HSNV135 – Model META_LEMA_ANI : tube under pressure and variable 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 variable temperature in time (thus several involved phases). This CAS-test is identical to the HSNV134 modeling A, except here, it occurs a phase shift.

There is no analytical solution. It is about a CAS-test of nonregression.

1 Problem of reference

1.1 Geometry

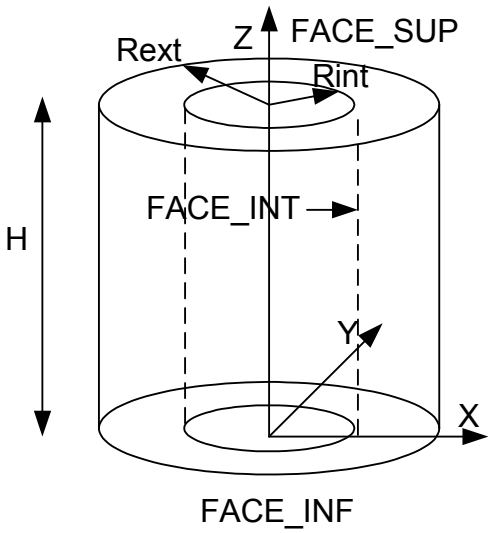

Figure 1.1-a: Geometry of the problem of reference

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

1.2 Material properties

The properties materials are described by the following parameters:

Thermal properties:

$\rho_{Cp}=2000000\,J.m^{-3.}{}^{\circ}C^{-1}$
$\lambda=9999.9\,W.m^{-1.}{}^{\circ}C^{-1}$

Metallurgical properties:

$TDEQ=809\,^{\circ}C$
$K=1.135.10^{-2}$
$N=2.187$
$T1C=831\,^{\circ}C$
$T2C=0.\,^{\circ}C$
QSR_K=14614
$AC=1.58.10^{-4}$
$M=4.7$
$T1R=949{,}1\,^{\circ}C$
$T2R=0.\,^{\circ}C$
$AR=-5.725$
$BR=0.05$

Thermoelastic mechanical properties:

Young modulus: $E=80\,000\,MPa$
Poisson's ratio: $\nu=0.35$

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

Mechanical properties of the law META_LEMA_ANI :

Parameters related to viscosity

- Phase α pure

```
F1_A = 2.39
F1_M = 0.07
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_MR Z_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:

One imposes a uniform temperature on all the tube:

Time (s)	Temperature ($°C$)
-1.	20.
0.	609.
36.1	609.
44.	799.7
46.	838.67
48.	876.52
49.2	894.5

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)
-1.0	0.
0.	0.
36.1	6.74
49.2	6.74

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

Time (s)	Pressure (MPa)
-1.0	0.
0.	0.
36.1	6.74*coeff
49.2	6.74*coeff

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

1.4 Initial conditions

Initially, the temperature is of $20\,°C$ and it tube is made up of 100% of cold phase α . that is to say:
$V1=1.0$
$V2=0.0$
$V3=20.$
$V4=-1.0$

$V1$: 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

There does not exist reference solution. It is about a test of nonregression.

3 Modeling A

3.1 Characteristics of modeling

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

Elements 2D **'AXIS' (QUA8)**

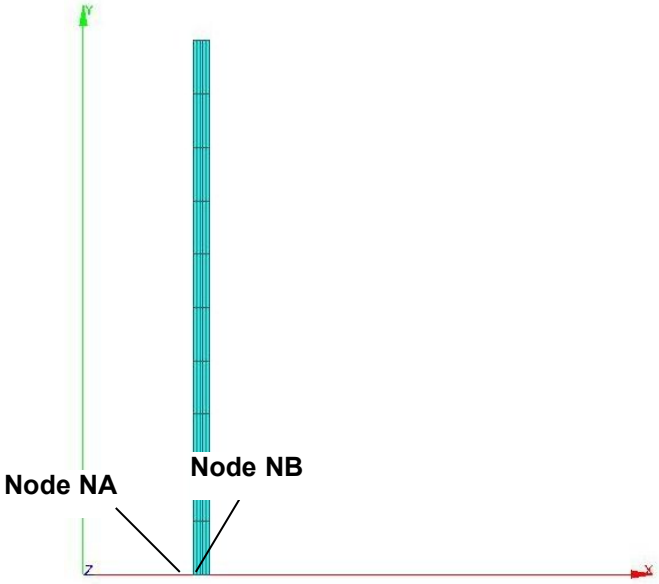

Figure 3.1-a: Geometry and grid of modeling

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

3.2 Characteristics of the grid

Many nodes: 181
Many meshs and types: 50 QUAD8, 30 SEG3.
Node NA : $X = Rint\ ,\ Y = 0.$
Node NB : $X = Rext\ ,\ Y = 0.$

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

3.4 Sizes tested and results

Identification	Size	*Aster*
$t=49.2\text{s}$ NA	SIXX	-6.61
$t=49.2\text{s}$ NA	SIZZ	43,449
$t=49.2\text{s}$ NA	SIYY	19.30
$t=49.2\text{s}$ NA	EPXX	-1.72E-02
$t=49.2\text{s}$ NA	EPZZ	4.055E-02
$t=49.2\text{s}$ NA	EPYY	-2.106E-03