SSNV148 - Weibull models and Rice-Tracey in 3D and discharge

Summarized:

This test of nonlinear quasi-static mechanics makes it possible to validate the Weibull models and of Rice and Tracey in 3D for nonmonotonous cases of mechanical loadings (cf POST_ELEM).

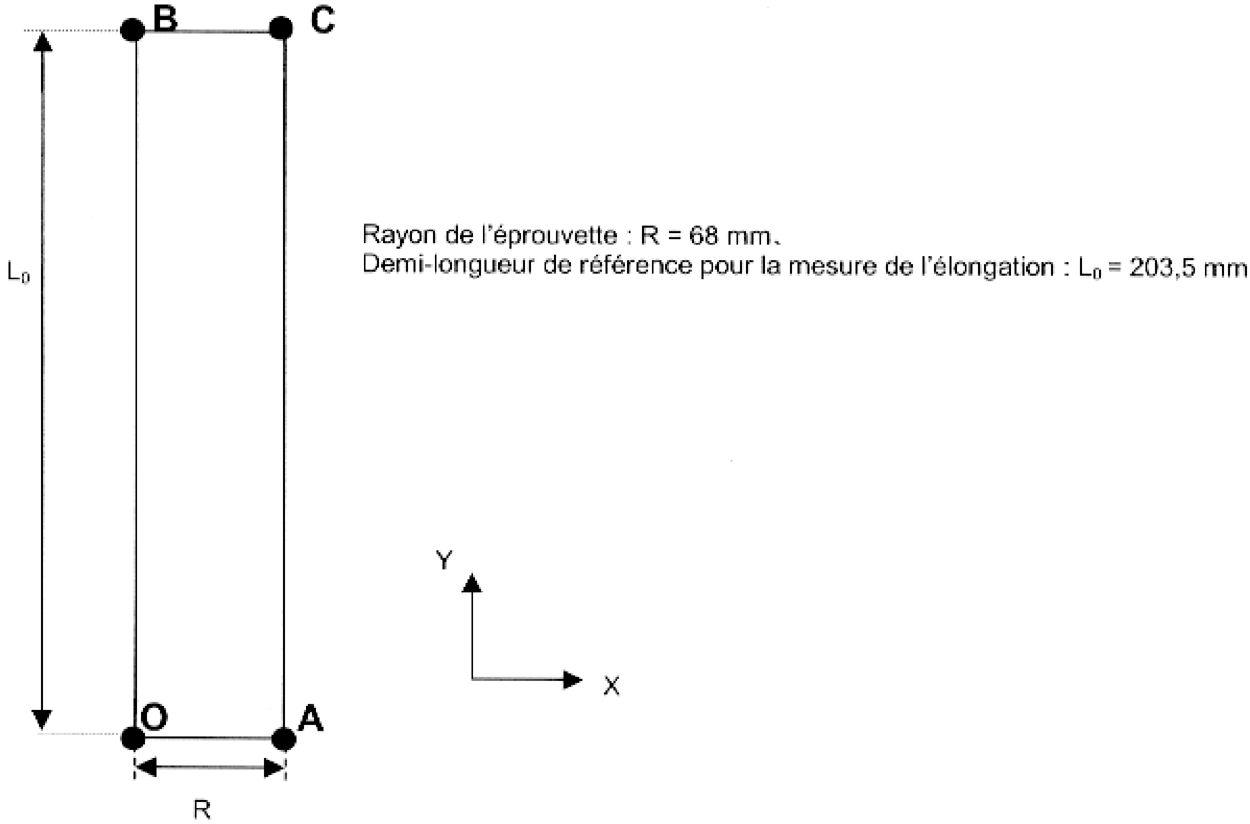
With the temperature of $-50°C$, a cylindrical test-tube smoothes is first of all deformed up to 10%. After having slightly discharged it, one maintains constant the level of strain reaches while decreasing in a homogeneous way the temperature of the test-tube until $-150°C$. A this new temperature, one applies an additional strain to reach 15% with the total. The probability of cleavage fracture as well as the growth rate of the cavities of the test-tube are calculated for the group of the way of loading.

The modelization of the test-tube is realized with elements 3D (HEXA20, PENTA15).

1 Problem of reference

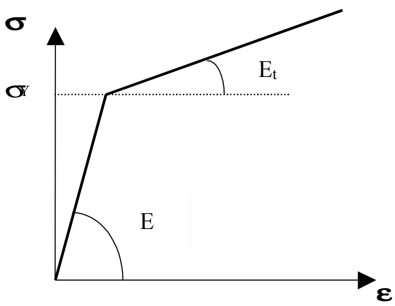
1.1 Geometry

One considers a half - cylindrical test-tube smooth.



1.2 Properties of the material

One adopts an elastoplastic constitutive law of Von Mises with linear isotropic hardening "`VMIS_ISOT_LINE`". The strains used in the behavior model are the linearized strains.



The Young modulus E , the tangent modulus E_t as well as the Poisson's ratio do not depend on the temperature. One takes: $E=200\,GPa$, $E_t=2000\,MPa$ and $\nu=0,3$.

The evolution of the elastic limit with the temperature is given in the following table:

Temperature $[°C]$	**– 150**	**– 100**	**– 50**
$\sigma_Y[MPa]$	750.700.650		

Lastly, thermal thermal expansion is neglected (thermal coefficient of thermal expansion taken equal to 0).

1.3 Boundary conditions and loadings

While referring to the figure of [§1.1] the boundary conditions are the following ones:

- on surface $SSUP$ BC ($Y=L_0$) imposed l displacement following the direction OY,
- on surface $SINF$ OA ($Y=0$) displacements blocked according to the direction OY,
- displacements of A blocked according to X and Z,
- displacements of B blocked according to Z.

The evolution temporal of the temperature (presumedly homogeneous in the test-tube) and of lengthening l are deferred in the following table:

Times $[s]$	10	20	30	40
Temperature $[°C]$	– 50	– 50	– 150	– 150
Displacement $l-L_0$ $[mm]$	20,35	20,30	20,30	32,525

1.4 Forced

Initial conditions and null strains.

2 Reference solutions

2.1 Method of calculating

In simple tension and with the assumption of the small strains, the stress tensile $\sigma(u)$ as well as the plastic multiplier $\dot{p}(u)$ at time u are given in the case considered by:

- if $0 \le u \le t_1^p$: $\sigma(u) = E\dfrac{l(u)-L_0}{L_0}\,\dot{p}(u)=0 l(t_1^p)=L_0\left(1+\dfrac{\sigma_Y(-50°C)}{E}\right)$
- if $t_1^p \le u \le 10$: $\sigma(u)=E_t\left(\dfrac{l(u)-L_0}{L_0}\right)+\dfrac{E-E_t}{E}\sigma_Y(-50°C)\,\dot{p}(u)=\left(1-\dfrac{E_t}{E}\right)\dfrac{\dot{l}(u)}{L_0}$,
- if $10 \le u \le 20$: $\sigma(u)=\sigma(u=10)-E\left(\dfrac{l(u=10)-l(u)}{L_0}\right)\dot{p}(u)=0$,
- if $20 \le u \le 30$: $\sigma(u)=\sigma(u=20)\,\dot{p}(u)=0$,
- if $30 \le u \le 40$: $\sigma(u)=\sigma(u=20)+E_t\left(\dfrac{l(u)-l(u=20)}{L_0}\right)\dot{p}(u)=\left(1-\dfrac{E_t}{E}\right)\dfrac{\dot{l}(u)}{L_0}$

2.2 Weibull

the probability of fracture cumulated P_f at time t is given by (cf `POST_ELEM`):

$$P_f(t) = 1 - \exp\left(-\sum_{dV}\left(\max_{t^p \le u \le t}\left(\frac{\sigma_I(u)}{\sigma_u(\theta(u))}\right)\right)^m \frac{dV}{V_0}\right).$$

The summation relates to the volumes of matter V_i plasticized (from time t_p), $\sigma_I(u)$ and $\theta(u)$ indicating the maximum principal stress and the temperature in each one of these volumes at various times (u) . Here, the volume V_0 of reference is equal to $50\,\mu m^3$. The modulus of Weibull m is equal to 24 while the stress of cleavage σ_u depends on the temperature according to:

Temperature $[°C]$	**– 50**	**– 100**	**– 150**
$\sigma_u[MPa]$	2800	2700	2600

the probability of cumulated fracture varies according to ($\theta(t), l(t)$) according to:

$$P_f(t) = 1 - \exp\left(-\left(\max_{t^p \le u \le t}\left(\frac{\sigma(u)}{\sigma_u(\theta(u))}\right)\right)^m \frac{V}{V_0}\right).$$

2.3 Rice and Tracey

In simple tension, the Napierian logarithm of the growth rate of the cavities at time t is given by (cf `POST_ELEM`):

$$Log\left(\frac{R(t)}{R_0}\right) = 0{,}283 \times \exp(0{,}5) \times \int_0^t \dot{p}(u)\,du$$

2.4 Quantities and results of reference

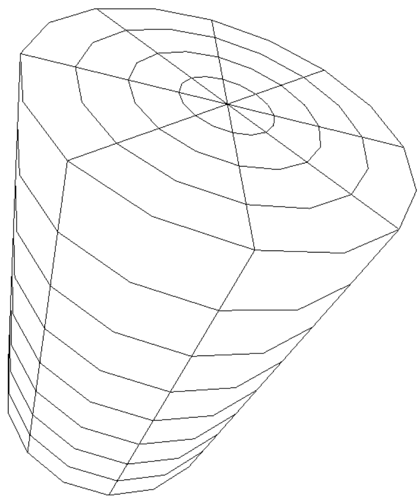
P_f and $\frac{R}{R_0}$ for the couples (temperature, displacements = $(l-l_0)$) following: $(-50{,}0\,°C, 20{,}35\,mm)$;
$(-50{,}0\,°C, 20{,}30\,mm)$; $(-150{,}0\,°C, 20{,}30\,mm)$ and $(-150{,}0\,°C, 32{,}53\,mm)$.

2.5 Uncertainties on the analytical

solution Solution.

3 Modelization A

3.1 Characteristic of the mesh



Many nodes: 1137
Number of meshes and types: 64 (PENTA15), 192 (HEXA20)

3.2 Quantities tested and results

		Reference	*Code_Aster*		Reference	*Code_Aster*	
$T[°C]$	$l-L_0[mm]$	P_f	P_f	% diff.	$\frac{R}{R_0}$	$\frac{R}{R_0}$	% diff.
– 50	20,35	0,01465	0,01481	1,1	1,0447	1,0458	0,1
– 50	20,30	0,01465	0,01481	1,1	1,0447	1,0458	0,1
– 150	20,30	0,01465	0,01481	1,1	1,0447	1,0458	0,1
– 150	32,525	1,0.1,0.0, 0			1,068	1,0701	0,2

4 Summary of the results

the results got by *Code_Aster* are very close to the analytical solutions of reference.