HSNV126 - Thermo-metal-worker-mechanics in simple tension

Summarized:

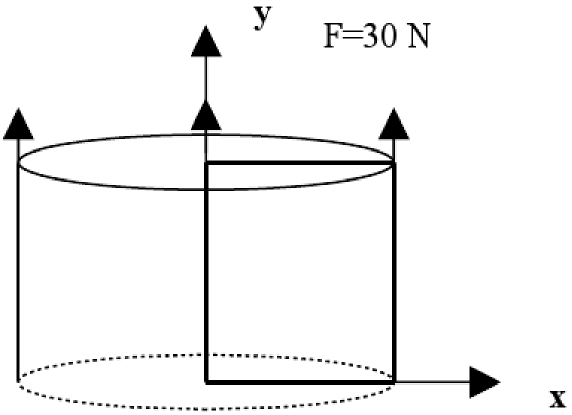
This test illustrates a mechanical computation with nonlinear hardening on a material (Zircaloy) undergoing metallurgical transformations.

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 taking into account will carry out a mechanical computation in the metallurgical phases (besides mechanical loadings). The material of mechanical computation is defined with `ELAS_META_FO` and `META_TRACTION`.

1 Problem of reference

It acts of a cylindrical bar in creep.

1.1 Geometry



Appears 1.1-a: Geometry and loading of the problem of reference

It is about a cylinder height $H=1000\,m$, and radius $R=1000\,m$.
The square in fat corresponds to the axisymmetric modelization used with the §3.

1.2 Material properties

The materials' properties are described by the following parameters:

For thermo-metal computation
(Steel $16\mathrm{MND5}$)
$\rho\,C_p=5260000\,J.m^{-3.}\,{}^\circ C^{-1}$
$\lambda=33.5\,W.m^{-1.}\,{}^\circ C^{-1}$

Coefficients for the metallurgy:

TRC “standard “
$AR3=830\,{}^\circ C\quad alpha=-0.0306$
$MS0=400\,{}^\circ C\quad AC1=724\,{}^\circ C\quad AC3=846\,{}^\circ C$
$\tau_1=0.034$, $\tau_3=0.034$

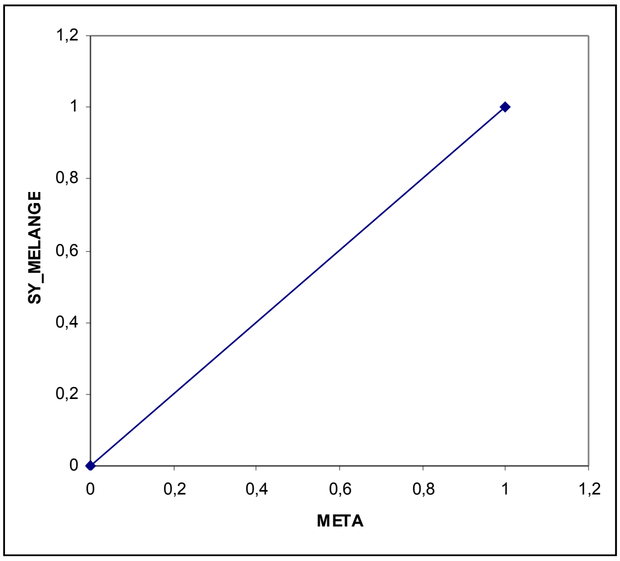
For computation thermo-metal-worker-mechanics

- Modulus Young: $E=200000\,Pa$
- Poisson's ratio: $\nu=0.3$

Definition of the elastic characteristics, thermal expansion and elastic limits for the modelization of an undergoing material of the metallurgical transformations:

- $T_{ref}=20°C$
- Average thermal coefficient of thermal expansion of the cold phases:
  $\alpha_f(T)=10E^{-6}$
- Average thermal coefficient of thermal expansion of the hot phase:
  $\alpha_\gamma(T)=0.0001$
- Temperature of definition of the coefficient of thermal expansion:
  $T_\gamma=20°C$
- Choice of the metallurgical phase of reference: cold
- Strain of the phase not of reference compared to the phase of reference to the temperature T_{ref} :
  $\Delta\varepsilon=1E^{-2}$
- Elastic limit of the cold phase 1 for a plastic behavior:
  $\mathrm{F\_sigm\_f}(T)=100$
- Elastic limit of the cold phase 2 for a plastic behavior:
  $\mathrm{F\_sigm\_f}(T)=100$
- Elastic limit of the cold phase 3 for a plastic behavior:
  $\mathrm{F\_sigm\_f}(T)=100$
- Elastic limit of the cold phase 4 for a plastic behavior:
  $\mathrm{F\_sigm\_f}(T)=100$
- Elastic limit of the hot phase for a plastic behavior:
  $\mathrm{F\_sigm\_f}(T)=100$

- Function used for the model of mixture on the elastic limit of the multiphase material for a viscous behavior:



Appear 1.2-a: Model of Definition

mixture of the 5 curves of tension used in the modelization of isotropic hardening nonlinear of an undergoing material of the metallurgical phase changes:

Isotropic curve hardening R according to the plastic strain cumulated p for the cold phase 1

with $20°C$:

with $120°C$:

0,0105		
0,1125		
0,1815		

Curve isotropic hardening R according to the plastic strain cumulated p for the cold phase 2:
idem preceding

Curve isotropic hardening R according to the plastic strain cumulated p for the cold phase 3:
idem preceding

Curve isotropic hardening R according to the plastic strain cumulated p for the cold phase 4:
idem preceding

Curve isotropic hardening R according to the plastic strain cumulated p for the 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 tensile force $F=30N$ 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 Initial conditions

the following variables are initialized:

$Z_f(x,y,0)=0.7$
$Z_p(x,y,0)=0.0$
$Z_b(x,y,0)=0.3$
$Z_m(x,y,0)=0.0$
$d(x,y,0)=0.0$

2 Reference solution

2.1 Results of reference

the results were got with a previous version of aster. It is about a test of NON-regression.

2.2 Uncertainty on the solution compared to result of NON-regression

uncertainty is of $1\,E^{-10}\%$.

3 Modelization A

3.1 Characteristic of the modelization

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

Elements 2D "AXIS" (QUA8)

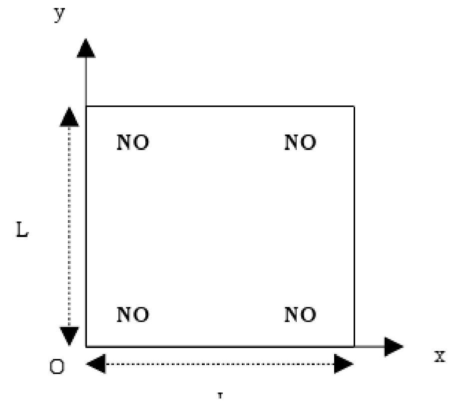


Figure 3.1-a: Geometry and mesh of the modelization

Cutting: 1 meshes QUAD4 according to the axis of x
the 1 meshes QUAD4 according to the axis of y

the conditions: Boundary $Uy=0$ on $NO1$ and $NO2$

$F=30\text{N}$ $NO3$ AND $NO4$

3.2 Characteristic of the mesh

Many nodes: 4
Number of meshes and types: 1 QUAD4, 4 SEG2.

3.3 Quantities tested and results

Identification	Quantity	Reference	*Aster*	% difference
$t=1.1\text{s}$ $NO3$	$SIYY$	60.	59.99	-1.28E-12
$t=1.4\text{s}$ $NO3$	$SIYY$	142.	142.	-1.62E-12
$t=2.0\text{s}$ $NO3$	$SIYY$	218.	218	-1.14E-13
$t=1.1\text{s}$ $NO3$	DY	4.	3.999	-6.04E-14
$t=1.4\text{s}$ $NO3$	DY	13.	13.	-2.52E-13
$t=2.0\text{s}$ $NO3$	DY	31.	31.	3.55E-15
$t=1.1\text{s}$ $NO3$	$V1$	0.	0	
$t=1.4\text{s}$ $NO3$	$V1$	0%.4.9E-3	4.899E-3	-3.79E-12%
$t=2.0\text{s}$ $NO3$	$V1$	1.91E-2	1.91E-2	-2.54E-13%
$t=1.1\text{s}$ $NO3$	$V7$	0.	0	0%
$t=1.4\text{s}$ $NO3$	$V7$	41.1	41.099	-3.96E-12%
$t=2.0\text{s}$ $NO3$	$V7$	117.58	117.58	-1.72E-12%

4 Modelization B

4.1 Characteristic of the modelization

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

Elements 2D “AXIS” (QUA8)

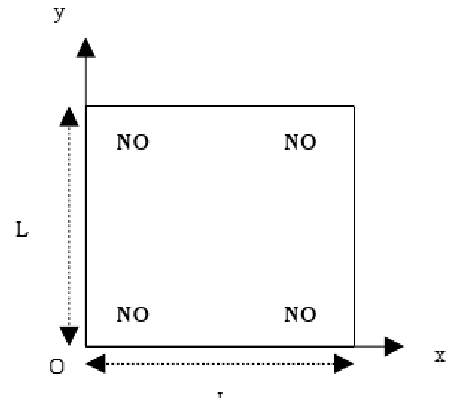


Figure 3.1-a: Geometry and mesh of the modelization

Cutting: 1 meshes QUAD4 according to the axis of x
the 1 meshes QUAD4 according to the axis of y

the Boundary conditions: $Uy=0$ on $NO1$ and $NO2$
$F=30\text{N}$ on $NO3$ AND $NO4$

The modelization B is the exact equivalent one of the modelization A in taking into account of the large deformations via key word `DEFORMATION=' SIMO_MIEHE'`.

4.2 Characteristics of the mesh

Many nodes: 4
Number of meshes and types: 1 QUAD4, 4 SEG2.

4.3 Quantities tested and results

Identification		Quantity	Reference	*Aster*	% difference
$t=1.1\text{s}$	$NO3$	$SIYY$	59.72	5.9724891293860E+01	0.005
$t=1.4\text{s}$	$NO3$	$SIYY$	141.	1.4099749961110E+02	-0.003
$t=2.0\text{s}$	$NO3$	$SIYY$	215.66	2.1566273036229E+02	0.003
$t=1.1\text{s}$	$NO3$	DY	4.	3.9975135788390	-0.002
$t=1.4\text{s}$	$NO3$	DY	13.	1.2997513578839E+01	-0.002
$t=2.0\text{s}$	$NO3$	DY	31.	3.0997513578839E+01	-0.002
$t=1.1\text{s}$	$NO3$	$V1$	0.	0.	0
$t=1.4\text{s}$	$NO3$	$V1$	4.8787000000000E-03	4.8787703363334E-03	0.001
$t=2.0\text{s}$	$NO3$	$V1$	1.8866000000000E-02	1.8866871352412E-02	0.005
$t=1.1\text{s}$	$NO3$	$V7$	0.	0.	0
$t=1.4\text{s}$	$NO3$	$V7$	41.82	4.1818031454286E+01	-0.005
$t=2.0\text{s}$	$NO3$	$V7$	117.2	1.1724097649622E+02	0.035

5 Comments

This case test of NON-regression makes it possible to check the coherence of *Code_Aster* of a version on the other with regard to the metallurgy.