# HSNV123 - summarized Thermo-metal-worker-mechanics

**EDGAR:**

This test illustrates a mechanical computation 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, META_ECRO_LINE and META_VISC_FO.

This case test of NON-regression makes it possible to check the coherence of *Code_Aster* from one version to another with regard to the metallurgy.

# 1 Problem of reference

It acts of a cylindrical bar in creep.

## 1.1 Geometry

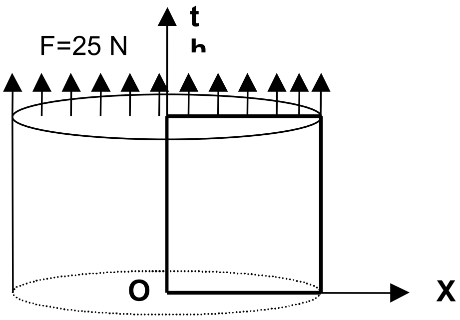



**Figure 1.1-a: Geometry and loading of the problem of reference**

It is about a cylinder height $H=1.0\,m$ , and radius $R=1.0\,m$ .
The square in fat corresponds to the axisymmetric modelization used to [§3].

## 1.2 Material properties

The materials' properties are described by the following parameters:

**For thermo-metal computation**
(Zircaloy)
$\rho C_p=2000000\,J.m^{-3.}{}^{\circ}C^{-1}$
$\lambda=9999.9\,W.m^{-1.}{}^{\circ}C^{-1}$

Coefficients for the metallurgy:
$teqd=809\,{}^{\circ}C$ $K=1.135\,E^{-2}$ $n=2.187$
$t1c=831\,{}^{\circ}C$ $t2c=0.$ $qsr=14614$ $Ac=1.58\text{E}-4$
$m=4.7$ $t1r=949{,}1\,{}^{\circ}C$ $t2e=0.$ $Ar=-5.725$ , $Br=0.05$

**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:***
- $T_{ref}=800\,{}^{\circ}C$
- Average thermal coefficient of thermal expansion of the cold phases: $\alpha_f(T)=0$
- Average thermal coefficient of thermal expansion of the hot phase: $\alpha_\gamma(T)=0$
- Temperature of definition of the coefficient of thermal expansion: $T_\gamma=800\,{}^{\circ}C$
- Choice of the metallurgical phase of reference: heat
- Strain of the phase not of reference compared to the phase of reference to the temperature $T_{ref}$ : $\Delta\varepsilon=0$
- Elastic limit of the cold phase 1 for a viscous behavior: $F_{sigm_f}(T)=0$
- Elastic limit of the cold phase 2 for a viscous behavior: $F_{sigm_f}(T)=0$

- Elastic limit of the hot phase for a viscous behavior: to see [Figure 1.2-a]

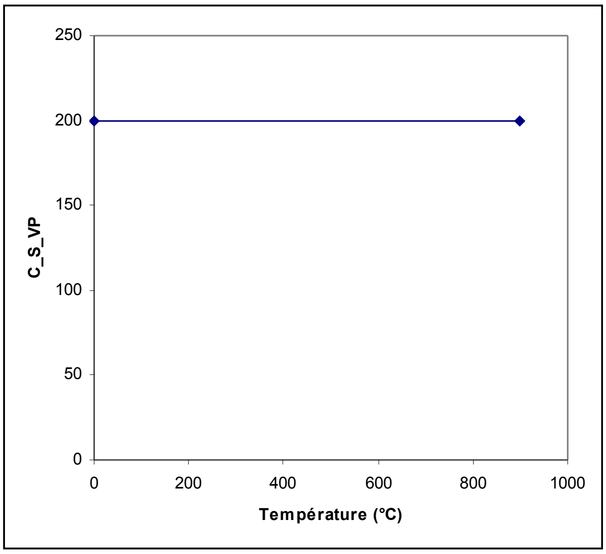
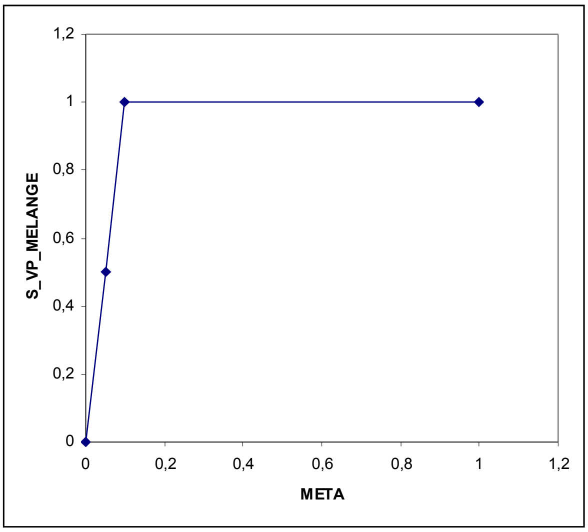



**Figure 1.2. - has: Elastic limit of the hot phase for a viscous behavior**

1) Function used for the model of mixture on the elastic limit of the multiphase material for a viscous behavior: $f$




**Appear 1.2-b: Model of Definition**

mixture of the hardening moduli used in the modelization of the phenomenon of isotropic hardening linear of an undergoing material of the metallurgical phase changes:

1) Slope of curve of tension for the cold phase 1

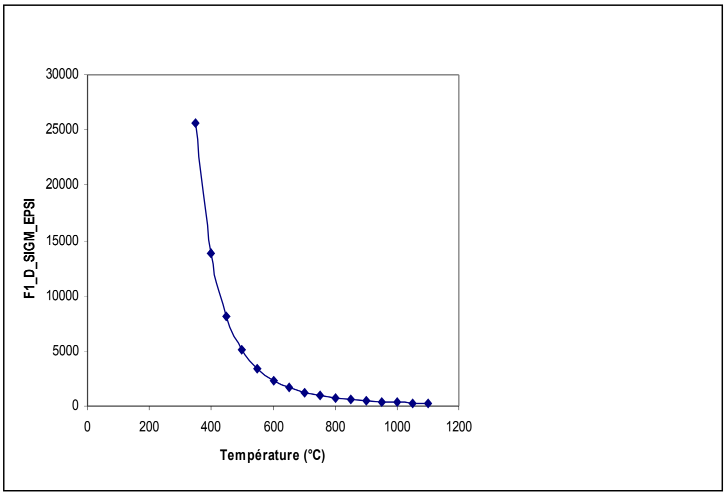



**Figure 1.2-c: Curve of tension for the cold phase 1**

- Slope of curve of tension for the cold phase 2:

$$f(T)=0$$

- Slope of curve of tension for the hot phase:

$$f(T)=0$$

***Definition of the viscous parameters of the viscoplastic constitutive law with taking into account of the metallurgy:***

1) Parameter $\eta$ viscoplastic flow model, for the cold phase 1

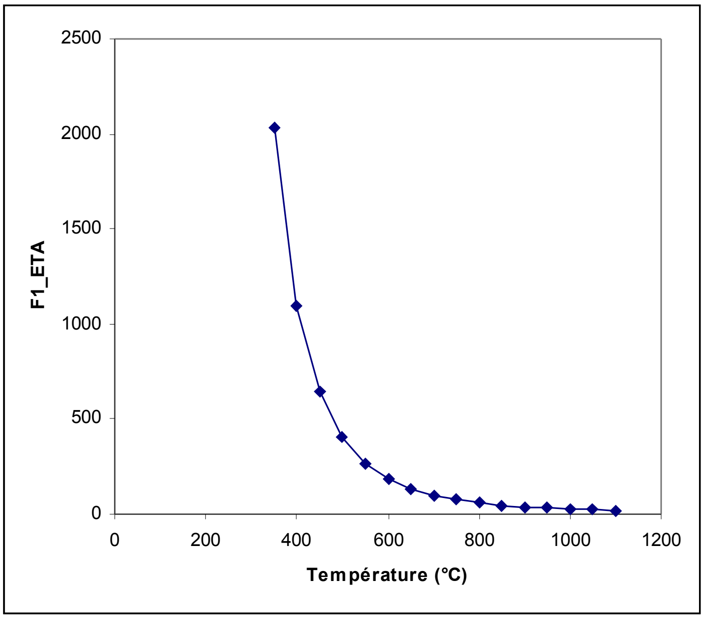



**Figure 1.2-d: Parameter $\eta$ viscoplastic flow model, for the cold phase 1**

1) Parameter $\eta$ viscoplastic flow model, for the cold phase 2

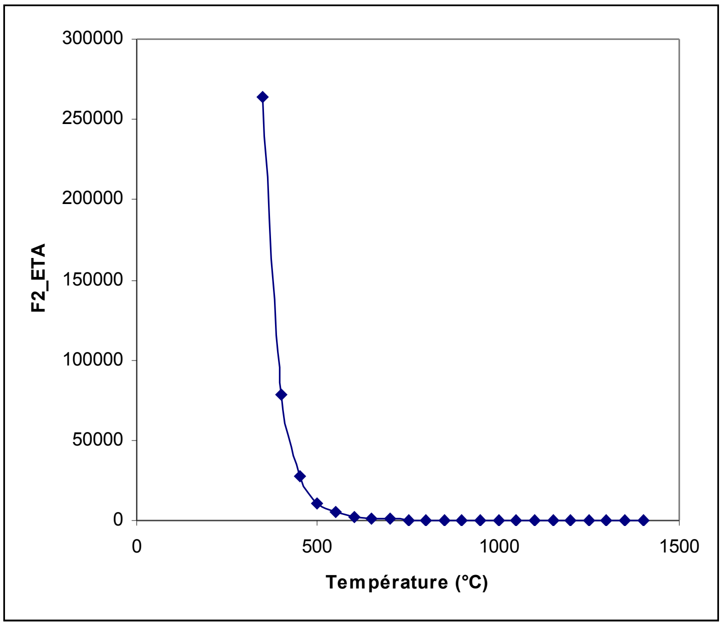



**Figure 1.2-e: Parameter $\eta$ of the viscoplastic flow model, for the cold phase 2**

- Parameter $\eta$ viscoplastic flow model, for the hot phase:
  $f(T)=0$
- Parameter $n$ of the viscoplastic flow model, for the cold phase 1:
  $f(T)=5.76$
- Parameter $n$ of the viscoplastic flow model, for the cold phase 2:
  $f(T)=2.94$
- Parameter $n$ of the viscoplastic flow model, for the hot phase:
  $f(T)=1.0$
- Parameter $C$ relating to the restoration of hardening of viscous origin, for the cold phase 1:
  $f(T)=13.70539827$
- Parameter $C$ relating to the restoration of hardening of viscous origin, for the cold phase 2:
  $f(T)=0$
- Parameter $C$ relating to the restoration of hardening of viscous origin, for the hot phase:
  $f(T)=0$
- Parameter $m$ relating to the restoration of hardening of viscous origin, for the cold phase 1:
  $f(T)=5.76$
- Parameter $m$ relating to the restoration of hardening of viscous origin, for the cold phase 2:
  $f(T)=1.0$
- Parameter $m$ relating to the restoration of hardening of viscous origin, for the hot phase:
  $f(T)=1.0$

## 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 $F=25\,N$ is imposed on the top of the cylinder

the temperature is imposed on all the cylinder for $t=120\mathrm{s}$ .

$$T(x, y, 120) = 800°C$$

## 1.4 Initial conditions

the following variables are initialized:

- $T(x, y, 0)=800°C$
- $V1(x, y, 0)=1.0$
- $V2(x, y, 0)=0.0$
- $V3(x, y, 0)=20.$
- $V4(x, y, 0)=0.$

$V1$ *: proportion of the cold phase* $\alpha$
$V2$ *: proportion of the cold phase* $\alpha$ *, mixed with the phase* $\beta$
$V3$ *: temperatures with the nodes*
$V4$ *: time corresponding to end or the initial temperature of the transformation to the equilibrium*

# 2 Reference solution

## 2.1 Results of reference

the results of reference 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 10%.

# 3 Modelization A

## 3.1 Characteristic of the modelization

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

**Eléments 2D "AXIS" (QUA8)**

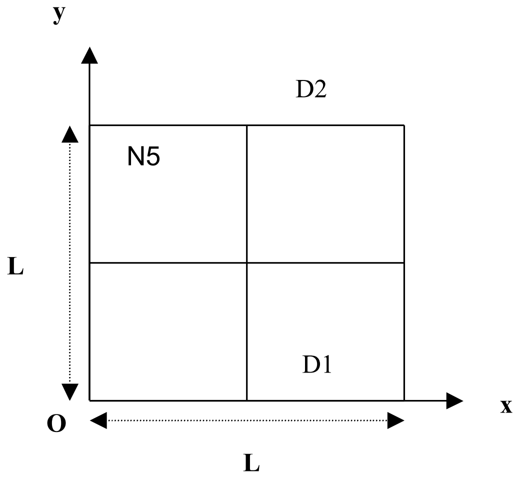



**Figure 3.1-a: Geometry and mesh of the modelization**

Cutting: 2 meshes QUAD8 according to the axis of $x$
the 2 meshes QUAD8 according to the axis of $y$

the Boundary conditions: $Uy=0$ on $D1$
$F=25\text{N}$ on $D2$

## 3.2 Characteristics of the mesh

Many nodes: 21
Number of meshes and types: 4 QUAD8, 8 SEG3.

## 3.3 Values tested

| Identification | Quantity | Reference | *Aster* | % difference |
|---|---|---|---|---|
| $t=120\text{s}$ $M3$ $N5$ | $EPYY$ | -3.1E-2 | -2.888E-2 | 6.8% |
| $t=120\text{s}$ $M3$ $N5$ | $SIYY$ | -25.0 | -24.99 | 8.90E-5% |