

HSNV134 – Model META_LEMA_ANI : tube under pressure and constant temperature

Summary:

This test constitutes a digital validation of the model of behavior META_LEMA_ANI mechanics with effect of the metallurgical transformations developed for material of the sheath of the fuel pins, Zircaloy. It is about a tube subjected to an internal pressure, with taking into account of the basic effect and at a uniform and constant temperature in time (thus only one involved phase). One cancels one of the coefficients material of the law in order to obtain the model of viscosity of Norton. One can then compare the solution obtained with the software ZMAT, which comprises the same law exactly.

1 Problem of reference

1.1 Geometry

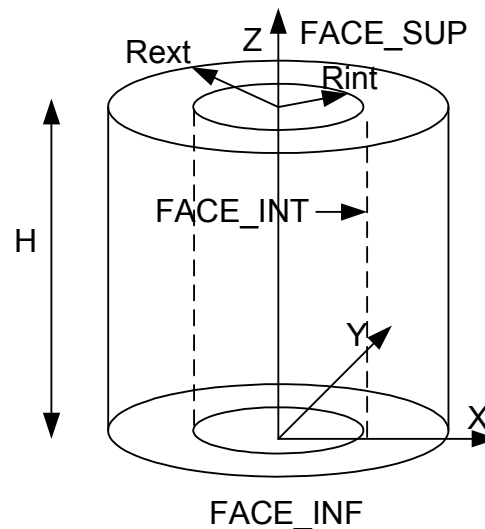


Figure 1.1-a: Geometry of the problem of reference

It is about a cylinder height $H=20\text{mm}$, of interior ray $R_{int}=4.118\text{mm}$ and of external ray $R_{ext}=4.746\text{mm}$.

1.2 Material properties

The properties materials are described by the following parameters:

Thermal properties:

$$\rho C_p = 2000000 \text{ J.m}^{-3} . ^\circ\text{C}^{-1}$$

$$\lambda = 9999.9 \text{ W.m}^{-1} . ^\circ\text{C}^{-1}$$

Metallurgical properties:

$$TDEQ = 809 \text{ } ^\circ\text{C}$$

$$K = 1.135 . 10^{-2}$$

$$N = 2.187$$

$$TIC = 831 \text{ } ^\circ\text{C}$$

$$T2C = 0 \text{ } ^\circ\text{C}$$

$$QSR_K = 14614$$

$$AC = 1.58 . 10^{-4}$$

$$M = 4.7$$

$$TIR = 949,1 \text{ } ^\circ\text{C}$$

$$T2R = 0 \text{ } ^\circ\text{C}$$

$$AR = -5.725$$

$$BR = 0.05$$

Thermoelastic mechanical properties:

YOUNG modulus: $E = 80\,000 \text{ MPa}$

Poisson's ratio: $NU = 0.35$

Identical for the phases heat and cold dilation coefficient $F_{ALPHA} = 8.E-6 \text{ } ^\circ C^{-1}$ and
 $C_{ALPHA} = 8.E-6 \text{ } ^\circ C^{-1}$

• **Mechanical properties of the law META_LEMA_ANI :**

Parameters related to viscosity

-Phase α pure

F1_A = 2.39
F1_M = 0.
F1_N = 4.39
F1_Q = 19922.8

-Mixture $\alpha + \beta$

F2_A = 0.22
F2_M = 0.77 E-4
F2_N = 2.96
F2_Q = 21023.7

-Phase β pure

C_A = 9.36
C_M = 0.99 E-4
C_N = 6.11
C_Q = 6219

Coefficient of the matrix of anisotropy in the plan (r, θ, z) -

-Phase α

F_MRR_RR = 0.4414
F_MTT_TT = 0,714
F_MZZ_ZZ = 1
F_MRT_RT = 0.75
F_MRZ_RZ = 0.75
F_MTZ_TZ = 0.75

-Phase β

C_MRR_RR = 1
C_MTT_TT = 1
C_MZZ_ZZ = 1
C_MRT_RT = 0.75
C_MRZ_RZ = 0.75
C_MTZ_TZ = 0.75

1.3 Boundary conditions and loadings

Thermal part: the temperature is imposed on all the cylinder on $700 \text{ } ^\circ C$ throughout all mechanical loading of 0 with 100s .

Mechanical part:

The lower part of the cylinder (FACE_INF) is blocked in following displacement z :
 $UZ(x, y, 0) = 0$

All the upper part of the cylinder (FACE_SUP) has a following displacement z uniform.

One imposes a pressure on the interior face of the tube (FACE_INT) :

Time (s)	Pressure (MPa)
0	0.
1.1	7.5

100.	9.5
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One takes account of the basic effect on the upper part of the tube (FACE_SUP):

Time (s)	Pressure (MPa)
0	0.
1.1	$-7.5 \times coef$
100.	$-9.5 \times coef$

With $coef = (Rint \times Rint) / [(Rext \times Rext) - (Rint \times Rint)]$

1.4 Initial conditions

Initially, the temperature is of $700^\circ C$ and it tube is made up of 100% of cold phase α , that is to say:

$$V1 = 1.0$$

$$V2 = 0.0$$

$$V3 = 20.$$

$$V4 = 0.$$

$V1$: proportion of the cold phase α

$V2$: proportion of the cold phase α , mixed with the phase β

$V3$: temperatures with the nodes

$V4$: time corresponding to or end the initial temperature of the transformation with balance

2 Reference solution

The results of reference are got with the software ZMAT which comprises the equivalent law with the file material .33 following:

```
*** material
*integration theta_method_a 1. 1.e-12 100

*** behavior gen_evp
** elasticity
Young 80000.
fish 0.35
** potential gen_evp ev
*flow norton
K 253.5497
N 4.39
*criterion anisotropic orthotropic
c11 0.294267      c22 0.6666667      c33 0,476
c44 0.5          c55 0.5          c66 0.5
c12 -0.242467   c23 -0.4242      c31 -0.0518
*isotropic constant
R0 0.
*** return
```

3 Modeling A

3.1 Characteristics of modeling

The modeling used in the CAS-test is the following one:

Elements 2D 'AXIS' (QUA8)

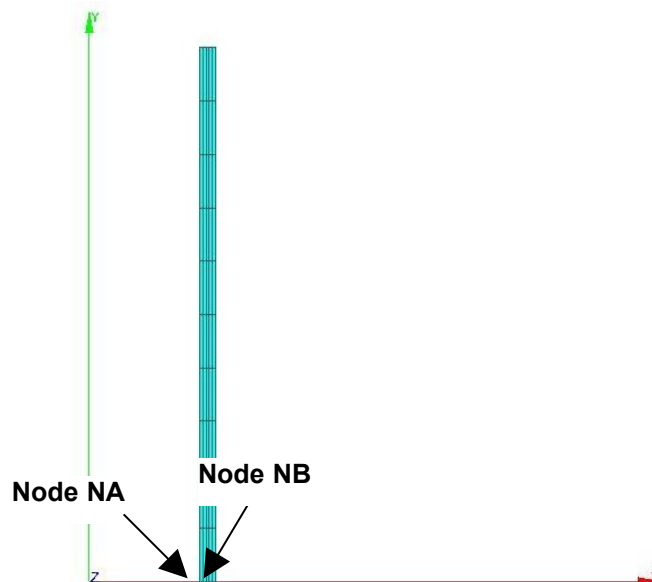


Figure 3.1-a: Geometry and grid of modeling

Cutting: 5 meshes QUAD8 according to the axis of x
 10 meshes QUAD8 according to the axis of y

3.2 Characteristics of the grid

Many nodes: 181
Many meshes and types: 50 QUAD8, 30 SEG3.
Node NA : $X = R_{int}$, $Y = 0$.
Node NB : $X = R_{ext}$, $Y = 0$.

3.3 Characteristics of the loading

Boundary conditions:

```
FACE_IMPO =_F (GROUP_MA=' FACE_INF', DNOR=0)
LIAISON_UNIF =_F (GROUP_MA=' FACE_SUP', DDL=' DY')
```

Loading:

```
PRES_REP=_F (GROUP_MA=' FACE_INT' PRES=1.),
           _F (GROUP_MA=' FACE_SUP' PRES=-coeff.),
```

with $coeff = (R_{int} \times R_{int}) / [(R_{ext} \times R_{ext}) - (R_{int} \times R_{int})]$

3.4 Sizes tested and results

Identification	Size	Reference
t=100s NA	SIXX	-9,442
t=100s NA	SIZZ	60,226
t=100s NA	SIYY	26,795
t=100s NA	EPXX	-9.49597E-03
t=100s NA	EPZZ	1.35633E-02
t=100s NA	EPYY	-3.7769E-03
t=100s NB	SIXX	3.28215E-02
t=100s NB	SIZZ	64,199
t=100s NB	SIYY	30,771
t=100s NB	EPXX	-6.58609E-03
t=100s NB	EPZZ	1.07189E-02
t=100s NB	EPYY	-3.7769E-03

4 Modeling B

4.1 Characteristics of modeling

The modeling used in the case test is the following one:

Elements 3D (HEXA20)

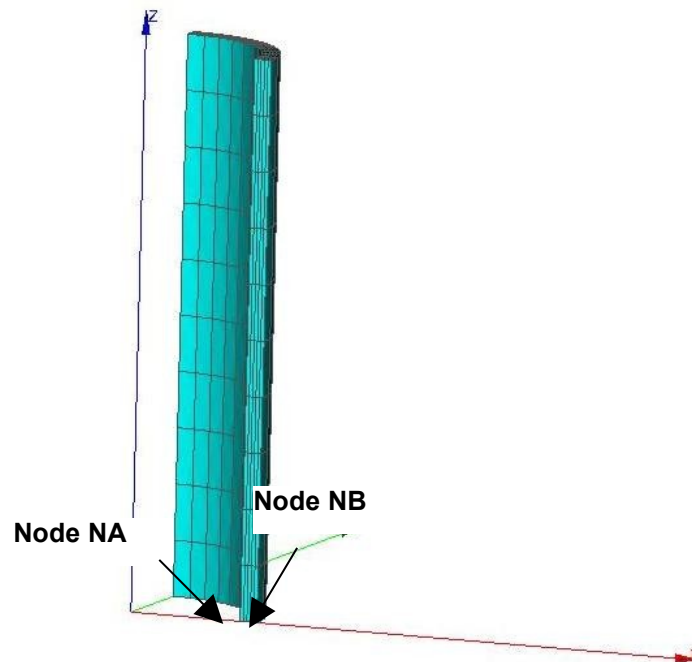


Figure 5.1-a: Geometry and grid of modeling

Cutting: 5 meshes HEXA20 according to the axis r (cylindrical reference mark)
 10 meshes HEXA20 according to the axis θ (cylindrical reference mark)
 10 meshes HEXA20 according to the axis z

4.2 Characteristics of the grid

Many nodes: 2651
Many meshes and types: 500 HEXA20, 400 QUAD8, 100 SEG3.
Node NA : $X = R_{int}$, $Y = 0$.
Node NB : $X = R_{ext}$, $Y = 0$.

4.3 Characteristics of the loading

Boundary conditions:

```
FACE_IMPO =_F (GROUP_MA=' FACE_INF', DNOR=0)
             _F (GROUP_MA=' FACE_X0', DX=0)
             _F (GROUP_MA=' FACE_Y0', DY=0)
LIAISON_UNIF =_F (GROUP_MA=' FACE_SUP', DDL=' DZ')
```

Loading:

```
PRES_REP=_F (GROUP_MA=' FACE_INT' PRES=1.),  
_F (GROUP_MA=' FACE_SUP' PRES=-coeff.),
```

with $coef = (Rint \times Rint) / [(Rext \times Rext) - (Rint \times Rint)]$

4.4 Sizes tested and results

Identification	Size	Reference
t=100s NA	SIXX	-9.4420
t=100s NA	SIZZ	60,226
t=100s NA	SIYY	26,795
t=100s NA	EPXX	-9.49597E-03
t=100s NA	EPZZ	1.35633E-02
t=100s NA	EPYY	-3.7769E-03
t=100s NB	SIXX	3.28215E-02
t=100s NB	SIZZ	64,199
t=100s NB	SIYY	30,771
t=100s NB	EPXX	-6.58609E-03
t=100s NB	EPZZ	1.07189E-02
t=100s NB	EPYY	-3.7769E-03

4.5 Comments

The values tested in 3D are those calculated in the cylindrical reference mark.

5 Conclusion

The values of reference are those obtained with ZMAT. Results got with *Code_Aster* are in very good agreement with ZMAT.