HSNV135 – Model META_LEMA_ANI : tube under pressure and variable temperature

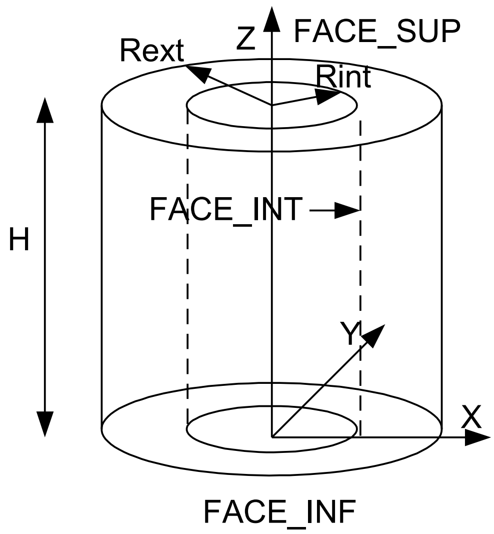
Abstract:

This test constitutes a numerical validation of the model of behavior META_LEMA_ANI mechanics with effect of the metallurgical transformations developed for the 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 with a uniform and variable temperature in time (thus several involved phases). This benchmark is identical to the HSNV134 modelization A, except here, it occurs a phase change.

There is no analytical solution. It is about a benchmark of non regression.

1 Problem of reference

1.1 Geometry



Appears 1.1-a: Geometry of the problem of reference

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

1.2 Material properties

The materials' properties are described by the following parameters:

Thermal properties:

$\rho_{Cp}=2000000\,J.m^{-3.}\,°C^{-1}$

$\lambda=9999.9\,W.m^{-1.}\,°C^{-1}$

Metallurgical properties:

$TDEQ=809\,°C$

$K=1.135.10^{-2}$

$N=2.187$

$T1C=831\,°C$

$T2C=0.\,°C$

$\text{QSR\_K}=14614$

$AC=1.58.10^{-4}$

$M=4.7$

$T1R=949{,}1\,°C$

$T2R=0.\,°C$

$AR=-5.725$

$BR=0.05$

Thermoelastic mechanical properties:

Young modulus: $E=80\,000\,MPa$

Poisson's ratio: $\nu=0.35$

Coefficient of thermal expansion identical for the phases heat and cold $F_{ALPHA} = 8.\mathrm{E}-6\,°C^{-1}$ and $C_{ALPHA} = 8.\mathrm{E}-6\,°C^{-1}$

Mechanical properties of model META_LEMA_ANI :

Parameters related to viscosity

•pure α Phase

```
F1_A = 2.39
F1_M = 0.07
F1_N = 4.39
F1_Q = 19922.8
```

•Mixture $\alpha+\beta$

```
formulates = 0.22
F2_M = 0.77 E-4
F2_N = 2.96
F2_Q = 21023.7
```

•pure β Phase

```
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 Phase (r, θ, z).

•plane 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

Left thermal:

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 ($\mathrm{FACE\_INF}$) is blocked in following displacement z : $UZ(x, y, 0) = 0$

All the upper part of the cylinder ($\mathrm{FACE\_SUP}$) has a displacement according to z uniform
One imposes a pressure on the interior face of the tube ($\mathrm{FACE\_INT}$):

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 end or the initial temperature of the transformation to the equilibrium

2 Reference solution

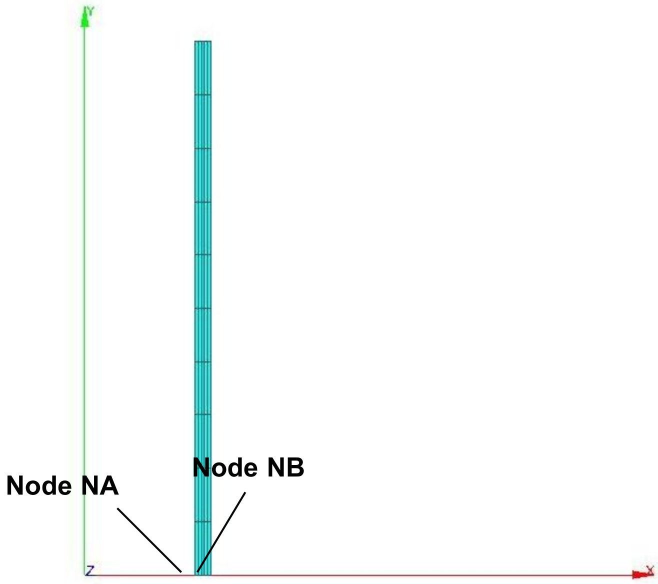
It does not exist of reference solution. It is about a test of non regression.

3 Modelization A

3.1 Characteristic of the modelization

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

Elements $2D$ **“AXIS” (QUA8)**



Appears 3.1-a: Geometry and mesh of the modelization

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

3.2 the Characteristics of the mesh

Many nodes: 181
Number of meshes and types: 50 QUAD8, 30 SEG3.
The node is outside the field of definition with a right profile of the EXCLU type node: NA $X=Rint, Y=0.$
The node is outside the field of definition with a right profile of the EXCLU type 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 Quantities tested and results

Identification	Quantity	*Aster*
$t=49.2s$ NA	SIXX	-6.61
$t=49.2s$ NA	SIZZ	43.449
$t=49.2s$ NA	SIYY	19.30
$t=49.2s$ NA	EPXX	-1.72E-02
$t=49.2s$ NA	EPZZ	4.055E-02
$t=49.2s$ NA	EPYY	-2.106E-03