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

Summary:

This test illustrates a mechanical calculation with nonlinear work hardening on a material of the type Steel 16MND5 undergoing of the metallurgical transformations.

Concretely, initially, the operator CALC_META calculate the metallurgical evolution associated with a given thermal history. This metallurgical evolution is then provided to STAT_NON_LINE who will carry out a mechanical calculation by taking of account the metallurgical phases (besides mechanical loadings). The material of mechanical calculation is defined with ELAS_META_FO and META_TRACTION.

1 Problem of reference

1.1 Geometry

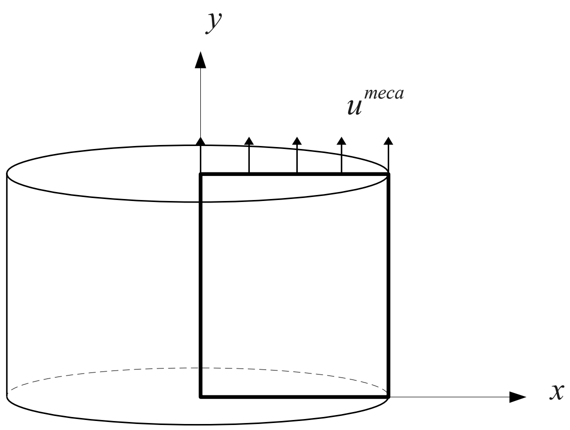


Figure 1.1-a: Geometry and loading of the problem of reference

It is about a cylinder height $H=1000\,mm$, and of ray $R=1000\,mm$.
The square in fat corresponds to the axisymmetric modeling used with the §3.

1.2 Material properties

The properties materials are described by the following parameters:

For thermo-metal calculation

- (Steel 16MND5)
- $\rho C_p = 5.26\mathrm{E}^{-3}\, J.mm^{-3.} \circ C^{-1}$
- $\lambda = 33.5\mathrm{E}^{-3}\, W.mm^{-1.} \circ C^{-1}$

Coefficients for the metallurgy:

- TRC “standard “
- $AR3 = 830\,°C$, $alpha = -0.0306$
- $MS0 = 400\,°C$, $AC1 = 724\,°C$, $AC3 = 846\,°C$
- $\tau_1 = 0.034$, $\tau_3 = 0.034$

For calculation thermo-metal-worker-mechanics

- Young modulus: $E = 200000\, MPa$
- Poisson's ratio: $\nu = 0.3$

Definition of the elastic characteristics, dilation and elastic limits for the modeling of an undergoing material of the metallurgical transformations:

- $T_{ref}=20°C$
- Thermal dilation coefficient average of the cold phases: $\alpha_f(T)=10E^{-6}$
- Thermal dilation coefficient average of the hot phase: $\alpha_\gamma(T)=10E^{-5}$
- Temperature of definition of the dilation coefficient: $T_\gamma=20°C$
- Choice of the metallurgical phase of reference: cold
- Deformation 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: $\text{F\_sigm\_f}(T)=100\,MPa$
- Elastic limit of the cold phase 2 for a plastic behavior: $\text{F\_sigm\_f}(T)=100\,MPa$
- Elastic limit of the cold phase 3 for a plastic behavior: $\text{F\_sigm\_f}(T)=100\,MPa$
- Elastic limit of the cold phase 4 for a plastic behavior: $\text{F\_sigm\_f}(T)=100\,MPa$
- Elastic limit of the hot phase for a plastic behavior: $\text{F\_sigm\_f}(T)=100\,MPa$
- Function used for the law of mixture on the elastic limit of multiphase material for a plastic behavior:

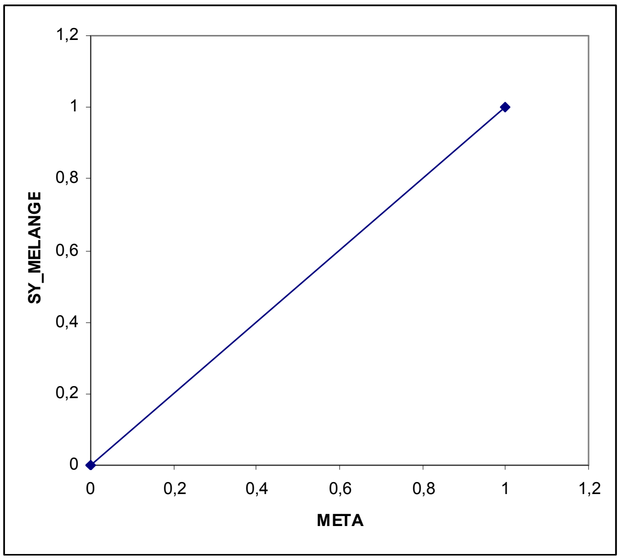


Figure 1.2-a: Law of mixture

Definition of the 5 traction diagrams used in the modeling of isotropic work hardening nonlinear of an undergoing material of the metallurgical phase shifts:

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

with $20°C$:

p	$\sigma(Mpa)$
0.99	250

With $120°C$:

p	$\sigma(MPa)$
0.0105	90
0,032	160
0,064	220
0.1125	250
0.1815	270

Isotropic curve work hardening R according to the cumulated plastic deformation p for the cold phase 2:
idem preceding

Isotropic curve work hardening R according to the cumulated plastic deformation p for the cold phase 3:
idem preceding

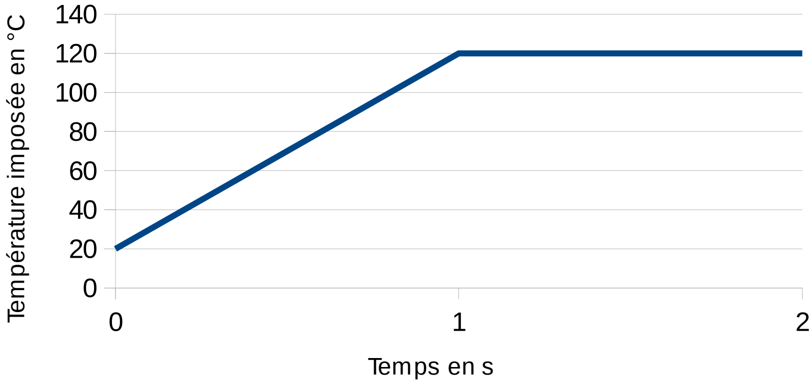
Isotropic curve work hardening R according to the cumulated plastic deformation p for the cold phase 4:
idem preceding

Isotropic curve work hardening R according to the cumulated plastic deformation 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 displacement $u^{meca}=30\,mm$ is imposed on the top of the cylinder.

The temperature is imposed on all the cylinder, such as:



1.4 Initial conditions

Initial temperature: $T(x, y, 0)=20°C$

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 not-regression.

2.2 Uncertainty on the solution compared to the result of not-regression

Uncertainty is of $1\,E^{-4}\%$.

3 Modeling A

3.1 Characteristics of modeling

Modeling $2\mathrm{D}$ axisymmetric:

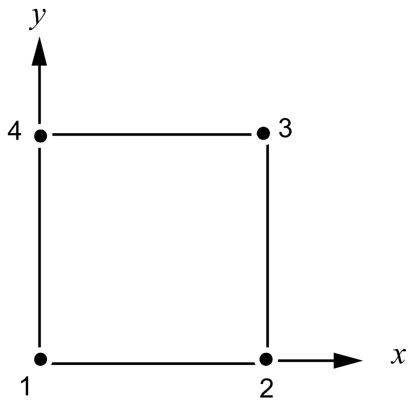


Figure 3.1-a: Geometry and grid of modeling

Boundary conditions: $Uy=0$ on $NO1$ and $NO2$
$Uy=u^{meca}=30\,mm$ on $NO3$ AND $NO4$

3.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 1 QUAD4, 1 SEG2.

3.3 Sizes tested and results

Identification		Size	Reference	Tolerance
$t=1.1\mathrm{s}$	$NO3$	$SIYY$	120.547945205	1.0E- 4%
$t=1.4\mathrm{s}$	$NO3$	$SIYY$	191.76201373	1.0E- 4%
$t=2.0\mathrm{s}$	$NO3$	$SIYY$	249.42791762	1.0E- 4%
$t=1.1\mathrm{s}$	$NO3$	DY	4.0	1.0E- 4%
$t=1.4\mathrm{s}$	$NO3$	DY	13.0	1.0E- 4%
$t=2.0\mathrm{s}$	$NO3$	DY	31.0	1.0E- 4%
$t=1.1\mathrm{s}$	$NO3$	$V1$	0.00239726027397	1.0E- 4%
$t=1.4\mathrm{s}$	$NO3$	$V1$	0.0110411899313	1.0E- 4%
$t=2.0\mathrm{s}$	$NO3$	$V1$	0.0287528604119	1.0E- 4%
$t=1.1\mathrm{s}$	$NO3$	$V7$	20.5479452055	1.0E- 4%
$t=1.4\mathrm{s}$	$NO3$	$V7$	91.76201373	1.0E- 4%
$t=2.0\mathrm{s}$	$NO3$	$V7$	149.42791762	1.0E- 4%
$t=1.1\mathrm{s}$	$NO3$	ε^{th}	0,001	1.0E- 4%
$t=1.1\mathrm{s}$	$NO3$	ε_{yy}^{meca}	0,003	1.0E- 4%
$t=1.4\mathrm{s}$	$NO3$	ε_{yy}^{meca}	0,012	1.0E- 4%
$t=2,0\,s$	$NO3$	ε_{yy}^{meca}	0.03	1.0E- 4%

$t=1.1\text{s}$	*NO3*	ε_{yy}^{plas}	0.00239726027397	1.0E- 4%
$t=1.4\text{s}$	*NO3*	ε_{yy}^{plas}	0.0110411899313	1.0E- 4%
$t=2{,}0\,s$	*NO3*	ε_{yy}^{plas}	0.0287528604119	1.0E- 4%

ε^{th} : thermal deformations - ε^{meca} : mechanical deformations - ε^{plas} : plastic deformations

4 Modeling B

4.1 Characteristics of modeling

Modeling $2D$ axisymmetric:

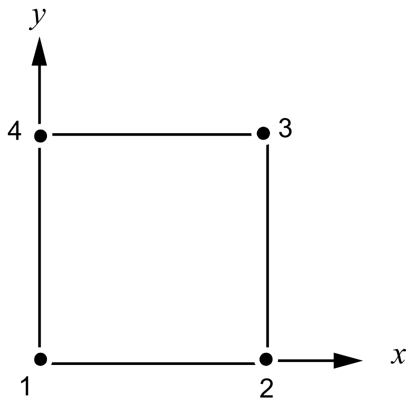


Figure 3.1-a: Geometry and grid of modeling

Boundary conditions: $Uy=0$ on $NO1$ and $NO2$
$Uy=u^{meca}=30\,mm$ on $NO3$ AND $NO4$

Modeling B is the exact equivalent one of modeling A by taking into account great deformations via the keyword `DEFORMATION=' SIMO_MIEHE'`.

4.2 Characteristics of the grid

Many nodes: 4
Many meshs and types: 1 `QUAD4`, 1 `SEG2`.

4.3 Sizes tested and results

Identification		Size	Reference	Tolerance
$t=1.1s$	$NO3$	$SIYY$	120.113910175	1.0E- 4%
$t=1.4s$	$NO3$	$SIYY$	190.879298792	1.0E- 4%
$t=2.0s$	$NO3$	$SIYY$	247.146107033	1.0E- 4%
$t=1.1s$	$NO3$	DY	3.99751358807	1.0E- 4%
$t=1.4s$	$NO3$	DY	12.9975135881	1.0E- 4%
$t=2.0s$	$NO3$	DY	30.9975135881	1.0E- 4%
$t=1.1s$	$NO3$	$V1$	0.00239196685483	1.0E- 4%
$t=1.4s$	$NO3$	$V1$	0.0109680756477	1.0E- 4%
$t=2.0s$	$NO3$	$V1$	0.0283169374338	1.0E- 4%
$t=1.1s$	$NO3$	$V7$	20.5025730414	1.0E- 4%
$t=1.4s$	$NO3$	$V7$	91.5239672252	1.0E- 4%
$t=2.0s$	$NO3$	$V7$	148.008633506	1.0E- 4%

5 Summary of the results

This case test of not-regression makes it possible to check the coherence of *Code_Aster* of a version on the other with regard to the metallurgy.