is written:
(E, E, E
X
y
Z) being the orthonormé reference mark associated the Cartesian co-ordinates (X, y, Z)
· for the pressure:
(px, y, Z) = A ex (pikx) + B ex (p-ikx)
· for vibratory speed:
(
1
***V** X, y, Z) = -*
[A (
exp ikx) - B E
(
*xp - ikx)]**E***
.c
X
0
0
· A and B are determined by the boundary conditions:
in X = 0
Vn = Vn0
in X = L
(pL, y, Z) = Z. (
***V** L, y, Z) .nL*
Z - .c
.c. V

With =

B
0
0 exp (- 2ikL)
0
0
N
and

B =
with K =
Z + .c

0
0
Z - .c
C

0
0 exp (-
0
2 ikL) -

1
Z + .c
0
0
In the studied case, the exit of the guide is anechoic: Z = C
0 0. One thus has:
· for the pressure:
p (X, y, Z) = C V exp (
0 0
- ikx)
N
· for speed:
(
***V** X, y, Z) = - V exp (- ikx) .e*
N
X
· and for the acoustic intensity:
1
1
***I** =*
V =*
2

p
C V .e
2
2 0 0 N
X
i.e. acoustic Intensité activates uniform in all the guide and parallel with the axis.
The Eigen frequencies are given for the guide closed at the two ends by:
/

1 2
2
2
2
C
m
N
p
F
= 0
+
+

m, N, p
where m, N, p are entireties 0
2 2
2
2
X
1
y
1
Z
1

2.2
Results of reference

Pressure at the points A, B, C, D (for modelings A, B, C, D, E).
Acoustic intensity at points A, B, C, D (for modelings A and C).
Eigen frequencies n°2 with n°9.

2.3
Uncertainty on the solution

Analytical solution

2.4 References
bibliographical

[1]
BOUIZI A. Résolution of the equations of linear accoustics by a method finite elements mixed - Thesis (1989).
Handbook of Validation
V8.22 booklet: Harmonic accoustics
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Code_Aster ®
Version
4.0
Titrate:
AHLV100 Guides wave at anechoic exit
Date:
13/10/98
Author (S):
***F. STIFKENS**, G. ROUSSEAU*
Key:
V8.22.100-B Page:
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3 Modeling
With

3.1
Characteristics of modeling

Formulation pressure elements "ACOUSTIC" 3D (ACOU_HEXA20 and ACOU_FACE8)
y
vis-a-vis impedance
imposed
B
D
X
vis-a-vis speed
C
normal imposéeA
Z
Cutting =
15
meshs HEXA20 according to the x axis
2
meshs HEXA20 according to the y axis
2
meshs HEXA20 according to the axis of Z
Limiting conditions:
VITE_FACE:

(Group_ma: Entry
Vnor: IH 0.014 0.)
IMPE_FACE:
(Group_ma: Exit
Impe: IH 445.9 0.)
Name of the nodes
With = No1
B = No780
C = No751
D = No763

3.2
Characteristics of the grid

A number of nodes:
471
A number of meshs and types:
60 HEXA20 8 QUAD8

3.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
"ACOUSTIC"
"3D"
ALL
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_C
AFFE_CHAR_ACOU
MODEL
[U4.25.03]
VITE_FACE
VNOR
GROUP_MA
IMPE_FACE
IMPE
CALC_MATR_ELEM
"RIGI_ACOU"
MODEL
[U4.41.01]
"MASS_ACOU"

CHAM_MATER
“AMOR_ACOU”
CHARGE
COMB_MATR_ASSE
COMB_R
PART
REALITY
[U4.53.01]
IMAG
MODE_ITER_SIMULT
“BAND”
[U4.52.01]
CALC_VECT_ELEM
“CHAR_ACOU”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.01]
CALC_ELEM
“PRES_ELNO_REEL”
NEAR
[U4.61.02]
“PRES_ELNO_IMAG”
CHAM_MATER
“INTE_ELNO_ACTI”
FREQ
“INTE_ELNO_REAC”
CALC_CHAM_ELEM
“PRES_ELNO_DBEL”
NEAR
“PRES_ELNO_REEL”
CHAM_MATER
“PRES_ELNO_IMAG”
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

***Code_Aster* ®**
Version
4.0
Titrate:

4
Results of modeling A
4.1 Values
tested
Localization
Sizes
Reference
Aster
% difference
With
p (real)
6.2426
6.2425
0.001
p (imag)
0.0000
0.0003
-
Intensité_Acou
0.0437
0.0450
2.97
B
p (real)
6.2426
6.2425
0.001
p (imag)
0.0000
0.0003
-
Intensité_Acou
0.0437
0.0450
2.97

C
p (real)
6.0237
6.0222
0.02
p (imag)
1.6387
1.6441
0.33
Intensité_Acou
0.04037
0.0450
2.97
D
p (real)
6.0237
6.0222
0.02
p (imag)
1.6387
1.6441
0.33
Intensité_Acou
0.0437
0.0450
2.97
Frequency (Hz)
Order of the clean mode I
m
N
p
Reference
Aster
% difference
2
1
0
0
171.5
171.500
+0.0001
3
2

0
0
343.0
343.007
+0.002
4
3
0
0
514.5
514.555
+0.01
5
4
0
0
686.0
686.226
+0.03
6
5
0
0
857.5
858.178
+0.08
7
0
0
1
857.5
860.719
+0.4
8
1
0
1
874.482
877.640
+0.4
9
2
0

1
923.556
926.568
+0.3

4.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
OPTION: "BAND" FREQ: (0. 300.)

4.3 Parameters
of execution

Version: 3.05
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
2.6 seconds
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

---

5 Modeling
B

5.1
Characteristics of modeling

Formulation pressure potential of elements displacements "3D_FLUIDE" (MEFL_HEXA20 and MEFL_FACE8)
y
vis-a-vis
impedance

imposed
B
D
X
vis-a-vis speed
C
normal
With
imposed
Z
Cutting =
15
meshs HEXA20 according to the x axis
2
meshs HEXA20 according to the y axis
2
meshs HEXA20 according to the axis of Z
Limiting conditions:
VITE_FACE:
(GROUP_MA: Entry
VNOR: 0.014)
IMPE_FACE:
(GROUP_MA: Exit
IMPE: 445.9)
Name of the nodes
With = No1
B = No780
C = No751
D = No763

5.2
Characteristics of the grid

A number of nodes:
471
A number of meshs and types:
60 HEXA20 8 QUAD8

5.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
“MECHANICAL”
“3D_FLUIDE”
GROUP_MA

[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
"RIGI_MECA"
MODEL
[U4.41.01]
"MASS_MECA"
CHAM_MATER
"IMPE_MECA"
CHARGE
CALC_VECT_ELEM
"CHAR_MECA"
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

Code_Aster ®
Version
4.0
Titrate:
AHLV100 Guides wave at anechoic exit
Date:
13/10/98
Author (S):
***F. STIFKENS**, G. ROUSSEAU*
Key:

V8.22.100-B Page:
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6
Results of modeling B
6.1 Values
tested
Localization
Reference
Reference
Aster
% difference
With
p (real)
6.2426
6.2425
0.001
p (imag)
0.0
0.0003
-
B
p (real)
6.2426
6.2425
0.001
p (imag)
0.0
0.0003
-
C
p (real)
6.0237
6.0222
0.02
p (imag)
1.6387
1.6444
0.34
D
p (real)
6.0237
6.0222
0.02

p (imag)
1.6387
1.6444
0.34

6.2 Parameters
of execution

Version: 3.05
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
5.7 seconds

---

7 Modeling
D

7.1
Characteristics of modeling

Formulation pressure potential of elements displacements "2D_FLUIDE" (MEFLSE3 and MEFLQU8)

y
vis-a-vis
impedance
imposed
B
D
X
vis-a-vis speed

With
C
imposed normal
Cutting =
15
meshs QUAD8 according to the x axis
2
meshs QUAD8 according to the y axis
Limiting conditions:
VITE_FACE:
(GROUP_MA: Entry
VNOR: 0.014)
IMPE_FACE:
(GROUP_MA: Exit
IMPE: 445.9)
Name of the nodes
With = No1
B = No780
C = No151
D = No153

7.2
Characteristics of the grid

A number of nodes:
125
A number of meshs and types:
30 QUAD8 4 SEG3

7.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
"MECHANICAL"
"2D_FLUIDE"
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR

GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

---

8 Results of modeling D

8.1 Values tested

Localization	Sizes	Reference	Aster	% difference
With	p (real)	6.2426	6.2425	0.001
	p (imag)	0.0	0.0003	-
B	p (real)	6.2426	6.2425	0.001
	p (imag)	0.0	0.0003	-
C	p (real)	6.0237	6.0222	

0.02
p (imag)
1.6387
1.6441
0.37
D
p (real)
6.0237
6.0222
0.02
p (imag)
1.6387
1.6441
0.37

8.2 Parameters
of execution

Version: 3.00
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
2.8 seconds

---

9 Modeling
E
9.1

Characteristics of modeling
Formulation pressure potential of displacements elements “AXIS_FLUIDE” (MEAXFLS3 and MEAXFLQ8)
vis-a-vis speed
With
C
imposed normal
y
B
D
vis-a-vis impedance
X
imposed
Cutting =
15
meshs QUAD8 according to the x axis
2
meshs QUAD8 according to the y axis
Limiting conditions:
VITE_FACE:
(GROUP_MA: Entry
VNOR: 0.014)
IMPE_FACE:
(GROUP_MA: Exit
IMPE: 445.9)
Name of the nodes
With = No1
B = No780
C = No151
D = No153

9.2

Characteristics of the grid

A number of nodes:
125
A number of meshs and types:
30 QUAD8 4 SEG3

9.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
“MECHANICAL”
“AXIS_FLUIDE”

GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

Code_Aster ®
Version
4.0
Titrate:
AHLV100 Guides wave at anechoic exit
Date:
13/10/98
Author (S):
F. STIFKENS, G. ROUSSEAU

Key:
V8.22.100-B Page:
11/30

10
Results of modeling E
10.1 Values
tested
Localization
Sizes
Reference
Aster
% difference

With
p (real)
6.2426
6.2425
0.001
p (imag)
0.0
0.0003
-
B
p (real)
6.2426
6.2425
0.001
p (imag)
0.0
0.0003
-
C
p (real)
6.0237
6.0222
0.02
p (imag)
1.6387
1.6441
0.37
D
p (real)
6.0237
6.0222

0.02
p (imag)
1.6387
1.6441
0.37

10.2 Parameters of execution

Version: 3.02
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
4.1 seconds

---

11 Modeling
F

11.1 Characteristics of modeling

Formulation pressure elements "ACOUSTIC" PLAN (SEG3 AND QUAD8)
y
vis-a-vis
impedance
imposed
B
D
X
vis-a-vis speed

With
C
imposed normal
Cutting =
15
meshs QUAD8 according to the x axis
2
meshs QUAD8 according to the y axis
Limiting conditions:
VITE_FACE:
(Group_ma: Entry
Vnor: 0.014)
IMPE_FACE:
(Group_ma: Exit
Impe: 445.9)
Name of the nodes
With = No1
B = No33
C = No2
D = No34

11.2 Characteristics of the grid

A number of nodes:
125
A number of meshs and types:
30 QUAD8 4 SEG3

11.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
"ACOUSTIC"
"PLANE"
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR
GROUP_MA

[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

12
Results of modeling F
12.1 Values
tested
Localization
Sizes
Reference
Aster

% difference
With
p (real, imag)
(-6.2426,0.0)
(-6.2425,0.0003)
0.005
B
p (real, imag)
(-6.2426,0.0)
(- 6.2425,0.0003)
0.005
C
p (real, imag)
(6.0237,1.6387)
(6.0222,1.6441)
0.089
D
p (real, imag)
(6.0237,1.6387)
(6.0222,1.6441)
0.089

12.2 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
3.8 seconds

---

13 Modeling
G

13.1 Characteristics of modeling

Formulation pressure elements "ACOUSTIC" 3D (ACOU_HEXA8 and ACOU_FACE4)
Cutting =
30
meshs HEXA8 according to the x axis
4
meshs HEXA8 according to the y axis
4
meshs HEXA8 according to the axis of Z
Limiting conditions:
VITE_FACE:
(Group_ma: bicycle
Vnor: IH 0.014 0.)
IMPE_FACE:
(Group_ma: impe
Impe: IH 445.9 0.)
Name of the nodes
With = No69
B = No95
C = No65
D = No876

13.2 Characteristics of the grid

A number of nodes:
775
A number of meshs and types:
480 HEXA8 32 QUAD4

13.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
"ACOUSTIC"
"3D"
ALL
[U4.22.01]
DEFI_MATERIAU
FLUID

RHO
[U4.23.01]
CELE_C
AFFE_CHAR_ACOU
MODEL
[U4.25.03]
VITE_FACE
VNOR
GROUP_MA
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_ACOU”
MODEL
[U4.41.01]
“MASS_ACOU”
CHAM_MATER
“AMOR_ACOU”
CHARGE
CALC_VECT_ELEM
“CHAR_ACOU”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
CALC_ELEM
“PRES_ELNO_REEL” NEAR
[U4.61.02]
“PRES_ELNO_IMAG” CHAM_MATER
“INTE_ELNO_ACTI” FREQ
“INTE_ELNO_REAC”
CALC_CHAM_ELEM
“PRES_ELNO_DBEL” NEAR
“PRES_ELNO_REEL” CHAM_MATER
“PRES_ELNO_IMAG”
MODE_ITER_SIMULT
“BAND”
[U4.52.01]
DYNA_LINE_HARM
[U4.54.01]
COMB_MATR_ASSE
COMB_R
PART

---

14 Results of modeling G

14.1 Values tested

Localization	**Sizes**	**Reference**	**Aster**	**% difference**
With	p (real, imag)	(-6.2426,0.0000)	(-6.2469,0.0137)	0.231
	Intensité_Acou	0.0437	0.0431	-1.47
B	p (real, imag)	(-6.2426,0.0000)	(-6.2469,0.0137)	0.231
	Intensité_Acou			

0.0437
0.0431
-1.47
C
p (real, imag)
(6.0237,1.6387)
(5.9663,1.8438)
3.411
Intensité_Acou
0.0437
0.0431
-1.47
D
p (real, imag)
(6.0237,1.6387)
(5.9663,1.8438)
3.411
Intensité_Acou
0.0437
0.0431
-1.47
Frequency (Hz)
Order of the clean mode I
m
N
p
Reference
Aster
% difference
2
1
0
0
171.5
171.578
0.046
3
2
0
0
343.0
343.627
0.183

4
3
0
0
514.5
516.618
0.412
5
4
0
0
686.0
691.026
0.733
6
5
0
0
857.5
867.326
1.146
7
0
0
1
857.5
879.674
2.586
8
1
0
1
874.482
896.251
2.489
9
2
0
1
923.556
944.408
2.258

14.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
option: “band” List_freq: (0. 1000.)

14.3 Parameters
of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
8.9 seconds

---

15 Modeling
H

15.1 Characteristics of modeling

Formulation pressure elements “ACOUSTIC” 3D (ACOU_PENTA15 and ACOU_FACE6)
Cutting =
15
meshs PENTA15 according to the x axis
2
meshs PENTA15 according to the y axis
2
meshs PENTA15 according to the axis of Z
Limiting conditions:
VITE_FACE:
(Group_ma: bicycle

Vnor: IH 0.014 0.)
IMPE_FACE:
(Group_ma: impe
Impe: IH 445.9 0.)
Name of the nodes
With = No28
B = No64
C = No24
D = No720

15.2 Characteristics of the grid

A number of nodes:
456
A number of meshs and types:
90 PENTA15 12 TRIA6

15.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
“ACOUSTIC”
“3D”
ALL
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_C
AFFE_CHAR_ACOU
MODEL
[U4.25.03]
VITE_FACE
VNOR
GROUP_MA
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_ACOU”
MODEL
[U4.41.01]
“MASS_ACOU”
CHAM_MATER
“AMOR_ACOU”

CHARGE
CALC_VECT_ELEM
“CHAR_ACOU”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
CALC_ELEM
“PRES_ELNO_REEL” NEAR
[U4.61.02]
“PRES_ELNO_IMAG” CHAM_MATER
“INTE_ELNO_ACTI” FREQ
“INTE_ELNO_REAC”
CALC_CHAM_ELEM
“PRES_ELNO_DBEL” NEAR
“PRES_ELNO_REEL” CHAM_MATER
“PRES_ELNO_IMAG”
MODE_ITER_SIMULT
“BAND”
[U4.52.01]
DYNA_LINE_HARM
[U4.54.01]
COMB_MATR_ASSE
COMB_R
PART
REALITY
[U4.53.01]
IMAG

17/30

16

Results of modeling C

16.1 Values

tested

Localization

Sizes

Reference

Aster

% difference

With

p (real, imag)

(-6.2426,0.0000)

(-6.2425-,0.0003)

0.005

Intensité_Acou

0.0437

0.0450

2.97

B

p (real, imag)

(-6.2426,0.0000)

(-6.2425,0.0003)

0.005

Intensité_Acou

0.0437

0.0450

2.97

C

p (real, imag)

(6.0237,1.6387)

(6.0222,1.6441)

0.089

Intensité_Acou

0.0437

0.0450

2.97

D

p (real, imag)

(6.0237,1.6387)

(6.0222,1.6441)

0.089

Intensité_Acou

0.0437
0.0450
2.97
Frequency (Hz)
Order of the clean mode I
m
N
p
Reference
Aster
% difference
2
1
0
0
171.5
171.500
0.000
3
2
0
0
343.0
343.007
0.002
4
3
0
0
514.5
514.555
0.011
5
4
0
0
686.0
686.226
0.033
6
5
0
0

857.5
858.178
0.079
7
0
0
1
857.5
860.470
0.346
8
1
0
1
874.482
877.395
0.333
9
2
0
1
923.556
926.335
0.301

16.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
option: “band” List_freq: (0. 1000.)

16.3 Parameters
of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
7.0 seconds

17 Modeling
I

17.1 Characteristics of modeling

Formulation pressure elements “ACOUSTIC” 3D (ACOU_PENTA6 and ACOU_FACE3)
Cutting =
30
meshs PENTA6 according to the x axis
4
meshs PENTA6 according to the y axis
4
meshs PENTA6 according to the axis of Z
Limiting conditions:
VITE_FACE:
(Group_ma: bicycle
Vnor: IH 0.014 0.)
IMPE_FACE:
(Group_ma: impe
Impe: IH 445.9 0.)
Name of the nodes
With = No110
B = No156
C = No106
D = No939

17.2 Characteristics of the grid

A number of nodes:
775
A number of meshs and types:
960 PENTA6 64 TRIA3

17.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
“ACOUSTIC”
“3D”
ALL
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_C
AFFE_CHAR_ACOU
MODEL
[U4.25.03]
VITE_FACE
VNOR
GROUP_MA
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_ACOU”
MODEL
[U4.41.01]
“MASS_ACOU”
CHAM_MATER
“AMOR_ACOU”
CHARGE
CALC_VECT_ELEM
“CHAR_ACOU”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
CALC_ELEM
“PRES_ELNO_REEL” NEAR
[U4.61.02]
“PRES_ELNO_IMAG” CHAM_MATER
“INTE_ELNO_ACTI” FREQ
“INTE_ELNO_REAC”
CALC_CHAM_ELEM
“PRES_ELNO_DBEL” NEAR
“PRES_ELNO_REEL” CHAM_MATER
“PRES_ELNO_IMAG”
MODE_ITER_SIMULT

“BAND”
[U4.52.01]
DYNA_LINE_HARM
[U4.54.01]
COMB_MATR_ASSE
COMB_R
PART
REALITY
[U4.53.01]
IMAG
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

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18 Results of modeling I

18.1 Values tested

Localization	Sizes	Reference	Aster	% difference
With	p (real, imag)	(-6.2426,0.0000)	(-6.2469-,0.0138)	0.231
	Intensité_Acou	0.0437	0.0431	-1.47
B	p (real, imag)	(-6.2426,0.0000)	(-6.2469,0.0138)	0.231
	Intensité_Acou	0.0437	0.0431	-1.47
C	p (real, imag)	(6.0237,1.6387)	(5.9663,1.8438)	

3.411
Intensité_Acou
0.0437
0.0431
-1.47
D
p (real, imag)
(6.0237,1.6387)
(5.9663,1.8438)
3.411
Intensité_Acou
0.0437
0.0431
-1.47
Frequency (Hz)
Order of the clean mode I
m
N
p
Reference
Aster
% difference
2
1
0
0
171.5
171.578
0.046
3
2
0
0
343.0
343.627
0.183
4
3
0
0
514.5
516.618
0.412

5
4
0
0
686.0
691.026
0.733
6
5
0
0
857.5
867.326
1.146
7
0
0
1
857.5
879.045
2.512
8
1
0
1
874.482
895.633
2.419
9
2
0
1
923.556
943.821
2.194

18.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
option: “band” List_freq: (0. 1000.)

18.3 Parameters of execution

Version: 3.07
Machine: CRAY C90

System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
9.7 seconds
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

---

19 Modeling
J

19.1 Characteristics of modeling

Formulation pressure elements "ACOUSTIC" 3D (ACOU_TETRA10 and ACOU_FACE6)
Cutting =
15
meshs TETRA10 according to the x axis
2
meshs TETRA10 according to the y axis
2
meshs TETRA10 according to the axis of Z
Limiting conditions:
VITE_FACE:
(Group_ma: bicycle
Vnor: IH 0.014 0.)
IMPE_FACE:
(Group_ma: impe
Impe: IH 445.9 0.)
Name of the nodes
With = No4
B = No76

C = No7
D = No73

19.2 Characteristics of the grid

A number of nodes:
870
A number of meshs and types:
421 TETRA10 16 TRIA6

19.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
“ACOUSTIC”
“3D”
ALL
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_C
AFFE_CHAR_ACOU
MODEL
[U4.25.03]
VITE_FACE
VNOR
GROUP_MA
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_ACOU”
MODEL
[U4.41.01]
“MASS_ACOU”
CHAM_MATER
“AMOR_ACOU”
CHARGE
CALC_VECT_ELEM
“CHAR_ACOU”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE

CALC_ELEM
“PRES_ELNO_REEL” NEAR
[U4.61.02]
“PRES_ELNO_IMAG” CHAM_MATER
“INTE_ELNO_ACTI” FREQ
“INTE_ELNO_REAC”
CALC_CHAM_ELEM
“PRES_ELNO_DBEL” NEAR
“PRES_ELNO_REEL” CHAM_MATER
“PRES_ELNO_IMAG”
MODE_ITER_SIMULT
“BAND”
[U4.52.01]
DYNA_LINE_HARM
[U4.54.01]
COMB_MATR_ASSE
COMB_R
PART
REALITY
[U4.53.01]
IMAG

---

20 Results of modeling J

20.1 Values tested

Localization
Sizes

Reference
Aster
% difference
With
p (real, imag)
(-6.2426,0.0000)
(-6.2483-,-0.0162)
0.272
Intensité_Acou
0.0437
0.0447
2.398
B
p (real, imag)
(-6.2426,0.0000)
(-6.2465,-0.0122)
0.205
Intensité_Acou
0.0437
0.0452
3.507
C
p (real, imag)
(6.0237,1.6387)
(6.0201,1.6491)
0.176
Intensité_Acou
0.0437
0.0443
1.283
D
p (real, imag)
(6.0237,1.6387)
(6.0284,1.6319)
0.133
Intensité_Acou
0.0437
0.0449
2.797
Frequency (Hz)
Order of the clean mode I
m
N

p
Reference
Aster
% difference
2
1
0
0
171.5
171.500
0.000
3
2
0
0
343.0
343.005
0.001
4
3
0
0
514.5
514.534
0.007
5
4
0
0
686.0
686.146
0.021
6
5
0
0
857.5
857.924
0.049
7
0
0
1

857.5
860.111
0.304
8
1
0
1
874.482
877.250
0.317
9
2
0
1
923.556
927.079
0.381

20.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
option: “band” List_freq: (0. 1000.)

20.3 Parameters
of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
9.5 seconds
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

Code_Aster ®
Version
4.0
Titrate:
AHLV100 Guides wave at anechoic exit
Date:
13/10/98
Author (S):

21 Modeling
K

21.1 Characteristics of modeling

Formulation pressure elements “ACOUSTIC” 3D (ACOU_TETRA4 and ACOU_FACE3)
Cutting =
30
meshs TETRA4 according to the x axis
4
meshs TETRA4 according to the y axis
4
meshs TETRA4 according to the axis of Z
Limiting conditions:
VITE_FACE:
(Group_ma: bicycle
Vnor: IH 0.014 0.)
IMPE_FACE:
(Group_ma: impe
Impe: IH 445.9 0.)
Name of the nodes
With = No18
B = No521
C = No15
D = No1028

21.2 Characteristics of the grid

A number of nodes:
685
A number of meshs and types:
2180 TETRA4 64 TRIA6

21.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
“ACOUSTIC”
“3D”
ALL
[U4.22.01]
DEFI_MATERIAU
FLUID

RHO
[U4.23.01]
CELE_C
AFFE_CHAR_ACOU
MODEL
[U4.25.03]
VITE_FACE
VNOR
GROUP_MA
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_ACOU”
MODEL
[U4.41.01]
“MASS_ACOU”
CHAM_MATER
“AMOR_ACOU”
CHARGE
CALC_VECT_ELEM
“CHAR_ACOU”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
CALC_ELEM
“PRES_ELNO_REEL” NEAR
[U4.61.02]
“PRES_ELNO_IMAG” CHAM_MATER
“INTE_ELNO_ACTI” FREQ
“INTE_ELNO_REAC”
CALC_CHAM_ELEM
“PRES_ELNO_DBEL” NEAR
“PRES_ELNO_REEL” CHAM_MATER
“PRES_ELNO_IMAG”
MODE_ITER_SIMULT
“BAND”
[U4.52.01]
DYNA_LINE_HARM
[U4.54.01]
COMB_MATR_ASSE
COMB_R
PART

---

22 Results of modeling K

22.1 Values tested

Localization	**Sizes**	**Reference**	**Aster**	**% difference**
With	p (real, imag)	(-6.2426,0.0000)	(-6.2321,0.0342)	0.574
	Intensité_Acou	0.0437	0.0431	-1.439
B	p (real, imag)	(-6.2426,0.0000)	(-6.1797,0.0300)	1.116
	Intensité_Acou			

0.0437
0.0427
-2.274
C
p (real, imag)
(6.0237,1.6387)
(5.8478,1.8750)
4.719
Intensité_Acou
0.0437
0.0421
-3.571
D
p (real, imag)
(6.0237,1.6387)
(5.9706,1.9224)
4.623
Intensité_Acou
0.0437
0.0427
-2.212
Frequency (Hz)
Order of the clean mode I
m
N
p
Reference
Aster
% difference
2
1
0
0
171.5
171.689
0.110
3
2
0
0
343.0
343.870
0.254

4
3
0
0
514.5
517.434
0.570
5
4
0
0
686.0
692.615
0.964
6
5
0
0
857.5
870.670
1.536
7
0
0
1
857.5
876.335
2.196
8
1
0
1
874.482
896.171
2.480
9
2
0
1
923.556
953.782
3.273

22.2 Remarks

Calculations of modes carried out by:
MODE_ITER_SIMULT
option: “band” List_freq: (0. 1000.)

22.3 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
11.7 seconds

---

23 Modeling Q

23.1 Characteristics of modeling

Formulation pressure elements “ACOUSTIC” PLAN (SEG2 AND QUAD4)
Cutting =
30
meshs QUAD4 according to the x axis
4
meshs QUAD4 according to the y axis
Limiting conditions:
VITE_FACE:
(Group_ma: Entry
Vnor: 0.014)
IMPE_FACE:

(Group_ma: Exit
Impe: 445.9)
Name of the nodes
With = No1
B = No237
C = No2
D = No205

23.2 Characteristics of the grid

A number of nodes:
155
A number of meshs and types:
120 QUAD8 8 SEG2

23.3 Functionalities
tested
Orders
Keys

AFFE_MODELE
“ACOUSTIC”
“PLANE”
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
CALC_VECT_ELEM
“CHAR_MECA”

MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

24
Results of modeling Q
24.1 Values
tested
Localization
Sizes
Reference
Aster
% difference
With
p (real, imag)
(-6.2426,0.0)
(-6.2469,0.0138)
0.231
B
p (real, imag)
(-6.2426,0.0)
(- 6.2469,0.0138)
0.231
C
p (real, imag)

(6.0237,1.6387)
(5.9663,1.8438)
3.411
D
p (real, imag)
(6.0237,1.6387)
(5.9663,1.8438)
3.411

24.2 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
4.0 seconds

---

25 Modeling R

25.1 Characteristics of modeling

Formulation pressure elements "ACOUSTIC" PLAN (SEG3 AND TRIA6)
Cutting =
15
meshs TRIA6 according to the x axis
2
meshs TRIA6 according to the y axis

Limiting conditions:
VITE_FACE:
(Group_ma: Entry
Vnor: 0.014)
IMPE_FACE:
(Group_ma: Exit
Impe: 445.9)
Name of the nodes
With = No1
B = NO5
C = No2
D = No6

25.2 Characteristics of the grid

A number of nodes:
155
A number of meshs and types:
60 TRIA6 4 SEG3

25.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
“ACOUSTIC”
“PLANE”
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”

CHAM_MATER
“IMPE_MECA”
CHARGE
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]

26
Results of modeling R
26.1 Values
tested
Localization
Sizes
Reference
Aster
% difference
With
p (real, imag)
(-6.2426,0.0)
(-6.2473,-0.0105)
0.184
B
p (real, imag)

(-6.2426,0.0)
(- 6.2436,-0.0029)
0.050
C
p (real, imag)
(6.0237,1.6387)
(6.0190,1.6517)
0.221
D
p (real, imag)
(6.0237,1.6387)
(6.0231,1.6446)
0.094

26.2 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
3.8 seconds

---

27 Modeling S

27.1 Characteristics of modeling

Formulation pressure elements "ACOUSTIC" PLAN (SEG2 AND TRIA3)

Cutting =
30
meshs TRIA3 according to the x axis
4
meshs TRIA3 according to the y axis
Limiting conditions:
VITE_FACE:
(Group_ma: Entry
Vnor: 0.014)
IMPE_FACE:
(Group_ma: Exit
Impe: 445.9)
Name of the nodes
With = No1
B = No237
C = No2
D = No205

27.2 Characteristics of the grid

A number of nodes:
155
A number of meshs and types:
240 TRIA3 8 SEG2

27.3 Functionalities
tested

Orders
Keys

AFFE_MODELE
“ACOUSTIC”
“PLANE”
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
VITE_FACE
VNOR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE

CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HX-XX/98/XXX - Ind X

---

28 Results of modeling S

28.1 Values tested

Localization	**Sizes**	**Reference**	**Aster**	**% difference**
With	p (real, imag)	(-6.2426,0.0)	(-6.1959,-0.0157)	0.803
B	p (real, imag)	(-6.2426,0.0)	(- 6.2444,0.0058)	0.097
C	p (real, imag)	(6.0237,1.6387)	(5.9655,2.0110)	6.036
D	p (real, imag)	(6.0237,1.6387)	(5.9199,1.9838)	5.774

28.2 Parameters of execution

Version: 3.07
Machine: CRAY C90
System:
UNICOS 80.
Obstruction memory:
8 megawords
Time CPU To use:
4.2 seconds

29
Summary of the results

Modelings give the awaited results. It will be noted however that times CPU are appreciably more important than those mentioned in the cards of validation AHLV100 of the 11/8/95 (V8.22.100 Document).

In modelings using of the tetrahedrons or the triangles, the distribution of the pressure is less uniform that in the other cases following the non-uniformity of the grid.

F. STIFKENS, G. ROUSSEAU
Key:
V8.22.101-A Page:
1/12
Organization (S): EDF/EP/AMV

Handbook of Validation
V8.22 booklet: Harmonic accoustics
V8.22.101 document

AHLV101 - Guide wave at anechoic exit

Summary:

A rectilinear guide of wave at anechoic exit, with rigid walls, whose propagation medium is air "normal", is excited by a harmonic incidental wave, normal with the face of entry. One calculates the field of acoustic pressure of the harmonic response by using the élasto-accoustics formulation in pressure-displacement-potential of displacements.

The tests relate to 3 different modelings (finite elements élasto-acoustics three-dimensional, two-dimensional and axisymmetric), they make it possible to validate the matrices of rigidity, mass, impedance and vector source for 3 modelings.

The result of reference comes from an analytical calculation.

---

1 Problem of reference

1.1 Geometry

y
wave
plane
B

exit
D
anechoic
O
X
.
With
C
rigid side surfaces
Z
Tube with rectangular section:
length:
L = lx = 1.0 m
height:
H = ly = 0.1 m
width:
L = lz = 0.2 m
Co-ordinates of the points (in m):
With
B
C
D
X
0.
0.
1.00
1.00
y
0.
0.05
0.
0.05
Z
0.20
0.10
0.20
0.10
1.2
Properties of materials
Air:
= 1.3 kg. m3
C = 343. m.s1
1.3

Boundary conditions and loading
Pressure of normal incidental wave at the entry
P = *P*

0 * exp
0 =
I
(*I T*) vec *P* 10 has. *Pa*
Frequency
F = 500 *Hz*
2
1
Impedance at the end CD
Z = .c =
- -
445 9
. *Kg.m*
S

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The frequencies of the excitation are rather low and jointly the guide of wave is sufficiently length compared to its side dimensions so that one limits oneself to the plane waves: the phenomenon is then identical in all points of a plan of wave, i.e. does not depend on the co-ordinates describing points of this plan, y and Z for example.
One gives on this assumption the well-known general solution of the equations of accoustics for

the two sizes **pressure** *p* and **acoustic speed** v:

X

X
v = F *T* -
G

T
éq 2.1-1
C +
+

C

X

X
p = *C* F *T* -
G

T
éq 2.1-2
C -
+

C

The guide is supposed to be closed at the end of X-coordinate L on an impedance *ZL*; there is one reflexion on the level of this impedance, which gives a wave of return *G*.
In each point of the guide, there is then superposition of the two functions *F* and *G*; by definition even final impedance *ZL* imposes on the point of X-coordinate L, between *p* and the *v* relation.
pL = *Z*
v
L

L
In the harmonic case *F* and *G* are written:
X

X
I T

F *T* -
I E
C

C =
X

X
I t+

G *T* +
R E
C

C =
where *I* and *R* are determined by the boundary conditions.
p
In the calculation of the impedance *Z* =
in any item *X the* variable time this time is eliminated,
v
in accordance with the calculation even of the impedances and is written:
X
X
- *I*
I
(
I E

C - *R E C*
Z *X*) = *Z0*
X
X
- *I*
I
I E
C + *R E C*

The final impedance becomes:
L
L
- *I*
I
I E
C - *R E C*
Z = *Z*
L
0
L
L
- *I*
I
I E
C + *R E C*
One calls *Z* = *C*
0
iterative impedance.

On the fluid border at the entry of the guide the condition limits of incidental wave type imposed on

P
P I.E.(internal excitation) T
=
I
0
, is obtained by writing at the border the following linear relation:
p - *C* v = *P*
N
I
éq 2.1-3
where v =
N
v. N is the speed according to unit normal **N outgoing** of the fluid.
One imposes moreover on the exit of the guide a value of final impedance *Z* = *Z*
L
0 which does one of them
anechoic end.
The final impedance is equal to the iterative impedance *Z0* when *R* = 0, i.e. when there is not
no the wave of return; one then has a pure travelling wave in the direction of the incidental wave, that is to say:
X
I T

C
v = *I E*
X
I T

C
p = *C IE*
thus the relation of imposed incidental wave [éq 2.1-3] is written:
p v = (
p
=)
0 + (=)
0 = 2
I
C

X
cv X
C IE T
N
I T
from where 2 are identified

C IE
= *pi*; one deduces the expression from it from the travelling wave of pressure in guide when one imposes *pi* on the entry of the guide:
X
X
P -
P
I T
I
I
0

C
p =
E
C =
E
2
2

2.2
Results of reference
Pressure at the points A, B, C, D (for modelings A, B, C).
2.3
Uncertainty on the solution
Analytical solution.
2.4 References
bibliographical

[1]
F. STIFKENS "Introduction into Code_Aster of condition limits of incidental wave type in vibroacoustic - Report/ratio HP-61/95/026/

---

3 Modeling
With
3.1
Characteristics of modeling
Pressure-potential formulation of elements displacements "3D_FLUIDE" (MEFL_HEXA20 and MEFL_FACE8)
y
vis-a-vis impedance
imposed
B
D
X
vis-a-vis wave
incidental imposed
C
With

Z
Cutting =
15
meshs HEXA20 according to the x axis
2
meshs HEXA20 according to the y axis
2
meshs HEXA20 according to the axis of Z
Limiting conditions:
ONDE_FLUI:
(GROUP_MA: Entry
NEAR: 1.0)
IMPE_FACE:
(GROUP_MA: Exit
IMPE: 445.9)
Name of the nodes
With = No1
B = No780
C = No751
D = No763
3.2
Characteristics of the grid
A number of nodes:
471
A number of meshs and types:
60 HEXA20 8 QUAD8
3.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
“MECHANICAL”
“3D”
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
ONDE_FLUI
NEAR

GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
“ONDE_FLUI”
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
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HP-51/96/094 - Ind A

4
Results of modeling A
4.1 Values
tested
Localization
Sizes

Reference
Aster
% difference
With
p (real)
0.5
0.499997
6 104
p (imag)
0.0
1.2 105
-
B
p (real)
0.5
0.499997
6 104
p (imag)
0.0
1.2 105
-
C
p (real)
0.482466
0.482352
2.4 102
p (imag)
0.131252
0.131670
3.2 101
D
p (real)
0.482466
0.482352
2.4 102
p (imag)
0.131252
0.131670
3.2 101

4.2 Parameters of execution

Version: 3.05.10
Machine: CRAY C90

System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
64.08 seconds
Handbook of Validation
V8.22 booklet: Harmonic accoustics
HP-51/96/094 - Ind A

---

5 Modeling
B

5.1
Characteristics of modeling

Formulation pressure potential of elements displacements “2D_FLUIDE” (MEFLSE3 and MEFLQU8)
y
vis-a-vis
impedance
imposed
B
D
X
vis-a-vis wave
With
C
incidental imposed
Cutting =
15
meshs QUAD8 according to the x axis
2
meshs QUAD8 according to the y axis

Limiting conditions:
ONDE_FLUI:
(GROUP_MA: Entry
NEAR: 1.0)
IMPE_FACE:
(GROUP_MA: Exit
IMPE: 445.9)
Name of the nodes
With = No1
B = NO3
C = No751
D = No153

5.2
Characteristics of the grid

A number of nodes:
125
A number of meshs and types:
30 QUAD8 4 SEG3

5.3 Functionalities
tested

Orders
Keys
AFFE_MODELE
“MECHANICAL”
“2D_FLUIDE”
GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
ONDE_FLUI
NEAR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]

“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
“ONDE_FLUI”
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]

---

6 Results of modeling B

6.1 Values tested

Localization	Sizes	Reference	Aster	% difference
With	p (real)	0.5	0.499997	6 104
	p (imag)	0.0	1.2 105	-
B	p (real)	0.5	0.499997	6 104
	p (imag)	0.0	1.2 105	-
C	p (real)	0.482466	0.482352	

2.4 102
p (imag)
0.131252
0.131670
3.2 101
D
p (real)
0.482466
0.482352
2.4 102
p (imag)
0.131252
0.131670
3.2 101

6.2 Parameters
of execution

Version: 3.05.10
Machine: CRAY C90
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
62.57 seconds

---

7 Modeling
C
7.1

Characteristics of modeling
Pressure-potential formulation of displacements elements "AXIS_FLUIDE" (MEAXFLS3 and MEAXFLQ8)
vis-a-vis impedance
vis-a-vis wave
imposed
incidental imposed
With
C
y
B
D
X
Cutting =
15
meshs QUAD8 according to the y axis
2
meshs QUAD8 according to the x axis
Limiting conditions:
ONDE_FLUI:
(GROUP_MA: Entry
NEAR: 1.0)
IMPE_FACE:
(GROUP_MA: Exit
IMPE: 445.9)
Name of the nodes
With = No1
B = NO3
C = No151
D = No153
7.2
Characteristics of the grid
A number of nodes:
125
A number of meshs and types:
30 QUAD8 4 SEG3
7.3 Functionalities
tested
Orders
Keys
AFFE_MODELE
"MECHANICAL"
"AXIS_FLUIDE"

GROUP_MA
[U4.22.01]
DEFI_MATERIAU
FLUID
RHO
[U4.23.01]
CELE_R
AFFE_CHAR_MECA
ONDE_FLUI
NEAR
GROUP_MA
[U4.25.01]
IMPE_FACE
IMPE
CALC_MATR_ELEM
“RIGI_MECA”
MODEL
[U4.41.01]
“MASS_MECA”
CHAM_MATER
“IMPE_MECA”
CHARGE
“ONDE_FLUI”
CALC_VECT_ELEM
“CHAR_MECA”
MODEL
[U4.41.02]
CHAM_MATER
CHARGE
DYNA_LINE_HARM
[U4.54.02]
Handbook of Validation
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HP-51/96/094 - Ind A

Code_Aster ®
Version
4.0
Titrate:
AHLV101 Guides wave at anechoic exit
Date:
12/01/98
Author (S):

8
Results of modeling C
8.1 Values
tested
Localization
Sizes
Reference
Aster
% difference
With
p (real)
0.5
0.499997
6 104
p (imag)
0.0
1.2 105
-
B
p (real)
0.5
0.499997
6 104
p (imag)
0.0
1.2 105
-
C
p (real)
0.482466
0.482352
2.4 102
p (imag)
0.131252
0.131670
3.2 101
D
p (real)
0.482466

0.482352
2.4 102
p (imag)
0.131252
0.131670
3.2 101

8.2 Parameters of execution

Version: 3.05.12
Machine: CRAY C98
System:
UNICOS 8.0
Obstruction memory:
8 megawords
Time CPU To use:
62.77 seconds

---

9 Summary of the results

The discretization is strong since it is approximately 45 nodes by wavelength. This is why us let us obtain results of a high precision: pressure calculated by Code_Aster at the point it less favorable differs from the theoretical value from less than 1%.

It should be also noted that all modelings used give identical results.

Version
4.0
Titrate:
SZLZ100 Tires on an eccentric cycle
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.100-A Page:
1/8
Organization (S): EDF/IMA/MMN

Handbook of Validation

V9.01 booklet: Tire

Document: V9.01.100

SZLZ100 - Tire on an eccentric cycle

Summary:

The purpose of this test is calculation of the damage starting from a history of loading in constraints, then of a history
of loading in deformations.

Starting from a simple history of loading defined by DEFI_FONCTION [U4.21.02], one extracts the cycles
elementary by the method of counting of cycles of the RCCM [R7.04.01], then one calculates the damage
elementary associated each cycle, by interpolation on the curve of Wöhler of material (if history of
loading in constraints and by interpolation on the curve of Manson-Whetstone sheath of material) (if history of
loading in deformations).

The curve of Wöhler is defined by DEFI_FONCTION [U4.21.02]. The interpolation is of logarithmic curve type on
the number of cycles to the rupture NR and on the alternate constraint Salt.

The curve of Manson-Whetstone sheath is also defined by DEFI_FONCTION.

To finish, one determines the total damage undergone by the part by cumulating all the elementary damage by
linear rule To mine.

In this test, one also checks the taking into account of the value of the average constraint on the calculation of
elementary damage by the method of Wöhler. The first calculation is carried out without correction, a second
with a correction To stack and the third with a correction of Goodman.

On this simple example, the extraction of the elementary cycles and the calculation of the damage can be made
manually, by applying the algorithms presented in the reference document [R7.04.01].

The results provided by operator POST_FATIGUE [U4.67.01] are of this fact very satisfactory.
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SZLZ100 Tires on an eccentric cycle
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.100-A Page:
2/8

1 Problem of reference

1.1 Geometry

The analysis consists in determining the damage undergone by a part in a point to which one provides the history
of loading.

To test the calculation of the damage by the method of Wöhler, one considers the history of loading in constraints and one extracts the elementary cycles by a method of counting of cycles, which is in this test method of the RCCM. Then one calculates the elementary damage due to each elementary cycle, by interpolation on the curve of Wöhler of material.

The curve of Wöhler is founie in the form of a function point by point, which gives the value of

a number of cycles to the rupture according to the alternate constraint *Salt* =
.
2

The interpolation is of logarithmic curve type on the X-coordinate and the ordinate and one authorize to prolong
linearly this function on the right and on the left.

Three different calls to operator POST_FATIGUE [U4.67.01] make it possible to take account or not of the average constraint of each elementary cycle.

The adopted correction is that of the diagram of Haigh, either according to the line of Goodman or according to
the parabola To stack [R7.04.01].

One determines the total damage by the linear rule of office plurality To mine.

To test the calculation of the damage by the method of Manson-Whetstone sheath, one considers the history of

loading in deformations and one extracts the elementary cycles by a method of counting of
cycles, which is in this test the method of the RCCM. Then one calculates the elementary damage due to each elementary cycle, by interpolation on the curve of Manson-Whetstone sheath of material.
The curve of Manson-Whetstone sheath is provided in the form of a function point by point, which gives the value

number of cycles to the rupture according to
.
2
One determines the total damage by the linear rule of office plurality To mine.

1.2
Material properties

The curve of Wöhler of the material, which gives the value of the number of cycles to the rupture according to
the alternate constraint is point by point defined by:
Salt
138.
152.
165.
180.
200.
250.
295.
305.
NR
1000000.
500000.
200000.
100000.
50000.
20000.
12000.
10000.
340.
430.
540.
690.
930.
1210.
1590.
2210.
2900.
5000.

2000.
1000.
500.
200.
100.
50.
20.
10.
Known = limit with the rupture of material = 850.
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SZLZ100 Tires on an eccentric cycle
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.100-A Page:
3/8
History of the loading
T
0.
1.
2.
3.
4.
(T)
50.
600.
50.
-500.
50.
The curve of Manson-Whetstone sheath of the material, which gives the value of the number of cycles to the rupture in

function of
is point by point defined by:

2
138.
152.
165.
180.
200.
250.
295.
305.
2
NR
1000000.
500000.
200000.
100000.
50000.
20000.
12000.
10000.
340.
430.
540.
690.
930.
1210.
1590.
2210.
2900.
5000.
2000.
1000.
500.
200.
100.
50.
20.
10.

History of the loading

T
0.
1.
2.
3.

4.
(T)
50.
600.
50.
-500.
50.

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The history of loading being very simple, the results of reference can be obtained manually by applying the algorithms presented in the reference document [R7.04.01].

2.2 Results of reference

The counting of the elementary cycles by method RCCM leads to:

Nb_Cycl = 2

Cycle 1
Vale_Min:
-500.
Vale_Max:
600.

Cycle 2
Vale_Min:
50.
Vale_Max:
50.

· **First call** to POST_FATIGUE:
calculation of the elementary damage by the method of Wöhler without correction of HAIGH:
Cycle 1
Too bad:
1.053257E3
Cycle 2
Too bad:
0.
calculation of the total damage by linear office plurality To mine:
Too bad: 1.053257E3
· **Second call** to POST_FATIGUE:
calculation of the elementary damage by the method of Manson-Whetstone sheath:
Cycle 1
Too bad:
1.053257E3
Cycle 2
Too bad:
0.
calculation of the total damage by linear office plurality To mine:
Too bad: 1.053257E3
· **Third call** to POST_FATIGUE:
calculation of the elementary damage by the method of Wöhler with correction To stack:
Cycle 1
Too bad:
1.063631E3
Cycle 2
Too bad:
0.
calculation of the total damage by linear office plurality To mine:
Too bad: 1.063631E3
· **Fourth call** to POST_FATIGUE:
calculation of the elementary damage by the method of Wöhler with correction of Goodman:
Cycle 1
Too bad:
1.250219E3
Cycle 2
Too bad:
0.
calculation of the total damage by linear office plurality To mine:
Too bad: 1.250219E3

2.3

Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
Estimate of tiredness to great numbers of cycles. Document [R7.04.01].

---

3 Modeling
With

3.1 Functionalities
tested

Order
POST_FATIGUE [U4.67.01].

Key word
Operand

HISTORY
SIGM:
COUNTING:
“RCCM”
TOO BAD:
“WOHLER”
MATER:
CORR_SIGM_MOYE:
“TO STACK”
“GOODMAN”
OFFICE PLURALITY:
“LINEAR”
INFORMATION:
2
HISTORY

EPSI:
COUNTING:
“RCCM”
TOO BAD:
“MANSON_COFFIN”
MATER:
OFFICE PLURALITY:
“LINEAR”
INFORMATION:
2
Key word
Operand
Keys
DEFI_MATERIAU
TIRE
WOHLER:
[U4.23.01]
KNOWN:
TIRE
'MANSON_COFFIN:

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster

% difference
NB_CYCL
2.
2.
0.
Cycle 1 VALE_MIN
-500.
-500.
0
VALE_MAX
600.
600.
0.
Cycle 2 VALE_MIN
50.
50.
0.
VALE_MAX
50.
50.
0.
First call to POST_FATIGUE:
Calculation of the damage:
Wöhler without correction
Cycle 1 DAMAGE
1.053257E3
1.053257E3
0.
Cycle 2 DAMAGE
0.
1.686747E7
1.69E7
DOMM_CUMU
1.053257E3
1.053425E3
0.016
Second call to POST_FATIGUE:
Calculation of the damage:
Manson-whetstone sheath
Cycle 1 DAMAGE
1.053257E3
1.053257E3
0.

Cycle 2 DAMAGE
0.
1.686747E7
1.69E7
DOMM_CUMU
1.053257E3
1.053425E3
0.016
Third call to POST_FATIGUE:
Calculation of the damage:
Wöhler correction To stack
Cycle 1 DAMAGE
1.063631E3
1.063631E3
0.
Cycle 2 DAMAGE
0.
1.686747E7
1.69E7
DOMM_CUMU
1.063631E3
1.063800E3
0.016
Fourth call to POST_FATIGUE:
Calculation of the damage:
Wöhler Goodman correction
Cycle 1 DAMAGE
1.250219E3
1.250219E3
0.
Cycle 2 DAMAGE
0.
1.686747E7
1.69E7
DOMM_CUMU
1.250219E3
1.250388E3
0.013
4.2 Parameters
of execution
Version: 3.06.18
Machine: CRAY C90
Obstruction memory:

8 MW
Time CPU To use:
3.4265 seconds
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

---

5 Summary of the results

This test is very simple and makes it possible to determine the values of reference manually, while applying algorithms described in the reference document [R7.04.01].

So the results of Code_Aster coincident perfectly with the values of reference.

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Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.101

SZLZ101 - Calculation of the damage/Method RAINFLOW

Summary:

The purpose of this test is calculation of the damage starting from a history of loading in constraints.
Starting from a simple history of loading defined by DEFI_FONCTION [U4.21.02], one extracts the cycles
elementary by the method of counting of cycles of the RAINFLOW [R7.04.01], then one calculates the damage
elementary associated each cycle, by interpolation on the curve of Wöhler of material.
One tests various possibilities of introducing the curve of Wöhler, as well as the taking into account of the coefficient of
elastoplastic concentration.
To finish, one determines the total damage undergone by the part by cumulating all the elementary damage by
linear rule To mine.
This example is a test of validation of software POSTDAM developed by Department REME, provided in
the handbook of validation of version 1.0 of this software.
The results provided by operator POST_FATIGUE [U4.67.01] are completely identical to those provided by
software POSTDAM.

Author (S):
A.M. DONORE

1
Problem of reference

1.1 Geometry

The analysis consists in determining the damage undergone by a part in a point to which one provides the history
of loading in constraints.

Starting from a simple history of loading defined by DEFI_FONCTION [U4.21.02], one extracts them elementary cycles by the method of counting of cycles of RAINFLOW [R7.04.01], then one calculates elementary damage associated each cycle, by interpolation on the curve of Wöhler of
material.

One tests various possibilities of introducing the curve of Wöhler and the taking into account or not of one
elastoplastic coefficient of concentration:

· The curve of Wöhler is defined in the form:

S
= alternate constraint = 1 2

=
alt
(*E E*
C
)
X
LOG10 (*Salt*)
2
3
1 *NR* if *S* > = *S*
0 + 1
+ 2
+
NR
has
has
X
has
X
a3 X
alt

I
= 10
D = 0.
if not
with:
EC. = Young Modulus associated with the curve with tiredness with material,
E = Young Modulus used to determine the constraints,
constants of the material a0, a1, a2 and a3,
and *IF* limit of endurance of material.
· The curve of Wöhler is defined in the same form and moreover one takes account of a coefficient of elastoplastic concentration defined by:
K = 1.
if
< 3S
E
m

K = 1+ (1 - *N*)/3
-1 /
-1
if
3
< <
E
(
Sm
) ((*Nm*))
S
3 *m S*
m
m
K = 1 *N*
if
3m *S*
<

E
m
where
Sm is the acceptable maximum constraint,
and *N* and *m* two constants depending on material.
·

The curve of Wöhler is defined in the analytical form of Basquin: **D** = **A Salt**
To finish, one determines the total damage undergone by the part by cumulating all the damage elementary by the linear rule To mine.

1.2

Material properties

Parameters of definition of the curve of Wöhler:

a0
a1
a2
a3
EC.
E
Sl
55.81
43.06
11.91
1.16
200000.
200000.
180.

Parameters of definition of the elastoplastic coefficient of concentration Ke:

Sm
N
m
126.
0.3
1.7

Parameters of definition of the curve of Wöhler in the form analytical of Basquin:

With

1.001730939 E-14
4.065

History of the loading

T
0.
1.
2.
(T)
0.
1000.
0.

Handbook of Validation
V9.01 booklet: Tire

---

2 Reference solution

2.1 Method of calculation used for the reference solution

This test results from the handbook of validation of software POSTDAM version 1.0. Reference solutions
are given in this document.

2.2 Results of reference

The counting of the elementary cycles by method RAINFLOW leads to:

Nb_Cycl = 1

Cycle 1
Vale_Min:
0.
Vale_Max:
1000.

· **First call** to POST_FATIGUE:

Cycle 1
Too bad:
2.858503E4

The calculation of the total damage by linear office plurality To mine:

Too bad: 2.858503E4

· **Second call** to POST_FATIGUE:

Cycle 1
Too bad:
1.224941E2

The calculation of the total damage by linear office plurality To mine:

Too bad: 1.224941E2

· **Third call** to POST_FATIGUE:

Cycle 1
Too bad:
9.377005E4
The calculation of the total damage by linear office plurality To mine:
Too bad: 9.377005E4

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
Handbook of validation POSTDAM 1.0. Baker I., Vatin E. HP-14/93/016/B.

Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

---

3 Modeling
With

3.1 Functionalities
tested

Order
POST_FATIGUE_T [U4.67.01].

Key word
Operands

HISTORY
SIGM:
COUNTING:
“RAINFLOW”
TOO BAD:
“WOHLER”
MATER: `

CORR_KE:
“RCCM”
OFFICE PLURALITY:
“LINEAR”
INFORMATION:
2
Key word
Operands
Keys
DEFI_MATERIAU
TIRE
A0:
[U4.23.01]
A1:
A2:
A3:
E_REFE:
SL:
N_KE_RCCM:
M_KE_RCCM:
SM_KE_RCCM:
ELAS
E:
NAKED:
TIRE
A_BASQUIN:
BETA_BASQUIN:
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

---

4 Results of modeling A

4.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
NB_CYCL	1.	1.	0.
Cycle 1 VALE_MIN	0.	0.	0.
VALE_MAX	1000.	1000.	0.
First call to POST_FATIGUE:			
Cycle 1 DAMAGE	2.858503E4	2.858503E4	0.
DOMM_CUMU	2.858503E4	2.858503E4	0.
Second call to POST_FATIGUE:			
Cycle 1 DAMAGE	1.22494E2	1.22494E2	0.
DOMM_CUMU	1.22494E2	1.22494E2	0.
Third call to POST_FATIGUE:			
Cycle 1 DAMAGE	9.377005E4	9.377005E4	0.

DOMM_CUMU
9.377005E4
9.377005E4
0.

4.2 Parameters of execution

Version: 3.06.18
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
2.9181 seconds

---

5 Summary of the results

The results provided by Code_Aster are perfectly identical to the values of reference.

A.M. DONORE
Key:
V9.01.102-A Page:
1/6
Organization (S): EDF/IMA/MMN

Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.102
SZLZ102 - Tire with various methods of counting

Summary:
This test relates to the methods of countings of cycles (RAINFLOW, RCCM) starting from a history of loading in constraints.
Starting from a simple history of loading defined by DEFI_FONCTION [U4.21.02], one extracts the cycles
elementary by the method of counting of cycles of the RAINFLOW [R7.04.01], then by the method of counting of cycles RCCM [R7.04.01].
One also tests the taking into account of the coefficient of stress concentration KT.
This example is a test of validation of software POSTDAM developed by Department REME, provided in
the Handbook of Validation of version 1.0 of this software.
The results provided by operator POST_FATIGUE [U4.67.01] are completely identical to those provided by
software POSTDAM.

---

1 Problem of reference

1.1 Geometry

The analysis consists in extracting the elementary cycles starting from a history from loading in constraints.

· First call to POST_FATIGUE:
One extracts the elementary cycles by the method of counting of cycles RAINFLOW, on history of loading 1 (T).

· Second call to POST_FATIGUE:
One extracts the elementary cycles by the method of counting of cycles RCCM, on the history of loading 1 (T).

· Third call to POST_FATIGUE:
One extracts the elementary cycles by the method of counting of cycles RAINFLOW, on the history of loading 2 (T) and one uses a coefficient of stress concentration KT = 2.

· Fourth call to POST_FATIGUE:
One extracts the elementary cycles by the method of counting of cycles RCCM, on the history of loading 2 (T) and one uses a coefficient of stress concentration KT = 2.

History of the loading

T
0.
1.
2.
3.
4.
5.
6.
7.
8.
1 (T)
0.
500.
200.
400.
300.
500.
-300.
200.
-500.
T
0.
1.
2.
3.
4.
5.
6.

7.
8.
2 (T)
0.
250.
100.
200.
150.
250.
-150.
100.
-250.
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

---

2 Reference solution

2.1 Method of calculation used for the reference solution

This test results from the handbook of validation of software POSTDAM version 1.0. Reference solutions are given in this document.

2.2 Results of reference

· **First call** to POST_FATIGUE: method RAINFLOW from 1 (T)

Nb_Cycl = 4

Cycle 1
Vale_Min:
300.
Vale_Max:
400.
Cycle 2
Vale_Min:
200.
Vale_Max:
500.
Cycle 3
Vale_Min:
-300.
Vale_Max:
200.
Cycle 4
Vale_Min:
-500.
Vale_Max:
500.

· **Second call** to POST_FATIGUE: method RCCM from 1 (T)
Nb_Cycl = 5
Cycle 1
Vale_Min:
-500.
Vale_Max:
500.
Cycle 2
Vale_Min:
-300.
Vale_Max:
500.
Cycle 3
Vale_Min:
0.
Vale_Max:
400.
Cycle 4
Vale_Min:
200.
Vale_Max:
300.
Cycle 5
Vale_Min:
88.8889
Vale_Max:
200.
· **Third call** to POST_FATIGUE: method RAINFLOW from 2 (T) with KT=2.
(Results identical to the first call to POST_FATIGUE since one takes a loading 2 (T) = 1/2 1 (T), then one multiplies the history of loading by a coefficient of concentration of constraints KT = 2.).
Nb_Cycl = 4
Cycle 1
Vale_Min:
300.
Vale_Max:
400.
Cycle 2
Vale_Min:
200.
Vale_Max:
500.
Cycle 3

Vale_Min:
-300.
Vale_Max:
200.
Cycle 4
Vale_Min:
-500.
Vale_Max:
500.
· **Fourth call** to POST_FATIGUE: method RCCM from 2 (T) with KT=2.
(Results identical to the second call to POST_FATIGUE since a loading is taken
2 (T) = 1/2 1 (T), then one multiplies the history of loading by a coefficient of concentration of constraints KT = 2.).
Nb_Cycl = 5
Cycle 1
Vale_Min:
-500.
Vale_Max:
500.
Cycle 2
Vale_Min:
-300.
Vale_Max:
500.
Cycle 3
Vale_Min:
0.
Vale_Max:
400.
Cycle 4
Vale_Min:
200.
Vale_Max:
300.
Cycle 5
Vale_Min:
88.8889
Vale_Max:
200.

2.3

Uncertainty on the solution

Analytical solution.

2.4 References

bibliographical
[1]
Handbook of validation of POSTDAM version 1.0. Baker I., Vatin E. HP-14/93/016B

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3 Modeling
With

3.1 Functionalities
tested

Order
POST_FATIGUE [U4.67.01]
Key word
Operands
HISTORY
SIGM:
COUNTING:
“RCCM”
“RAINFLOW”
COEF_MULT
KT:
INFORMATION:
1

Titrate:
SZLZ102 Tires with various methods of counting
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.102-A Page:
5/6

4
Results of modeling A

4.1 Values
tested

Identification	Reference	Aster	% difference
First call to POST_FATIGUE and Third call to POST_FATIGUE			
NB_CYCL	4.	4.	0.
Cycle 1 VALE_MIN	300.	300.	0.
VALE_MAX	400.	400.	0.
Cycle 2 VALE_MIN	200.	200.	0.
VALE_MAX	500.	500.	0.
Cycle 3 VALE_MIN	-300.	-300.	0.

VALE_MAX
200.
200.
0.
Cycle 4 VALE_MIN
-500.
-500.
0.
VALE_MAX
500.
500.
0.
Second call to POST_FATIGUE
and Fourth call to POST_FATIGUE
NB_CYCL
5.
5.
0.
Cycle 1 VALE_MIN
-500.
-500.
0.
VALE_MAX
500.
500.
0.
Cycle 1 VALE_MIN
-300.
-300.
0.
VALE_MAX
500.
500.
0.
Cycle 1 VALE_MIN
0.
0.
0.
VALE_MAX
400.
400.
0.
Cycle 1 VALE_MIN

200.
200.
0.
VALE_MAX
300.
300.
0.
Cycle 1 VALE_MIN
88.8889
88.8889
0.
VALE_MAX
200.
200.
0.

4.2 Parameters
of execution

Version: 3.06.18
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
2.2582 seconds

5
Summary of the results

The results of Code_Aster are identical to the values of reference provided in the handbook of validation of version 1.0 of POSTDAM.

Code_Aster ®
Version
4.0
Titrate:
SZLZ103 Method RAINFLOW
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.103-A Page:
1/6
Organization (S): EDF/IMA/MMN

Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.103
SZLZ103 - Method RAINFLOW

Summary:
The purpose of this test is to test the method of counting of cycles RAINFLOW starting from a history of loading in constraints.
The functionality of filtering of the history of loading, and the taking into account of a coefficient are also tested
of stress concentration KT.
This example is a test of validation of software POSTDAM developed by Department REME, provided in
the Handbook of Validation of version 1.0 of this software.
The results provided by operator POST_FATIGUE [U4.67.01] are completely identical to those provided by
software POSTDAM.

Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SZLZ103 Method RAINFLOW
Date:

1
Problem of reference

1.1 Geometry

The analysis consists in extracting the elementary cycles by the method of counting of cycles of RAINFLOW [R7.04.01].

One filters initially the history of loading in constraints with a level of filter of 0.9.

Then one applies a coefficient of stress concentration KT = 1.

History of the loading

T
0.
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
1 (T)
4.
7.
2.
10.
9.6
9.8
5.
9.
3.
4.
2.
2.4
2.2

12.
14.
15.
16.
17.
18.
19.
20.
21.
22.
23.
24.
25.
26.
27.
28.
5.
11.
1.
4.
3.
10.
6.
8.
12.
4.
8.
1.
9.
4.
6.

2
Reference solution
2.1
Method of calculation used for the reference solution

This test results from the handbook of validation of software POSTDAM version 1.0. Reference solutions
are given in this document.

2.2
Results of reference

The counting of the elementary cycles by method RAINFLOW leads to:
Nb_Cycl = 12
Cycle 1
Vale_Min:
5.
Vale_Max:
11.
Cycle 2
Vale_Min:
3.
Vale_Max:
4.
Cycle 3
Vale_Min:
6.
Vale_Max:
10.
Cycle 4
Vale_Min:
1.
Vale_Max:
12.
Cycle 5
Vale_Min:
4.
Vale_Max:
8.
Cycle 6
Vale_Min:
4.

Vale_Max:
6.
Cycle 7
Vale_Min:
4.
Vale_Max:
7.
Cycle 8
Vale_Min:
2.
Vale_Max:
9.
Cycle 9
Vale_Min:
5.
Vale_Max:
9.
Cycle 10
Vale_Min:
3.
Vale_Max:
4.
Cycle 11
Vale_Min:
2.
Vale_Max:
10.
Cycle 12
Vale_Min:
1.
Vale_Max:
12.

2.3
Uncertainty on the solution

Analytical solution.

2.4 References
bibliographical

[1]
Handbook of validation POSTDAM 1.0. Baker I., Vatin E. HP-14/93/016/B.

Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

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3 Modeling With

3.1 Functionalities tested

Order
POST_FATIGUE [U4.67.01].

Key word	**Operands**
HISTORY	SIGM:
COUNTING:	"RAINFLOW"
DELTA_OSCI:	
COEF_MULT	KT:
INFORMATION:	1

4
Results of modeling A
4.1 Values
tested
Identification
Reference
Aster
% difference
NB_CYCL
12.
12.
0.
Cycle 1 VALE_MIN
5.
5.
0
VALE_MAX
11.
11.
0.
Cycle 2 VALE_MIN
3.
3.
0.
VALE_MAX
4.
4.
0.
Cycle 3 VALE_MIN
6.
6.
0.
VALE_MAX
10.
10.
0.
Cycle 4 VALE_MIN
1.
1.
0.
VALE_MAX

12.
12.
0
Cycle 5 VALE_MIN
4.
4.
0.
VALE_MAX
8.
8.
0
Cycle 6 VALE_MIN
4.
4.
0.
VALE_MAX
6.
6.
0.
Cycle 7 VALE_MIN
4.
4.
0.
VALE_MAX
7.
7.
0.
Cycle 8 VALE_MIN
2.
2.
0.
VALE_MAX
9.
9.
0.
Cycle 9 VALE_MIN
5.
5.
0
VALE_MAX
9.
9.
0.

Cycle 10 VALE_MIN
3.
3.
0.
VALE_MAX
4.
4.
0.
Cycle 11 VALE_MIN
2.
2.
0.
VALE_MAX
10.
10.
0.
Cycle 12 VALE_MIN
1.
1.
0.
VALE_MAX
12.
12.
0.

4.2 Parameters
of execution

Version: 3.06.18
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
1.7426 seconds

---

5 Summary of the results

The Aster results are perfectly identical to the values of reference provided in the Handbook of Validation of version 1.0 of software POSTDAM.

Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.105

SZLZ105 - Counting of cycles by RAINFLOW and calculation of the damage

Summary:

Transitory linear elastic problem quasi-static in mechanics of the structures.

Calculation of the final damage in an element subjected to a cyclic loading, with an elastic behavior linear.

A modeling in plane constraints and a modeling in 3D.

This test validates the method of counting of cycles (RAINFLOW) established in operator CALC_FATIGUE [U4.67.01] as well as the method of calculation of the damage in imposed constraint (curve of Wöhler) or imposed deformation (curve of Manson-Whetstone sheath). The reference solution is an analytical solution.

It also validates the calculation of the constraints and equivalent deformations using the options EQUI_ELGA_SIGM, EQUI_ELNO_SIGM, EQUI_ELGA_EPSI, EQUI_ELNO_EPSI, EQUI_ELGA_EPME and EQUI_ELNO_EPME.

---

1 Problem of reference

1.1 Geometry

y

4
3
F (T)
1
2
X

1.2
Material properties

Linear elasticity: E = 1. MPa = 0.3

NR (cycles)
NR (cycles)
1000.
1000.

10.
2 (MPa)
10.
2
Curve of Wöhler
Curve of Manson-Whetstone sheath

1.3
Boundary conditions and loadings

- *Blocked on face 1-4 following X - node 1 blocked according to Y.*
- *In unit simple traction on the face 2-3.*
- *Loading F (T) in teeth of saw (according to the Article of Downing and Socie 1982) [bib1].*

F (T)
4
3
2
1
T
1 2
3 4 5 6 7
8

- 3

1.4 Conditions
initial

Null constraints and deformations.

2
Reference solution

2.1
Method of calculation used for the reference solution

Analytical solution

.

calculation of the constraints and deformations. For a loading in simple traction, one obtains a state of homogeneous constraint uniaxial in any point:

0 0

0 0

= 0 0 0
and
= 0

0

0 0 0

0 0

= =
VMIS
TRESCA,
the equivalent sizes are thus

=

VMIS_SG

2
=
-
INVA_
,
2

3
and

2
+
2

=
-
INVA_2SG
**** sign***

3

3

·

then manual calculation of the cycles by the method of RAINFLOW, as well as amplitudes of

loading

or

2

2

cycles

/ 2

INVA-2/2

1

1.

0.8667

2

0.5

0.433315

3

1.

0.8667

4

3.5

3.03335

·

finally carryforward of these values on the curves of Wöhler or Manson-Whetstone sheath to estimate it

1

unit damage with each cycle I, is Dui =

(NR

NR

I being the number of cycles with rupture for

I

a given amplitude), as well as the damage cumulated D = Dui (linear rule of office plurality of

I

TO MINE).

Note:

One will use as equivalent constraint
=
VMIS_SG
and like equivalent deformation
2
+

2
-
= -
INVA
SG
** sign*
.
3

3
2

2.2
Results of reference

.
Being given the values of the parameters of loading used, one obtains simply in end loading (increment 8) = -3.
= -3.
= 0 9
.

= 2 6
INVA 2
.
–
.
.
For the calculation of the damage, one obtains:
4
D
=
-
4 8133
.
10 3 = Of

Wöhler
I
i=1
4

D
=
-
4 6
. 7 10 3
= Of
Manson
I
i=1

2.3 References bibliographical

[1]
DOWNING and SOCIE, 1982. "Simple Rainflow counting algorithms". Int. J. Tire,
January 1982 (p. 31).

---

3 Modeling With

3.1 Characteristics of modeling

Modeling in plane constraints:

y
F (NR)
4
F/2
3
4
3
2
1
T (S)
1 2 3 4 5 6 7 8
1
2
- 3
X
F/2

3.2
Characteristics of the grid

1 mesh QUAD4.

Square
width = 1

thickness = 1

3.3 Functionalities
tested

Order Mot-clé Key word
Key argument
factor
simple
CALC_FATIGUE
OPTION
"DOMA_ELNO_SIGM" [U4.67.02]
"DOMA_ELNO_EPSI"

HISTORY
EQUI_GD
“VMIS_SG”

“INVA_2SG”
HISTORY
RESULT

TOO BAD
“WOHLER”

“MANSON_COFFIN”

MATER

CALC_ELEM
OPTION
“EQUI_ELGA_SIGM”
[U4.61.02]

“EQUI_ELNO_SIGM”

“EQUI_ELGA_EPSI”

“EQUI_ELNO_EPSI”

DEFI_MATERIAU TIRES WOHLER

[U4.23.01]

MANSON_COFFIN

Titrate:
SZLZ105 Counting of cycles by RAINFLOW and calculation of the damage
Date:
28/10/99
Author (S):
A.M. DONORE, Key P. SCHOENBERGER
:
V9.01.105-C Page:
5/8

4
Results of modeling A

4.1 Values
tested

Identification Reference
Aster %
difference
in all nodes at the end of the loading in

constraint or in deformation
Wöhler damage
4.8133 10-3 4.813315
10-3
0.0003
Damage Manson-Whetstone sheath
4.6705 10-3 4.67048
10-3
-0.0003

-3.
-3.
0.
VMIS
3. 3.
0.
TRESCA
3. 3.
0.
VMIS_SG
-3.

-3.
0.

-3.
-3.
0.

0.9 0.9
0.

2.6 2.6
0.
INVA_2
INVA_2SG
-2.6
-2.6
0.

4.2 Remarks

Fast test in CPU.

4.3 Parameters of execution

Version: 5.02.10

Machine: SGI - Origin 2000

Obstruction memory:
128 Mo
Time CPU To use: 4.84 seconds

Titrate:
SZLZ105 Counting of cycles by RAINFLOW and calculation of the damage
Date:
28/10/99
Author (S):
A.M. DONORE, Key P. SCHOENBERGER
:
V9.01.105-C Page:
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5 Modeling
B

5.1
Characteristics of modeling

Modeling in 3D:

y
1
2
F/4
5
6
F/4
3
4
F/4
X
7
8
F/4

5.2
Characteristics of the grid

1 mesh HEXA8.

cubic of width = 1

5.3 Functionalities

tested

Order Mot-clé Key word
Key argument
factor
simple
CALC_FATIGUE
OPTION
"DOMA_ELNO_SIGM" [U4.67.02]
"DOMA_ELNO_EPSI"

"DOMA_ELNO_EPME"

HISTORY
EQUI_GD
"VMIS_SG"

"INVA_2SG"
HISTORY
RESULT

TOO BAD
"WOHLER"

"MANSON_COFFIN"

MATER

CALC_ELEM
OPTION
"EQUI_ELGA_SIGM"
[U4.61.02]

"EQUI_ELNO_SIGM"

"EQUI_ELGA_EPSI"

"EQUI_ELNO_EPSI"

"EQUI_ELGA_EPME"

"EQUI_ELNO_EPME"

DEFI_MATERIAU TIRES WOHLER

[U4.23.01]

MANSON_COFFIN

6
Results of modeling B

6.1 Values
tested

Identification Reference
Aster %
difference
in all nodes at the end of the loading

Wöhler damage
4.8133 10-3 4.813315
10-3

0.
Damage Manson-Whetstone sheath
4.6705 10-3 4.67048
10-3
0.

-3.
-3.
0.
VMIS
3. 3.
0.
TRESCA
3. 3.
0.
VMIS_SG
-3.
-3.
0.

-3.
-3.
0.

0.9 0.9
0.

2.6 2.6
0.
INVA_2
INVA_2SG
-2.6
-2.6
0.

(- HT) INVA_2
2.6 2.6
0.
(- HT) INVA_2SG
-2.6
-2.6
0.

6.2 Remarks

Same results and reference that in plane constraints.

6.3 Parameters
of execution

Version: 5.02.10

Machine: SGI - Origin 2000

Obstruction memory:
128 Mo
Time CPU To use: 5.34 seconds

7
Summary of the results

This test validates the method and the calculation of the damage of Wöhler and Manson-Whetstone sheath.

The results of Code_Aster are identical to those obtained analytically.

Code_Aster ®
Version
4.0
Titrate:
SZLZ106 Tires under random request
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.106-A Page:
1/6
Organization (S): EDF/IMA/MMN
Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.106

SZLZ106 - Tire under random request

Summary:

The purpose of this test is calculation of the damage starting from a random request which is characterized by its spectral moments.

From the spectral moments of the random loading one determines the average damage undergone by the structure [R7.04.02].

With this intention one has two methods of counting of cycles of constraints:

· method of counting of the peaks of constraints,
· method of the goings beyond of a given level.

One tests also various possibilities of introduction the curve of Wöhler as well as the taking into account of elastoplastic coefficient of concentration Ke.

The results of reference of this test are the values provided by software POSTDAM developed by Department REME (EDF-DER-EP).

The results provided by operator POST_FATI_ALEA [U4.67.05] are completely identical to those provided by software POSTDAM.

Version
4.0
Titrate:
SZLZ106 Tires under random request
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.106-A Page:
2/6
1
Problem of reference
The analysis consists in determining the average damage undergone by a part subjected to a loading random.
Loading of the random type is entirely characterized by the values of the spectral moments of order 0, 2 and 4: 0, 2 and 4 which is introduced under key words MOMENT_SPEC_0, MOMENT_SPEC_2 and MOMENT_SPEC_4.
For the calculation of the damage it is necessary to choose a method of counting among the two available ones in
Code_Aster:
· method of counting of the peaks of constraints,
· method of counting of going beyond of a given level.
It is necessary moreover introduce the curve of Wöhler of the material which can be defined in three forms
distinct mathematics:
· function point by point, which gives the value of the number of cycles to the rupture, according to the alternate constraint Salt,
·
analytical form of Basquin: D = A S

alt
· analytical form "current zone"
Salt = forced alternate = 1/2 (EC/E)
X = LOG10 (Salt)
NR
has
has
X
has
X
has
X

=
+
+
+
10 0
1
2
2
3
3
.

D =
1. /NR
if Salt ³ = Sl
0.
if not
where EC. = Young Modulus associated with the curve with tiredness with material,
E = Young Modulus used to determine the constraints,
constants of the material a0, a1, a2 and a3,
and Sl limit of endurance of material.
Moreover, one can possibly take account of an elastoplastic coefficient of concentration Ke, defined by:
K = 1
if
< 3S
E
m

K = 1+ (1 - N)/3
-1 /
-1
if
3
< <
E
(
Sm
) ((Nm))

S
m
3 S
m
m
K =1/N
if
m
3 S
<

E
m
where Sm is the acceptable maximum constraint,
and N and m two constants depending on material.
In this test, for a single given random loading, one determines the average damage in ten distinct configurations, according to the shape of the curve of Wöhler and the method of counting of cycles.
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

1.1 Material properties for the study of tiredness

The properties of material relate to the data of a curve of Wöhler making it possible to determine it a number of cycles to the rupture for a level of loading given.

1.1.1 Curve of Wöhler in analytical form Basquin

Configuration 1
With

1.0017309939 E14
4.065
Configuration 2
With

32. E13
5.

1.1.2 Curve of Wöhler in form "current zone"

Parameters of definition of configuration 3:
a0
a1
a2
a3
EC.
E
Sl
11.495
-5.
0.25
0.07
220000.
200000.
5.

Parameters of definition of configuration 4:
a0
a1
a2
a3
EC.
E
Sl
11.495
-5.
0.25
0.07
220000.
200000.
5.
Moreover, one takes one account an elastoplastic coefficient of concentration Ke defined by parameters for this configuration.
Sm
N
m
60.
0.6
1.4

1.1.3 Curve of Wöhler in form function point by point (configuration 5)

Salt
1.
2.
5.
25.
30.
35.
40.
NR
3.125E+11
976562.5E+4
1.E+8
32000.
12860.09
5949.899
3051.76
Salt
45.
50.

55.
60.
65.
70.
75.
NR
1693.51
1000.0
620.921
401.8779
269.329
185.934
131.6869
Salt
80.
85.
90.
95.
100.
105.
110.
NR
95.3674
70.4296
52.9221
40.3861
31.25
24.4852
19.40379
Salt
115.
120.
125.
130.
135.
140.
145.
NR
15.5368
12.55869
10.23999
8.41653
6.96917

5.81045
4.8754
Salt
150.
155.
160.
165
170.
175.
180.
NR
4.11523
3.49294
2.98023
2.55523
2.20093
1.90397
1.65382
Salt
185.
190.
195.
200.
NR
1.44209
1.26207
1.10835
0.976562

1.2
History of the loading

The random loading is entirely characterized by the values of the spectral moments:

0
2
4
182.5984664
96098024.76
6.346193569E+13

2 Reference solution

2.1 Method of calculation used for the reference solution

The values of reference mentioned in this document are the values provided by the software POSTDAM developed by Department REME.

2.2 Results of Reference

Configuration 1
Configuration 2
Method of counting
Level
PEAK
Level
PEAK
Average damage
3.851827E7
3.853037E7
3.129527E3
3.129848E3
Configuration 3
Configuration 4
Method of counting
Level
PEAK
Level
PEAK
Average damage
2.298920E3
2.299282E3
2.298920E3

2.299282E3
Configuration 5
Method of counting
Level
PEAK
Average damage
3.129531E3
3.129903E3

2.3 Functionalities tested

Order
Key word
Operand
Keys
POST_FATI_ALEA
MOMENT_SPEC_0:
[U4.67.05]
MOMENT_SPEC_2:
MOMENT_SPEC_4:
COUNTING:
“LEVEL”
COUNTING:
“PEAK”
TOO BAD:
“WOHLER”
MATER:
CORR_KE:
“RCCM”
DURATION:
DEFI_MATERIAU
TIRE
WOHLER:
[U4.23.01]
TIRE
A_BASQUIN:
BETA_BASQUIN:
TIRE
A0:
A1:
A2:
A3:
SL:
E_REFE:

N_KE_RCCM:
M_KE_RCCM:
SM_KE_RCCM
ELAS
E:
NAKED:
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/038 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SZLZ106 Tires under random request
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.106-A Page:
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3
Results of modeling A
3.1 Values
tested
Configuration 1:
Configuration 1:
Method going beyond of level
Method peaks of constraints
Reference
Aster
%
Reference
Aster
%
difference
difference
Too bad
3.851827E7
3.8517772E7
0.001
3.853037E7

3.8529874E7
0.001
means
Configuration 2:
Configuration 2:
Method going beyond of level
Method peaks of constraints
Reference
Aster
%
Reference
Aster
%
difference
difference
Too bad
3.129527E3
3.1294844E3
0.001
3.129848E3
3.1298563E3
0.001
means
Configuration 3:
Configuration 3:
Method going beyond of level
Method peaks of constraints
Reference
Aster
%
Reference
Aster
%
difference
difference
Too bad
2.298920E3
2.2988724E3
0.002
2.299282E3
2.2992316E3
0.002
means

Configuration 4:
Configuration 4:
Method going beyond of level
Method peaks of constraints
Reference
Aster
%
Reference
Aster
%
difference
difference
Too bad
2.298920E3
2.2988724E3
0.002
2.299282E3
2.2992316E3
0.002
means
Configuration 5:
Configuration 5:
Method going beyond of level
Method peaks of constraints
Reference
Aster
%
Reference
Aster
%
difference
difference
Too bad
3.129531E3
3.1294837E3
0.002
3.129903E3
3.1298556E3
0.002
means
3.2 Parameters
of execution
Version: 3.06.18

Machine: CRAY C90
Obstruction memory:
8Mw
Time CPU To use:
5.017 seconds

---

4 Summary of the results

The results obtained with Code_Aster are completely similar to those provided by the software POSTDAM.

Organization (S): EDF/IMA/MMN
Handbook of Validation

V9.01 booklet: Tire
Document: V9.01.107
SZLZ107 - Criteria of tiredness of CROSSLAND and
DANG VAN-PAPADOPOULOS
Summary:
The purpose of this test is calculation of the criteria of CROSSLAND and DANG VAN-PAPADOPOULOS.
Starting from a periodic and radial multiaxial loading, one calculates the value of the criterion of CROSSLAND, then
value of the criterion of DANG VAN-PAPADOPOULOS.
The loading being radial the values of the two criteria must be identical.
This test results from the thesis of I. PAPADOPOULOS "Tires polycyclic metals: a new approach" and corresponds to a test of Gough-Pollard [bib1].
The results provided by operator POST_FATIGUE [U4.67.01] are completely satisfactory.
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/068 - Ind A

Code_Aster ®
Version
4.0
Titrate:
SZLZ107 Criteria of tiredness CROSSLAND and PAPADOPOULOS
Date:
19/01/98
Author (S):
A.M. DONORE
Key:
V9.01.107-A Page:
2/6

1 Problem of reference

The analysis consists in determining the criterion of CROSSLAND and the criterion of DANG VAN-PAPADOPOULOS in a point of a structure subjected to a periodic multiaxial loading radial.

Criterion of CROSSLAND:

+ has
- B
max
< =
has
P
0

= 1
~
~
2
2
2
2
2
2
(1) - (0) = 1
1 (~ ~ ~
~
~
~
11 + 22 + 33 + 2 12 + 2 13 +
has
Max Max S T
S T
Max Max
S
S
S
S
S
2s)
2
23
0 *t0T*
0 *t1T*
2
0 *t0T*
0 *t1T*
2
= amplitude of cission
with *S*
~ deviative of the tensor of the constraints
where
1
Pmax = *max* (*trace*
()) = maximum hydrostatic pressure

0 *tT* 3
has =

D
D
0
0
(0 -
) (
)
and
B =
3
3
0
with 0 = limit of endurance in alternate pure shearing
d0 = limit of endurance in alternate pure traction and compression
The criterion is: *Rcrit* = + has *P*
-
has
B
max
If *Rcrit* is negative or null, there is no damage. If *Rcrit* is positive it is succeptible y to have too bad.

Criterion of DANG VAN-PAPADOPOULOS:

*K** + has *P*
- B < =
max
0
*
where *K*
R
=
where *R* ray of the smallest sphere circumscribed with the way of loading in
2
the space of the diverters of constraints ~
S
R = *max* (*s*~ (*T*) - *C**): (*s*~ (*T*) - *C**)
where *C* * is the center of the hypersphère

0 *tT*
C * = *Min max* (*s*~ (*T*) - *C)*: (*s*~ (*T*) - *C)*
CK
0 *tT*
1
P

max = *max* (
trace ()) = maximum hydrostatic pressure

0 *tT* 3
D
D
has =
0
0
(

0 -
) (
)
and
B = 0
3
3
with 0 = limit of endurance in alternate pure shearing
d0 = limit of endurance in alternate pure traction and compression
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/068 - Ind A

---

*
The criterion is: *Rcrit* = *K* + has *Pmax* - B
If *Rcrit* is negative or null, there is no damage. If *Rcrit* is positive it is succeptible y to have too bad.

1.1
Material properties

0 = limit of endurance in alternate pure shearing = 352. MPa

d0 = limit of endurance in alternate pure traction and compression = 540.97 MPa

1.2

History of the loading

T
1.
2.
3.
xx (T)
411.
0.
-411.
xy (T)
205.
0.
-205.
yy (T) = zz (T) = xz (T) = yz (T)
0.
0.
0.

The loading is considered periodic.

2

Reference solution

2.1

Method of calculation used for the reference solution

The results of reference result from the thesis of I. PAPADOPOULOS [bib1]. For the criterion of CROSSLAND, one can also obtain them manually.

The loading being radial the two criteria must provide the same results.

2.2

Results of Reference

For the **criterion of CROSSLAND**, one tests the value of the amplitude of cission, the value of the pressure
hydrostatic maximum and the value of the criterion:

= 313.579 MPa
= 137. MPa
=
has
P
Rcrit
8.281
max
-

For the **criterion of DANG VAN-PAPADOPOULOS**, one tests the value of the ray of the smallest sphere circumscribed with the loading, the value of the maximum hydrostatic pressure and the value of the criterion:

K^* = 313.579 MPa

P

= 137. MPa

$Rcrit$ =

max

8.281

2.3

Uncertainty on the solution

Analytical solution.

2.4 References

bibiographic

[1]

Thesis of I. PAPADOPOULOS "Tires polycyclic metals: a new approach"

(1987) ENPC.

---

3 Modeling

3.1 Functionalities

tested

Order

Key word

Operand

Key

[U4.67.01]

POST_FATIGUE

HISTORY

SIGM_XX

SIGM_YY
SIGM_ZZ
SIGM_XY
SIGM_XZ
SIGM_YZ
CRITERION
“CROSSLAND”
“PAPADOPOULOS”
MATER
INFORMATION
DEFI_MATERIAU
TIRE
D0
[U4.23.01]
TAU0
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/068 - Ind A

4
Results of modeling
4.1 Values
tested
Identification
Reference
Aster
% difference
Criterion of CROSSLAND
PRES_HYDRO_MAX (Pmax)
137.
137.

0.
AMPLI_CISSION (A)
313.579
313.579
0.
Criterion (Rcrit)
8.281
8.2809
0.001
Criterion of DANG VAN-PAPADOPOULOS
PRES_HYDRO_MAX (Pmax)
137.
137.
0.
RAYON_SPHERE (k*)
313.579
313.579
0.
Criterion (Rcrit)
8.281
8.2809
0.001

4.2 Parameters of execution

Version: 3.06.18
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
2.54 seconds

5
Summary of the results

The results provided by Code_Aster coincident perfectly with the values of reference.

Organization (S): EDF/IMA/MMN
Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.108

SZLZ108 - Damage by the methods of TAHERI (“TAHERI_MANSON” and “TAHERI_MIXTE”)

Summary:

The purpose of this test is calculation of the damage starting from a history of purely uniaxial loading in deformations by methods “TAHERI_MANSON” or “TAHERI_MIXTE”.

The methods of Taheri apply only to loadings in deformations and do not allow
contrary to the method of Manson-Whetstone sheath to hold account about appearance of the cycles of constraints.

---

1 Problem of reference

The analysis consists in determining the damage undergone by a structure subjected to a history of

loading in deformations. One uses the method of Rainflow to determine the number of cycles elementary and it half amplitude of each cycle.
For the loadings considered, the method of Rainflow determines 5 cycles of half amplitude:
1
2
3
4
5
= 0 2
. 5,
= 0 2
. 5,
= 0 7
. 5,
= 0 2
. 5 and
= 17
. 5 .
2
2
2
2
2
Then one calculates the damage undergone by the structure by the method of TAHERI_MANSON and the method
TAHERI_MIXTE.
As long as the amplitude of deformations of the various cycles applied to the structure remains increasing
1 2

...
N

, the methods of TAHERI_MANSON and TAHERI_MIXTE are identical to
2
2
2
method of MANSON_COFFIN (calculation of the number of cycles to the rupture, *Nrupt*, by interpolation on
the curve of Manson-Whetstone sheath and calculation of the damage by 1 *NR*
).
rupt

I
i-1
On the other hand if a cycle *I* presents a half amplitude
lower than
, methods of
2
2
Taheri differ from the method of Manson-Whetstone sheath.

.
I
The method of "TAHERI_MANSON" consists in determining an amplitude of constraint
with
2
I
to leave
and
2
max (maximum value of the half amplitude of deformation met before
cycle *I*).

With this intention, the user must provide a tablecloth
,
2

2
max under the operand
TAHERI_NAPPE.

*
I
I
From
, one determines a half amplitude of deformations
using a function
2
2
introduced under operand TAHERI_FONC. The value of the elementary damage of cycle *I*, is
*i
determined by interpolation of
on the curve of Manson_Coffin.
2
· For method "TAHERI_MIXTE", one proceeds in the same way for the determination of the half

I
amplitude of constraint
, then one determines the value of the elementary damage of cycle *I*
2
I
by interpolation of
on the curve of Wöhler.
2
This method thus requires the data of the curves of Wöhler and Manson_Coffin.
One determines the total damage by linear office plurality of the elementary damage.

1.1
Material properties
For the calculation of the damage of "TAHERI_MANSON", one needs the curve of Manson_Coffin, one

tablecloth allowing to calculate
from
and
2

2
max and of a function allowing to calculate
*

from
. The tablecloth (cyclic curve of work hardening with pre-work hardening) is introduced

2
2
under operand TAHERI_NAPPE and the function (cyclic curve of work hardening) under the operand TAHERI_FONC. The curve of Manson_Coffin as for it is introduced into DEFI_MATERIAU [U4.23.01].
For the calculation of the damage of “TAHERI_MIXTE”, one needs the curve of Manson_Coffin, of curve of Wöhler and a tablecloth (cyclic curve of work hardening with pre-work hardening) allowing

to calculate
from
and
2

2
max. the tablecloth is introduced under operand TAHERI_NAPPE.
curve of Manson_Coffin and the curve of Wöhler is introduced into DEFI_MATERIAU.
Curve of Manson_Coffin
Curve of Wöhler
Nrupt
200 000.
200 000.

2
2.
200.
2
Tablecloth of Taheri (curves of cyclic work hardening with pre-work hardening)

max = 1.
max = 0.5
525.

2
2
25.
550.
50.

10.
2
10.
2
Function of Taheri (cyclic curve of work hardening)
2
10.

1000.
2

1.2
History of the loading

T
0.
1.
2.
3.
4.
5.
6.
(T)
0.
3.5
3.
3.5
3.
3.5

1.
7.
8.
9.
2.5
0.
0.5

2
Reference solution

2.1
Method of calculation used for the reference solution

The history of loading being very simple, the results of reference can be obtained manually by applying the algorithms presented in the reference document [R7.04.01].

2.2
Results of Reference

Calculation of the elementary damage by the method of **TAHERI_MANSON**:

Cycle
1
Too bad
:
5.7142857E-6
Cycle
2
Too bad
:
5.7142857E-6
Cycle
3
Too bad
:
8.E-6
Cycle
4
Too bad
:
6.6666667E-6
Cycle
5
Too bad
:
4.E-5

calculation of the total damage by linear office plurality To mine:
Too bad: 6.6095E-5

Calculation of the elementary damage by the method of **TAHERI_MIXTE**:
Cycle
1
Too bad
:
5.7142857E-6
Cycle
2
Too bad
:
5.7142857E-6
Cycle
3
Too bad
:
8.E-6
Cycle
4
Too bad
:
6.6666667E-6
Cycle
5
Too bad
:
4.E-5
calculation of the total damage by linear office plurality To mine:
Too bad: 6.6095E-5

2.3
Uncertainty on the solution

Analytical solution.

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3 Modeling

3.1 Functionalities
tested

Order
Key word
Operand
Key
[U4.67.01]
POST_FATIGUE
HISTORY
EPSI
COUNTING
“RAINFLOW”
TOO BAD
“TAHERI_MANSON”
“TAHERI_MIXTE”
TAHERI_NAPPE
TAHERI_FONC
MATER
OFFICE PLURALITY
“LINEAR”
INFORMATION
2
DEFI_MATERIAU
TIRE
WOHLER
[U4.23.01]
MANSON_COFFIN

---

4 Results of modeling

4.1 Values tested

Identification	Reference	Aster	% difference
Method "TAHERI_MANSON"			
Cycle 1 DAMAGE	5.7142857E6	5.7142857E6	0.
Cycle 2 DAMAGE	5.7142857E6	5.7142857E6	0.
Cycle 3 DAMAGE	8.E6	7.9999999E6	0.
Cycle 4 DAMAGE	6.6666667E6	6.6666666E6	0.
Cycle 5 DAMAGE	4.E5	3.9999999E6	0.
DOMM_CUMU	6.6095E5	6.6095238E5	0.
Method "TAHERI_MIXTE"			
Cycle 1 DAMAGE	5.7142857E6	5.7142857E6	0.

Cycle 2 DAMAGE
5.7142857E6
5.7142857E6
0.
Cycle 3 DAMAGE
8.E6
7.9999999E6
0.
Cycle 4 DAMAGE
6.6666667E6
6.6666666E6
0.
Cycle 5 DAMAGE
4.E5
3.9999999E6
0.
DOMM_CUMU
6.6095E5
6.6095238E5
0.

4.2 Parameters
of execution

Version: 3.06.18
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
2.42 seconds

5
Summary of the results

The results provided by Code_Aster coincide perfectly with the values of reference.

A.M. DONORE
Key:
V9.01.109-A Page:
1/6
Organization (S): EDF/IMA/MMN
Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.109
SZLZ109 - Damage of Lemaitre
in postprocessing

Summary:
The purpose of this test is calculation of the damage of “LEMAITRE” starting from a history of multiaxial loading
unspecified and of the history of the cumulated plastic deformation.
The damage is calculated
(
D T) starting from the data of the tensor of the constraints (*T*) and the formation
figure cumulated (
p T) in every moment *Ti* (provided by the user). Moreover, one calculates the total damage
NR
D = (
D Ti).
i=1
The characteristics material E (Young modulus), (Poisson's ratio) and S (parameter of material)
must depend on the temperature T (T

(T) must thus be provided by the user at the same moments as
(*T*) and
(
p T)).

Key:
V9.01.109-A Page:
2/6

1
Problem of reference

The damage is calculated
(
D T) starting from the data of the tensor of the constraints (*T*) and of
cumulated plastic deformation (
p T).

1
1
3
D =
(1+) 2 +
(1 - 2) 2

(
if
1 -) 2
eq
H
p
p
Pd
D

ES
3
2ES

>
D =

0 if not
eq is the equivalent constraint of von Mises
H forced hydrostatic

Pd threshold of damage
S characteristic material (MPa)
NR
One also calculates the total damage *D* = (
D Ti).
i=1

1.1
Material properties

Temp (°C)
E (MPa)

S (MPa)
0.
2.E+5
0.
7.
20.
2.E+5
0.
7.
40.
2.E+5
0.
7.
Pd = 0.02

1.2
History of the loading

T
43.11
100.
1000.
10000.
20000.
21000.
22000.
22200.
22400.
xx (T)
300.
300.
300.
300.
300.

300.
300.
300.
300.
yy (T) =
0.
0.
0.
0.
0.
0.
0.
0.
0.
zz (T) =
xy (T) =
xz (T) =
yz (T)
Temp
20.
20.
20.
20.
20.
20.
20.
20.
20.
T
p (T) (cumulated Plastic deformation)
43.11
0.019996
100.
0.046384
1000.
0.46384
10000.
4.6384
20000.
9.2768
21000.
9.74064
22000.

10.20448
22200.
10.297248
22400.
10.390016

---

2 Reference solution

2.1 Method of calculation used for the reference solution

The history of loading being very simple, the results of reference can be obtained manually by applying the algorithms presented in the reference document [R7.04.01]

2.2 Results of Reference

T	**p (T) (cumulated Plastic deformation)**
43.11	0.
100.	0.000848907
1000.	0.014474925
10000.	0.178374238
20000.	0.524693005
21000.	0.602827469

22000.
0.73829052
22200.
0.792149807
22400.
0.967604351
The value of the cumulated damage is: 3.819263222
2.3
Uncertainty on the solution
Analytical solution.
2.4 References
bibiographic
[1]
A.M. DONORE: Estimate of the fatigue life to great numbers of cycles and in oligocyclic fatigue. Note [R7.04.01] Index B.

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3 Modeling
3.1 Functionalities
tested
Order
Key word
Operand
Key
POST_FATIGUE
HISTORY
SIGM_XX
[U4.67.01]
SIGM_YY

SIGM_ZZ
SIGM_XY
SIGM_XZ
SIGM_YZ
EPSP
TEMP
TOO BAD
“LEMAITRE”
MATER
OFFICE PLURALITY
“LINEAR”
INFORMATION
DEFI_MATERIAU
ELAS_FO
E
[U4.23.01]
NAKED
DOMMA_LEMAITRE
S
EPSP_SEUIL
Handbook of Validation
V9.01 booklet: Tire
HI-75/96/068 - Ind A

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4 Results of modeling

4.1 Values tested

Identification	**Reference**	**Aster**	**% difference**
Point 1 Damage	0.	0.	0.
Point 2 Damage	0.000848907	0.000849061	0.
Point 3 Damage	0.014474925	0.014474926	0.
Point 4 Damage	0.178374238	0.178374284	0.
Point 5 Damage	0.524693005	0.5246932887	0.
Point 6 Damage	0.602827469	0.602827891	

0.
Point 7 Damage
0.73829052
0.73829154
0.
Point 8 Damage
0.792149807
0.79215143
0.
Point 9 Damage
0.967604351
0.96767208
0.007
DOMM_CUMU
3.819263
3.8193343
0.002

4.2 Parameters of execution

Version: 3.06.19
Machine: CRAY C90
Obstruction memory:
8 MW
Time CPU To use:
2.44 seconds

---

5 Summary of the results

The results provided by Code_Aster coincide with the values of reference.

Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.110

SZLZ110 - Damage of generalized Lemaître in postprocessing CALC_ELEM

Summary:

The purpose of this test is calculation of the damage of Lemaître generalized "LEMAIT_S" starting from the data of the tensor
constraints and plastic deformation cumulated at every moment Ti (provided by the user).

The cumulated damage is also calculated.

The characteristics material E (Young modulus), (Poisson's ratio), S and Pd (parameters of material) can depend on the temperature, which must thus be provided by the user at the same moments as them constants and plastic deformation.

1
Problem of reference

One calculates the damage D (T) starting from the data of the tensor of the constraints (T) and of cumulated plastic deformation p (T) resulting from a calculation in thermomechanics. The kinetics of damage is given by:

S

1

D& =

1 (+) 2
+ 3
1
eq
(1- 2) 2

H p

if
&
p > p

(
D
1 - D) 2s 3ES
2ES

D = 0
if not

is the equivalent constraint of von Mises
eq
is the hydrostatic constraint
H
p represents the threshold of damage
D
S is a characteristic of the material (MPa)
S is a characteristic of material

NR
One also calculates the total damage D = D (T.
I)
i=1

1.1 Properties
materials

Temp (°C)
E (MPa)

S (MPa)
Pd
S
Case 1
Case 2
0. 143006.0E+6
0.33
7.0 1.005E-6
0.8
1.003
20. 143006.0E+6
0.33
7.0 1.005E-6
0.8
1.003
40. 143006.0E+6
0.33
7.0 1.005E-6
0.8
1.003

Two values of the exhibitor S are successively used for the validation of the developments in CALC_ELEM.

1.2 Loading

The loading corresponds to a tensile test at constant temperature and speed of deformation imposed. It is defined in the paragraph [§2.2].

2
Reference solution

2.1
Method of calculation used for the reference solution

The reference solution is generated starting from option POST_FATIGUE. Adopted methodology consist in defining a history of loading in constraints and to recover the evolution of cumulated plastic deformation associated starting from a tensile test 3D in thermo-viscoplasticity.

The history of loading (T) and p (T) is then used in a calculation POST_FATIGUE with parameters materials presented at the paragraph [§1.1] to define a reference solution.

2.2
Results of Reference

The result of reference of the damage of Lemaître is obtained for a tensile test to deformation imposed and on constant temperature. The state of stresses and cumulated plastic deformation resulting of this test are as follows:

Time [S]	Constraint Sxx (T) [Pa]	Cumulated plastic deformation P (T)
50	7.15030E+06	0.000000E+00
100	1.43006E+07	0.000000E+00
150	2.14509E+07	0.000000E+00
200	2.86012E+07	0.000000E+00
250	3.57515E+07	0.000000E+00
300	4.29018E+07	0.000000E+00
350	5.00521E+07	0.000000E+00
400		

5.72024E+07 0.000000E+00
450
6.43527E+07 0.000000E+00
500
7.15030E+07 0.000000E+00
550
7.86533E+07 0.000000E+00
600
8.58036E+07 0.000000E+00
650
9.29539E+07 0.000000E+00
700
1.00091E+08 9.547120E-08
750
1.06433E+08 5.747160E-06
800
1.10614E+08 2.650910E-05
850
1.12888E+08 6.060610E-05
900
1.14130E+08 1.019250E-04
950
1.14913E+08 1.464460E-04
1000
1.15508E+08 1.922890E-04

This history of loading is then used with operator POST_FATIGUE option LEMAIT_S
to estimate the damage according to time with the properties materials defined in the paragraph
[§1.1]. The temperature is supposed to be constant and equalizes to 20 °C. One finds, according to the value of
parameter S used, following damage:

Damage (reference)
Time [S]
Case s=0.8
Case s=1.003
50
0.00000E+00 0.00000E+00
100 0.00000E+00
0.00000E+00
150 0.00000E+00
0.00000E+00
200 0.00000E+00
0.00000E+00
250 0.00000E+00
0.00000E+00
300 0.00000E+00
0.00000E+00
350 0.00000E+00
0.00000E+00
400 0.00000E+00
0.00000E+00
450 0.00000E+00
0.00000E+00
500 0.00000E+00
0.00000E+00
550 0.00000E+00
0.00000E+00
600 0.00000E+00
0.00000E+00
650 0.00000E+00
0.00000E+00
700 0.00000E+00
0.00000E+00
750 5.43732E-03
3.19264E-02
800 2.75450E-02
1.90334E-01
850 6.75939E-02

1.00000E+00
900 1.21543E-01
1.00000E+00
950 1.87318E-01
1.00000E+00
1000 2.66202E-01 1.00000E+00
Cumulated damage
6.75640E-01
4.22226E+00

2.3
Uncertainty on the solution

Numerically generated solution.

2.4 References
bibliographical

[1]
A.M. DONORE: Estimate of the fatigue life to great numbers of cycles and in
oligocyclic fatigue. Note [R7.04.01] Index B.

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3 Modeling

3.1 Functionalities
tested

Order

CALC_ELEM
OPTION
ENDO_ELGA

ENDO_ELNO_ELGA

DEFI_MATERIAU ELAS_FO
E

NAKED

RHO

TEMP_DEF_ALPHA

ALPHA

DOMMA_LEMAITRE
S

EPSP_SEUIL

EXP_S

THER_FO LAMBDA

RHO_CP

LEMAITRE_FO NR

UN_SUR_K

UN_SUR_M

CIN2_CHAB_FO R_0

R_I

B

C1

C2

K

W

G1

G2

A_I

4
Results of modeling

4.1 Values
tested

One tests the values of sizes DOM_LEM and D_CUMULE.

Identification Reference
Aster %
difference

S = 0.8
S = 1.003
S = 0.8
S = 1.003
S = 0.8

S = 1.003
Point 1 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 2 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 3 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 4 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 5 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 6 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 7 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 8 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 9 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 10 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 11 Damage
0,0000000 0,0000000 0,0000000 0,0000000

0,00000%
0,00000%
Point 12 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 13 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 14 Damage
0,0000000 0,0000000 0,0000000 0,0000000
0,00000%
0,00000%
Point 15 Damage
0,0054373 0,0319264 0,0054373 0,0319262 -0,00059% -0,00077%
Point 16 Damage
0,0275450 0,1903340 0,0275449 0,1903330 -0,00041% -0,00051%
Point 17 Damage
0,0675939 1,0000000 0,0675938 1,0000000 -0,00021%
0,00000%
Point 18 Damage
0,1215430 1,0000000 0,1215426 1,0000000 -0,00036%
0,00000%
Point 19 Damage
0,1873180 1,0000000 0,1873169 1,0000000 -0,00058%
0,00000%
Point 20 Damage
0,2662020 1,0000000 0,2662008 1,0000000 -0,00046%
0,00000%
D_CUMULE 0,6756392
4,2222604 0,6756362 4,2222592
0,00045%
-0,00003%

5
Summary of the results

The results provided by Code_Aster coincide with the values of reference.

Handbook of Validation

Handbook of Validation
V9.01 booklet: Tire
Document: V9.01.111

SZLZ111 - Damage of Lemaître-Sermage
in postprocessing POST_FATIGUE

Summary:

The purpose of this test is calculation of the damage of Lemaître-Sermage "LEMAITRE" starting from a history of unspecified multiaxial loading and of the history of the cumulated plastic deformation.

One calculates the damage starting from the data of the tensor of the constraints and the plastic deformation cumulated in every moment Ti (provided by the user). Moreover, one calculates the cumulated damage.

The characteristics material E (Young modulus), (Poisson's ratio) and S (parameter of material) must depend on the temperature T. This one must thus be provided by the user at the same moments as (T) and p (T).

---

1 Problem of reference

One calculates the damage, D (T), starting from the data of the tensor of the constraints, (T), and of cumulated plastic deformation, p (T).

S

1

D& =
1 (+) 2
+ 3
1

eq
(1- 2) 2

H p

if
&
p > p

(
D
1 - D) 2s 3ES
2ES

D = 0
if not

eq is the equivalent constraint of von Mises
H is the hydrostatic constraint
Pd represents the threshold of damage
S is a characteristic materials (MPa)
S is a characteristic materials

NR
The cumulated damage is also calculated: D = D (Ti).
i=1

1.1 Properties
materials

Temp (°C)
E (MPa)

S (MPa)
0. 2.E+5 0. 7.
20. 2.E+5 0. 7.
40. 2.E+5 0. 7.

Pd = 0.02

1.1.1 Modeling
With

In this modeling, one checks the calculation of the damage of Lemaître-Sermage compared to reference solution given in [V9.01.109]. Values of the exhibitor S and S in the expression of the damage of generalized Lemaître are worth:

S = 1.0 and S = 7.0

1.1.2 Modeling B

In this second modeling, one checks the calculation of the damage of Lemaître-Sermage per report/ratio with an analytical solution obtained by applying the algorithms presented in the document of reference [R7.04.01]. Values of the exhibitor S and S in the expression of the damage of Generalized Lemaître are worth:

S = 1.003 and S = 7.0

Handbook of Validation

V9.01 booklet: Tire HT-66/04/005/A

1.2 History of the loading

T 43.11
100.
1000.
10000.
20000. 21000. 22000. 22200. 22400.
xx (T)
300. 300. 300. 300. 300. 300. 300. 300. 300.
yy (T) =
0. 0. 0. 0. 0.
0.
0.
0. 0.
zz (T) =
0. 0. 0. 0. 0.
0.
0.
0. 0.
xy (T) =
0. 0. 0. 0. 0.
0.
0.
0. 0.
xz (T) =
0. 0. 0. 0. 0.
0.
0.

0. 0.
yz (T)
0. 0. 0. 0. 0.
0.
0.
0. 0.
Temp
20.
20.
20.
20. 20. 20. 20. 20. 20.

T
p (T) (cumulated Plastic deformation)
43.11 0.019996
100. 0.046384
1000. 0.46384
10000. 4.6384
20000. 9.2768
21000. 9.74064
22000. 10.20448
22200. 10.297248
22400. 10.390016
Handbook of Validation
V9.01 booklet: Tire HT-66/04/005/A

2
Reference solution

2.1
Method of calculation used for the reference solution

The history of loading being very simple, the results of reference can be obtained manually by applying the algorithms presented in the reference document [R7.04.01]

2.2
Results of Reference

2.2.1 Modeling
With
T D (T)
(Damage)
43.11 0.
100. 0.000848907
1000. 0.014474925
10000. 0.178374238
20000. 0.524693005
21000. 0.602827469
22000. 0.73829052
22200. 0.792149807
22400. 0.967604351

The value of the cumulated damage is: 3.819263222

2.2.2 Modeling
B

The results of reference for the case test number 2 are obtained using the Excel spreadsheet in which the expression of the damage of Lemaître-Sermage was established according to a diagram of integration
numerical identical to that used in routine POST_FATIGUE of Code_Aster.

One initially checks that uncertainty on the results obtained for the value S = 1.0 via Microsoft Excel is acceptable:

Too bad
Too bad
(calculation Excel)
(reference solution)
Difference
0,0000000000 0,0000000000
0,00000%
0,0008489062 0,0008489070

-0,00010%
0,0144749268 0,0144749250
0,00001%
0,1783742841 0,1783742380
0,00003%
0,5246932887 0,5246930050
0,00005%
0,6028278917 0,6028274690
0,00007%
0,7382915411 0,7382905200
0,00014%
0,7921514337 0,7921498070
0,00021%
0,9676720845 0,9676043510
0,00700%

In the second time, one generates a reference solution for a value of S = 1.003:

T	D (T) (Damage solution Excel)
43.11	0.0
100.	0.004742198
1000.	0.083020455
10000.	1.809947268
20000.	2.003578566
21000.	0.083020455
22000.	0.178700399
22200.	0.199207053
22400.	0.220252827

The value of the cumulated damage is: 4.582469221

2.3
Uncertainty on the solution

2.3.1 Modeling
With

Analytical solution.

2.3.2 Modeling
B

Analytical solution.

2.4 References
bibiographic

[1]
A.M. DONORE: Estimate of the fatigue life to great numbers of cycles and in
oligocyclic fatigue. Note [R7.04.01] Index B.

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3 Modeling
With

3.1 Functionalities

tested

Order

POST_FATIGUE HISTORY
SIGM_XX

SIGM_YY

SIGM_ZZ

SIGM_XY

SIGM_XZ

SIGM_YZ

EPSP

TEMP

TOO BAD
“LEMAITRE”

MATER

“LINEAR” OFFICE PLURALITY

INFORMATION

DEFI_MATERIAU ELAS_FO
E

NAKED

DOMMA_LEMAITRE
S

EPSP_SEUIL

EXP_S

4
Results of modeling A

Identification Reference
***Aster** %*
difference
Point 1 Damage
0.
0.
0,00000
Point 2 Damage
0.000848907
0.000849061
-0,01814
Point 3 Damage
0.014474925
0.014474926
-0,00001
Point 4 Damage
0.178374238

0.178374284
-0,00003
Point 5 Damage
0.524693005
0.5246932887
-0,00005
Point 6 Damage
0.602827469
0.602827891
-0,00007
Point 7 Damage
0.73829052
0.73829154
-0,00014
Point 8 Damage
0.792149807
0.79215143
-0,00020
Point 9 Damage
0.967604351
0.96767208
-0,00700
DOMM_CUMU 3.819263
3.8193343
-0,00187

---

5 Modeling

B

5.1 Functionalities tested

Order

POST_FATIGUE HISTORY SIGM_XX

SIGM_YY

SIGM_ZZ

SIGM_XY

SIGM_XZ

SIGM_YZ

EPSP

TEMP

TOO BAD "LEMAITRE"

MATER

"LINEAR" OFFICE PLURALITY

INFORMATION

DEFI_MATERIAU ELAS_FO
E

NAKED

DOMMA_LEMAITRE
S

EPSP_SEUIL

EXP_S

6
Results of modeling B

Identification Reference
***Aster** %*
difference
Point 1 Damage
0,0000000000
0,0000000000
0,00000
Point 2 Damage
0,0008401910
0,0008401914
0,00005
Point 3 Damage
0,0143249000
0,0143248741

-0,00018
Point 4 Damage
0,1762380000
0,1762381211
0,00007
Point 5 Damage
0,5133290000
0,5133285359
-0,00009
Point 6 Damage
0,5863320000
0,5863316643
-0,00006
Point 7 Damage
0,7028150000
0,7028154063
0,00006
Point 8 Damage
0,7412430000
0,7412431087
0,00001
Point 9 Damage
0,7967720000
0,7967724320
0,00005
DOMM_CUMU 3,5318900000
3,5318943339
0,00012

7
Summary of the results

The results provided by Code_Aster coincide with the values of reference.

Handbook of Validation
V9.01 booklet: Tire HT-66/04/005/A
