HSNV139 - Plate in traction-shearing: elastoplasticity with metallurgy

Summary:

This test of nonlinear quasi-static mechanics consists in charging in traction-shearing a square plate. It is largely inspired by tests SSNP14 [`V6.03.014`] and SSNP15 [`V6.03.015`] from guide VPCS.
The objective of this case test is the validation of two elastoplastic laws of behavior with metallurgy, in the case of a material of the type **Zircaloy** :

- the elastoplastic law of behavior of VonMises with linear kinematic work hardening,
- the elastoplastic law of behavior of Von Mises with linear isotropic work hardening, in great deformations.

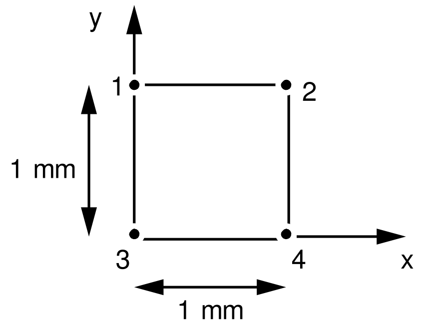
The temperature and the metallurgical state are constant. The elastoplastic behavior with metallurgy is compared to elastoplastic behavior are equivalent without metallurgy.

The plate is modelled by a voluminal element (`HEXA8`).

1 Problem of reference

1.1 Geometry

The constraints and deformations are homogeneous in the element of volume. This one can be represented by an element plan or voluminal, for example:



1.2 Material properties

The properties materials are described by the following parameters:

Thermo-metallurgical parameters:

- Zircaloy:
  - $\rho C_p = 2.0\mathrm{E}^{-3} J.mm^{-3.} \circ C^{-1}$
  - $\lambda = 9.9999 W.mm^{-1.} \circ C^{-1}$

- Coefficients for the metallurgy:
  - $teqd = 809 \circ C$, $K = 1.135 E^{-2}$, $n = 2.187$
  - $t1c = 831 \circ C$, $t2c = 0.$, $qsr = 14614$, $Ac = 1.58\mathrm{E}-4$
  - $m = 4.7$, $t1r = 949{,}1 \circ C$, $t2r = 0.$, $Ar = -5.725$, $Br = 0.05$

Parameters thermo-metal-worker-mechanics:

- Parameters thermo-metal-worker-rubber bands:
  - Young modulus: $E = 195000 MPa$
  - Poisson's ratio: $\nu = 0.3$
  - Thermal dilation coefficient average of the cold phases: $\alpha_f = 15\mathrm{E}\text{-}6$
  - Thermal dilation coefficient average of the hot phases: $\alpha_\gamma = 23\mathrm{E}\text{-}6$
  - Temperature of definition of the dilation coefficient: $T_{ref} = 600 \circ C$
  - Choice of the metallurgical phase of reference: *Froide*
  - Deformation of the phase not of reference compared to the phase of reference, with T_{ref} : $\Delta \varepsilon_{f\gamma}^{T_{ref}} = 2.52\mathrm{E}^{-3}$
  - Elastic limit of the cold phase 1: $\sigma_{y,1} = 181 MPa$
  - Elastic limit of the cold phase 2: $\sigma_{y,2} = 181 MPa$
  - Elastic limit of the hot phase: $\sigma_{y,\gamma} = 0 MPa$
  - Function of mixture (calculation of the elastic limit of multiphase material): *fonction identité*

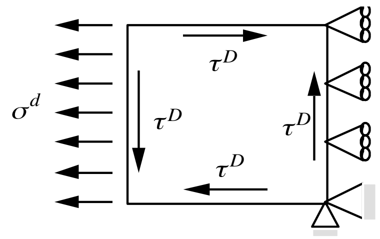
- Parameters thermo-metal-worker-plastics (law with linear work hardening)
  - Slope of the traction diagram of the cold phase 1: $E_{T,1} = 1930 MPa$

- Slope of the traction diagram of the cold phase 2: $E_{T,2}=1930\,MPa$
- Slope of the traction diagram of the hot phase: $E_{T,\gamma}=0\,MPa$

1.3 Boundary conditions and loadings

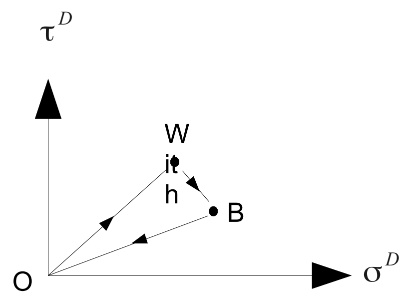
- **Modeling a:**

The element of volume is blocked according to Ox along the side $[2,4]$ while being subjected to a traction σ^D and a shearing force τ^D.



The way of loading is the following:

	σ^D [MPa]	τ^D [MPa]
A	151.2	93.1
B	257.2	33.1



Way OA of $t=0$ with $1s$.
Way AB of $t=1$ with $2s$.
Way BO of $t=2$ with $3s$.

The temperature is imposed constant and equalizes with 600°C.

- **Modeling b:**

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

2 Reference solution

2.1 Method of calculating used for the reference solution

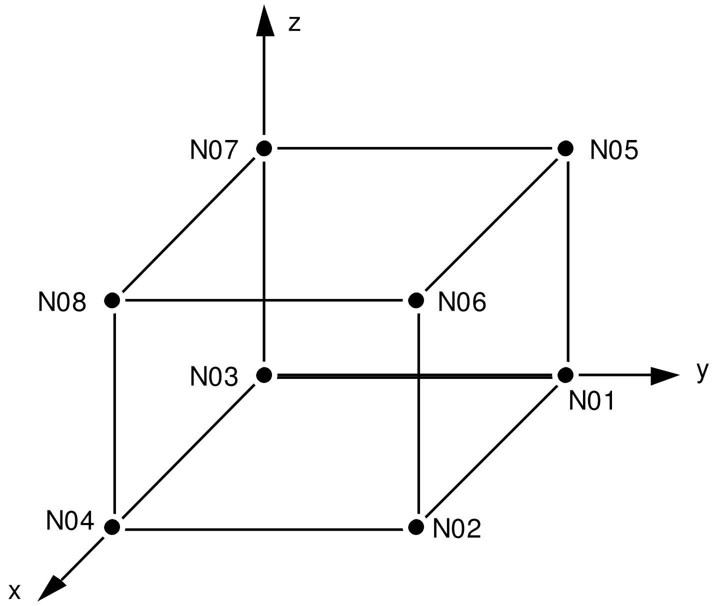
The reference solution is obtained by solving the problem of reference by considering only the mechanical behavior.

2.2 Results of reference

One will be interested in the values of the constraints σ_{xx} and σ_{xy}, and of the total deflections ε_{xx}, ε_{yy} and ε_{xy}.

3 Modeling A

3.1 Characteristics of modeling



The loading and the boundary conditions are modelled by:

On the node `N04`, `DX=DY=0`
On the node `N08`, `DX=DY=DZ=0`
On the node `N02`, `DX=0.`
On the node `N06`, `DX=0.`

One imposes a nodal force on:

`(N01 N03 N05 N07)`, $FX=-\frac{1}{4}\sigma_d(t)$, $FY=-\frac{1}{4}\tau_d(t)$

`(N03 N04 N07 N08)`, $FX=-\frac{1}{4}\tau_d(t)$

`(N02 N04 N06 N08)`, $FY=\frac{1}{4}\tau_d(t)$

`(N01 N02 N05 N06)`, $FX=\frac{1}{4}\tau_d(t)$

Mechanical calculation is carried out with the elastoplastic law of behavior of VonMises with linear kinematic work hardening (keyword `'RELATION = META_P_CL'`).

3.2 Characteristics of the grid

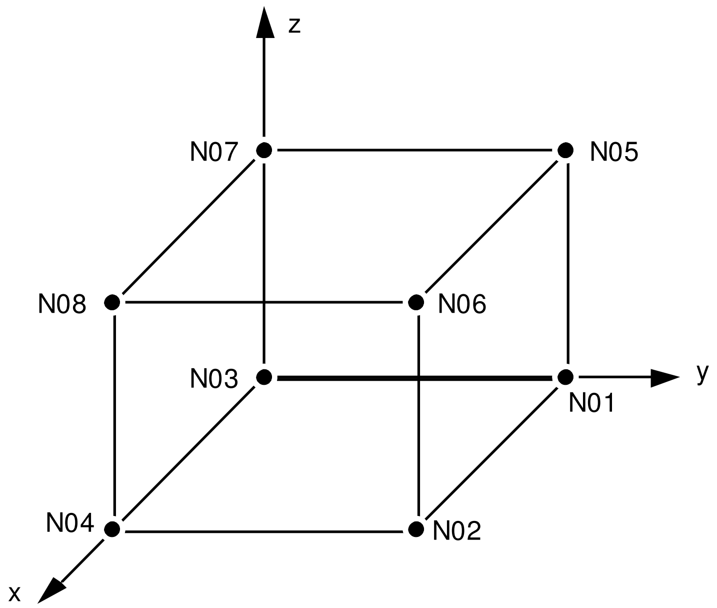
Many nodes: 8
Number of meshs and type: 1 `HEXA8, 4 QUAD4`

3.3 Sizes tested and results

Variables	Moments (s)	Type of Reference	Reference	% tolerance
σ_{xx}	1	AUTRE_ASTER	151.2	$1.E^{-8}$
σ_{xy}	1	AUTRE_ASTER	93.1	$1.E^{-8}$
ε_{xx}	1	AUTRE_ASTER	0.0148297136069	$1.E^{-8}$
ε_{yy}	1	AUTRE_ASTER	-0.00725977988037	$1.E^{-8}$
ε_{xy}	1	AUTRE_ASTER	0.0136014010824	$1.E^{-8}$
σ_{xx}	2	AUTRE_ASTER	257.2	$1.E^{-8}$
σ_{xy}	2	AUTRE_ASTER	33.1	$1.E^{-8}$
ε_{xx}	2	AUTRE_ASTER	0.0406564534069	$1.E^{-8}$
ε_{yy}	2	AUTRE_ASTER	-0.0200644318317	$1.E^{-8}$
ε_{xy}	2	AUTRE_ASTER	0.0198372954357	$1.E^{-8}$
σ_{xx}	3	AUTRE_ASTER	4.67477798665E-13	$1.E^{-8}$
σ_{xy}	3	AUTRE_ASTER	2.92922830899E-14	$1.E^{-8}$
ε_{xx}	3	AUTRE_ASTER	0.039337479048	$1.E^{-8}$
ε_{yy}	3	AUTRE_ASTER	-0.019668739524	$1.E^{-8}$
ε_{xy}	3	AUTRE_ASTER	0.019616628769	$1.E^{-8}$

4 Modeling B

4.1 Characteristics of modeling



The loading and the boundary conditions are modelled by:

On the node N04, DX=DY=0
On the node N08, DX=DY=DZ=0
On the node N02, DX=0.
On the node N06, DX=0.

One imposes a nodal force on:

(N01 N03 N05 N07), $FX=-\frac{1}{4}\sigma_d(t)$, $FY=-\frac{1}{4}\tau_d(t)$

(N03 N04 N07 N08), $FX=-\frac{1}{4}\tau_d(t)$

(N02 N04 N06 N08), $FY=\frac{1}{4}\tau_d(t)$

(N01 N02 N05 N06), $FX=\frac{1}{4}\tau_d(t)$

Mechanical calculation is carried out with the elastoplastic law of behavior of VonMises with linear isotropic work hardening (keyword 'RELATION = META_P_IL') and in great deformations (keyword 'DEFORMATION = SIMO_MIEHE')

4.2 Characteristics of the grid

Many nodes: 8
Number of meshs and type: 1 HEXA8, 4 QUAD4

4.3 Sizes tested and results

Variables	Moments (s)	Type of Reference	Reference	% tolerance
σ_{xx}	1	AUTRE_ASTER	148.56612701	$1.E^{-8}$
σ_{xy}	1	AUTRE_ASTER	94.6669933181	$1.E^{-8}$
ε_{xx}	1	AUTRE_ASTER	0.015468475646	$1.E^{-8}$
ε_{yy}	1	AUTRE_ASTER	-0.00768174092805	$1.E^{-8}$
ε_{xy}	1	AUTRE_ASTER	0.0141972994127	$1.E^{-8}$
σ_{xx}	2	AUTRE_ASTER	248.713357259	$1.E^{-8}$
σ_{xy}	2	AUTRE_ASTER	27.5330374296	$1.E^{-8}$
ε_{xx}	2	AUTRE_ASTER	0.0385022874704	$1.E^{-8}$
ε_{yy}	2	AUTRE_ASTER	-0.0195587811987	$1.E^{-8}$
ε_{xy}	2	AUTRE_ASTER	0.0210883631486	$1.E^{-8}$
σ_{xx}	3	AUTRE_ASTER	1.409651686078	$1.E^{-8}$
σ_{xy}	3	AUTRE_ASTER	0.718644752334	$1.E^{-8}$
ε_{xx}	3	AUTRE_ASTER	0.037173466674	$1.E^{-8}$
ε_{yy}	3	AUTRE_ASTER	-0.0191595912069	$1.E^{-8}$
ε_{xy}	3	AUTRE_ASTER	0.0209115907367	$1.E^{-8}$

5 Summary of the results

The results are very satisfactory: the solution calculated by taking of account the metallurgy is very close to the reference solution (purely mechanical calculation).