HSNV138 – Tube under pressure: writing of the matrix of anisotropy of law META_LEMA_ANI in Cartesian coordinates

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. In addition, one tests here the possibility of giving the matrix of anisotropy of this law in Cartesian coordinates. One can then compare the solution obtained with that which the programming of this law with MFront gives, which comprises the same functionality exactly.

1 Problem of reference

1.1 Geometry

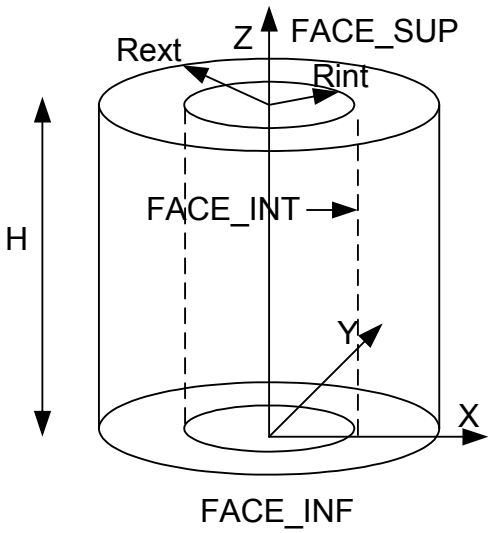

Figure 1.1-a: Geometry of the problem of reference

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

1.2 Material properties

The properties materials are described by the following parameters:

Thermal properties:

$\rho C_p=2000000\,J.m^{-3}.°C^{-1}$
$\lambda=9999.9\,W.m^{-1}.°C^{-1}$

Metallurgical properties:

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

Thermoelastic mechanical properties:

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

Poisson's ratio: $NU=0.35$

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.
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 reference mark (Ox, Oy, Oz) .

- Phase α

```
F_MXX_XX = 0.4414
F_MYY_YY = 0,714
F_MZZ_ZZ = 1
F_MXY_XY = 0.75
F_MXZ_XZ = 0.75
F_MYZ_YZ = 0.75
```

- Phase β

```
C_MXX_XX = 1
C_MYY_YY = 1
C_MZZ_ZZ = 1
C_MXY_XY = 0.75
C_MXZ_XZ = 0.75
C_MYZ_YZ = 0.75
```

1.3 Boundary conditions and loadings

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

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

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 $700\,°C$ 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 by a calculation on the problem of reference defined above by using the behavior AnistropicLemaitreViscoplasticBehaviour.mfront (see [V1.03.129]).
This behavior is programmed while requiring of the user to give the matrix of anisotropy of the law in Cartesian coordinates.

This calculation thus resembles that of test MFRON04B, where one would have omitted the rotation and the off-centring of the tube as well as the call to AFFE_CARA_ELEM and with the procedure ANGLE_CYL (which provided the occurrences of the keyword SOLID MASS of the operator AFFE_CARA_ELEM allowing to define the local reference mark of each mesh).

3 Modeling A

3.1 Characteristics of modeling

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

Elements 3D (HEXA20)

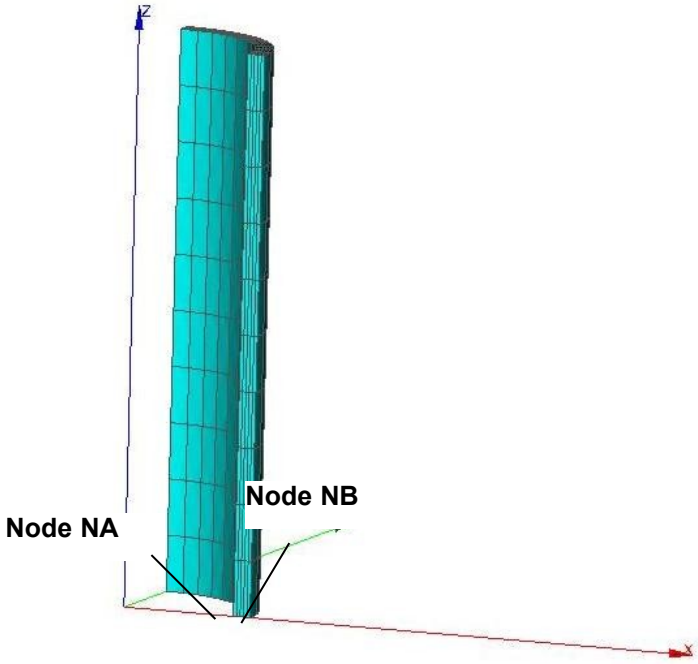

Figure 5.1-a: Geometry and grid of modeling

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

3.2 Characteristics of the grid

Many nodes: 2651
Many meshs and types: 500 HEXA20, 400 QUAD8, 100 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)
           _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 $coef = (Rint \times Rint) / [(Rext \times Rext) - (Rint \times Rint)]$

3.4 Sizes tested and results

Identification	Size	Reference
t=100s NA	SIXX	-11,022
t=100s NA	SIZZ	33.94
t=100s NA	SIYY	59,678
t=100s NA	EPXX	-1.008E-02
t=100s NA	EPZZ	1.09E-04
t=100s NA	EPYY	1.028E-02
t=100s NB	SIXX	0.8979
t=100s NB	SIZZ	42.73
t=100s NB	SIYY	66,735
t=100s NB	EPXX	-7.603E-03
t=100s NB	EPZZ	1.09E-04
t=100s NB	EPYY	7.908E-03

4 Summary of the results

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