

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

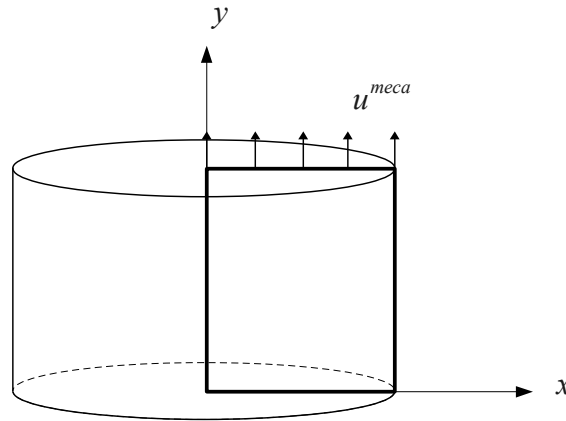


Figure 1.1-a: Geometry and loading of the problem of reference

It is about a cylinder height $H = 1000 \text{ mm}$, and of ray $R = 1000 \text{ mm}$.

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)
- $\rho C_p = 5.26E^{-3} \text{ J.mm}^{-3} \cdot \text{°C}^{-1}$
- $\lambda = 33.5E^{-3} \text{ W.mm}^{-1} \cdot \text{°C}^{-1}$

Coefficients for the metallurgy:

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

For calculation thermo-metal-worker-mechanics

- Young modulus: $E = 200000 \text{ MPa}$
- 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:

- $T_{ref} = 20^{\circ}C$
- Thermal dilation coefficient average of the cold phases: $\alpha_f(T) = 10 E^{-6}$
- Thermal dilation coefficient average of the hot phase: $\alpha_y(T) = 10 E^{-5}$
- Temperature of definition of the dilation coefficient: $T_y = 20^{\circ}C$
- 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} : $\Delta \varepsilon = 1 E^{-2}$
- Elastic limit of the cold phase 1 for a plastic behavior: $F_{sigm_f}(T) = 100 MPa$
- Elastic limit of the cold phase 2 for a plastic behavior: $F_{sigm_f}(T) = 100 MPa$
- Elastic limit of the cold phase 3 for a plastic behavior: $F_{sigm_f}(T) = 100 MPa$
- Elastic limit of the cold phase 4 for a plastic behavior: $F_{sigm_f}(T) = 100 MPa$
- Elastic limit of the hot phase for a plastic behavior: $F_{sigm_f}(T) = 100 MPa$
- Function used for the law of mixture on the elastic limit of multiphase material for a plastic behavior:

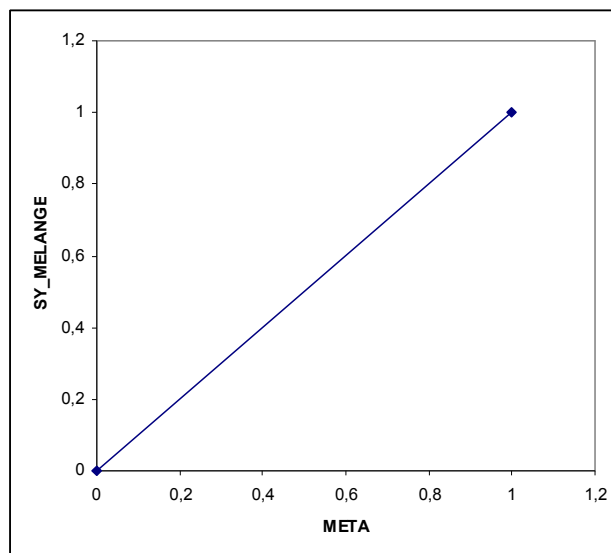


Figure 1.2-a: Law of mixture

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 $20^{\circ}C$:

p	$\sigma(Mpa)$
0.99	250

With $120^{\circ}C$:

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 $u^{mecc} = 30\text{ mm}$ is imposed on the top of the cylinder.

The temperature is imposed on all the cylinder for:

$T(x, y, t) = 120^{\circ}C$

1.4 Initial conditions

Initial temperature: $T(x, y, 0) = 20^{\circ}C$

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 $1 E^{-10}\%$.

3 Modeling A

3.1 Characteristics of modeling

Modeling 2D axisymmetric:

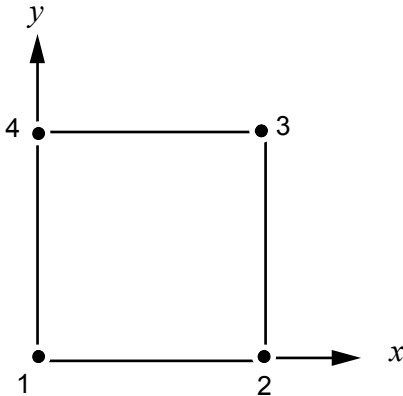


Figure 3.1-a: Geometry and grid of modeling

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

3.2 Characteristics of the grid

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

3.3 Sizes tested and results

Identification	Size	Reference	Tolerance
$t=1.1\text{ s}$ <i>NO3</i>	<i>SIYY</i>	120.547945205	1.0E-10
$t=1.4\text{ s}$ <i>NO3</i>	<i>SIYY</i>	191.76201373	1.0E-10
$t=2.0\text{ s}$ <i>NO3</i>	<i>SIYY</i>	249.42791762	1.0E-10
$t=1.1\text{ s}$ <i>NO3</i>	<i>DY</i>	4.0	1.0E-10
$t=1.4\text{ s}$ <i>NO3</i>	<i>DY</i>	13.0	1.0E-10
$t=2.0\text{ s}$ <i>NO3</i>	<i>DY</i>	31.0	1.0E-10
$t=1.1\text{ s}$ <i>NO3</i>	<i>VI</i>	0.00239726027397	1.0E-10
$t=1.4\text{ s}$ <i>NO3</i>	<i>VI</i>	0.0110411899313	1.0E-10
$t=2.0\text{ s}$ <i>NO3</i>	<i>VI</i>	0.0287528604119	1.0E-10
$t=1.1\text{ s}$ <i>NO3</i>	<i>V7</i>	20.5479452055	1.0E-10
$t=1.4\text{ s}$ <i>NO3</i>	<i>V7</i>	91.76201373	1.0E-10
$t=2.0\text{ s}$ <i>NO3</i>	<i>V7</i>	149.42791762	1.0E-10

4 Modeling B

4.1 Characteristics of modeling

Modeling 2D axisymmetric:

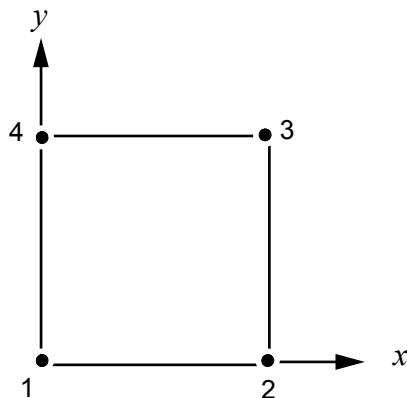


Figure 3.1-a: Geometry and grid of modeling

Boundary conditions: $U_y=0$ on *NO1* and *NO2*
 $U_y=u^{mecc}=30\text{ mm}$ 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 meshes and types: 1 QUAD4, 1 SEG2.

4.3 Sizes tested and results

Identification	Size	Reference	Tolerance
$t=1.1\text{s}$ <i>NO3</i> <i>SIYY</i>		120.113910175	1.0E-10
$t=1.4\text{s}$ <i>NO3</i> <i>SIYY</i>		190.879298792	1.0E-10
$t=2.0\text{s}$ <i>NO3</i> <i>SIYY</i>		247.146107033	1.0E-10
$t=1.1\text{s}$ <i>NO3</i> <i>DY</i>		3.99751358807	1.0E-10
$t=1.4\text{s}$ <i>NO3</i> <i>DY</i>		12.9975135881	1.0E-10
$t=2.0\text{s}$ <i>NO3</i> <i>DY</i>		30.9975135881	1.0E-10
$t=1.1\text{s}$ <i>NO3</i> <i>VI</i>		0.00239196685483	1.0E-10
$t=1.4\text{s}$ <i>NO3</i> <i>VI</i>		0.0109680756477	1.0E-10
$t=2.0\text{s}$ <i>NO3</i> <i>VI</i>		0.0283169374338	1.0E-10
$t=1.1\text{s}$ <i>NO3</i> <i>V7</i>		20.5025730414	1.0E-10
$t=1.4\text{s}$ <i>NO3</i> <i>V7</i>		91.5239672252	1.0E-10
$t=2.0\text{s}$ <i>NO3</i> <i>V7</i>		148.008633506	1.0E-10

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.