SSNP131 – Identification of the energy parameter Gp in 2D and in 3D

Summarized

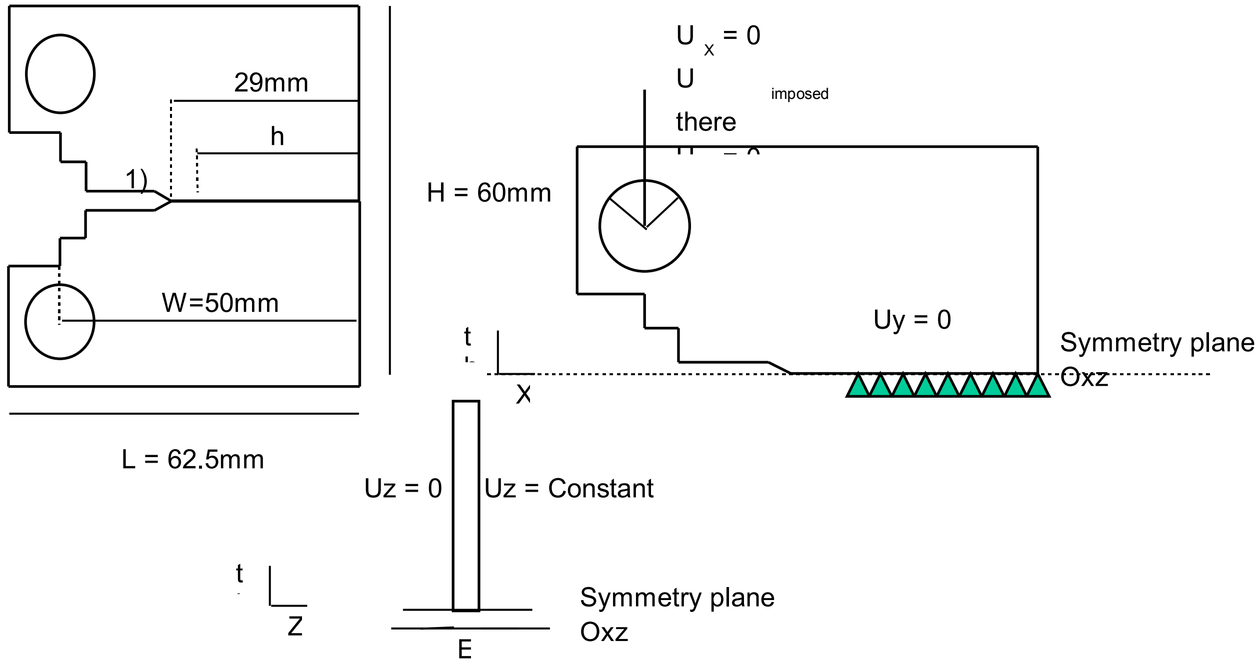
This test of nonlinear quasi-static mechanics makes it possible to present the computation of the parameter G_p resulting from the energy approach of the elastoplastic fracture and the identification of the breaking values corresponding to values of experimental tenacity given. It requires to represent crack by a notch and to finely net the vicinity of the bottom of notch. It also requires to calculate elastic strain energy on the zone of virtual propagation of the notch, cut out in “chips”.

The modelization A is realized with quadratic $2D$ elements, in plane strain. The mesh represents the zones known as chips; the computation of the parameter is carried out by means of the properties of the mesh (CALC_GP) or by automatic creation of these zones (CALC_GP).

The modelization B is identical to the modelization A, but uses an unspecified mesh; only the automatic definition of the chips is used (CALC_GP)

1 Problem of reference

1.1 Geometry



One considers a test-tube $CT25$ with a length of ligament: $a=27.5\,mm$ ($a/W=0.55$). Along the axis z, the thickness is $e=1\,mm$. The test-tube $CT25$ is modelled first of all in plane strains, then in $3D$. By reason of symmetry, half of this one is represented in $2D$ and a quarter in $3D$.

1.2 Material properties

Modulus Young: $214100\,Mpa$
Poisson's ratio: $\nu=0.3$. Curve of tension used is presented in the following table:

ϵ	$\sigma(\mathrm{MPa})$
0.003439678	740.6632663
0.004628373	842.148772
0.00607988	876.3117064
0.007654628	895.2063119
0.010417548	911.0718694
0.014178015	925.022448
0.017543214	935.2135771
0.021942493	945.6948965
0.027416704	960.732311
0.033866984	975.8041996
0.040205805	988.2450325
0.046616375	1000.143035
0.052903597	1010.004051
0.058235889	1017.5664

Table 1.1

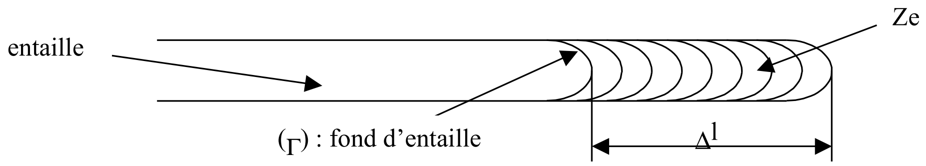
1.3 Boundary conditions and loadings

In $2\mathrm{D}$, the loading is of standard displacement imposed in a point located at the center of the pin which is modelled by four indeformable angular sectors. Half of the test-tube being modelled, a condition of symmetry is applied to the ligament ($y=0$).
In $3\mathrm{D}$, the loading is of standard displacement imposed on the segments located on the axis of the pin which is modelled by four indeformable angular sectors. The quarter of the test-tube being modelled, a condition of symmetry is applied to the face corresponding to the ligament ($y=0$), and another on the face $z=0$.

2 Reference solution

2.1 Méthode de calcul used for the reference solution in 2D

One uses the energy method of the elastoplastic fracture based on the parameter Gp [1], [2].
The bottom of notch is made of a half-circle of radius R. The zone Ze length Δl corresponds to the virtual propagation of the notch and is cut out in "chips".



One at every moment determines there the evolution of the quantity $Gp(\Delta l)$ defined by:

$$Gp(\Delta l)=2[W_{elas}(\Delta l)]/\Delta l$$

where $W_{elas}(\Delta l)$ is the elastic strain energy calculated on the zone Ze. One must then calculate the maximum of this quantity compared to Δl, which one calls " Gp ".

$$Gp=\underset{\Delta l}{Max}\{Gp(\Delta l)\}$$

The time criticizes where the propagation of the default will start is then that where tenacity $Kj=Kj_{crit}$. It is said whereas Gp reached the breaking value " Gpc ".

2.2 Méthode de calcul used for the reference solution in 3D

the bottom of notch is rectilinear. The front corresponding is described by slices. Each slice consists of chips. This zone corresponds to the virtual propagation of the notch.

One at every moment determines in each chip the evolution of the quantity $Gp(\Delta S)$ defined by:

$$Gp(\Delta S)=2[W_{elas}(\Delta S)]/\Delta S$$

where $W_{elas}(\Delta S)$ is the elastic strain energy calculated on the zone cumulated of chip according to a slice and ΔS is the surface of the chips cumulated of the bottom of notch to the chip concerned. Then one calculates on each slice the maximum of this quantity called " Gp " compared to ΔS.

$$(Gp)_{tranche\,i}=\underset{\Delta S}{Max}\{Gp(\Delta S)\}$$

A each chip, is associated a distance ΔL which corresponds to the interior distance from the chip at the bottom of notch.

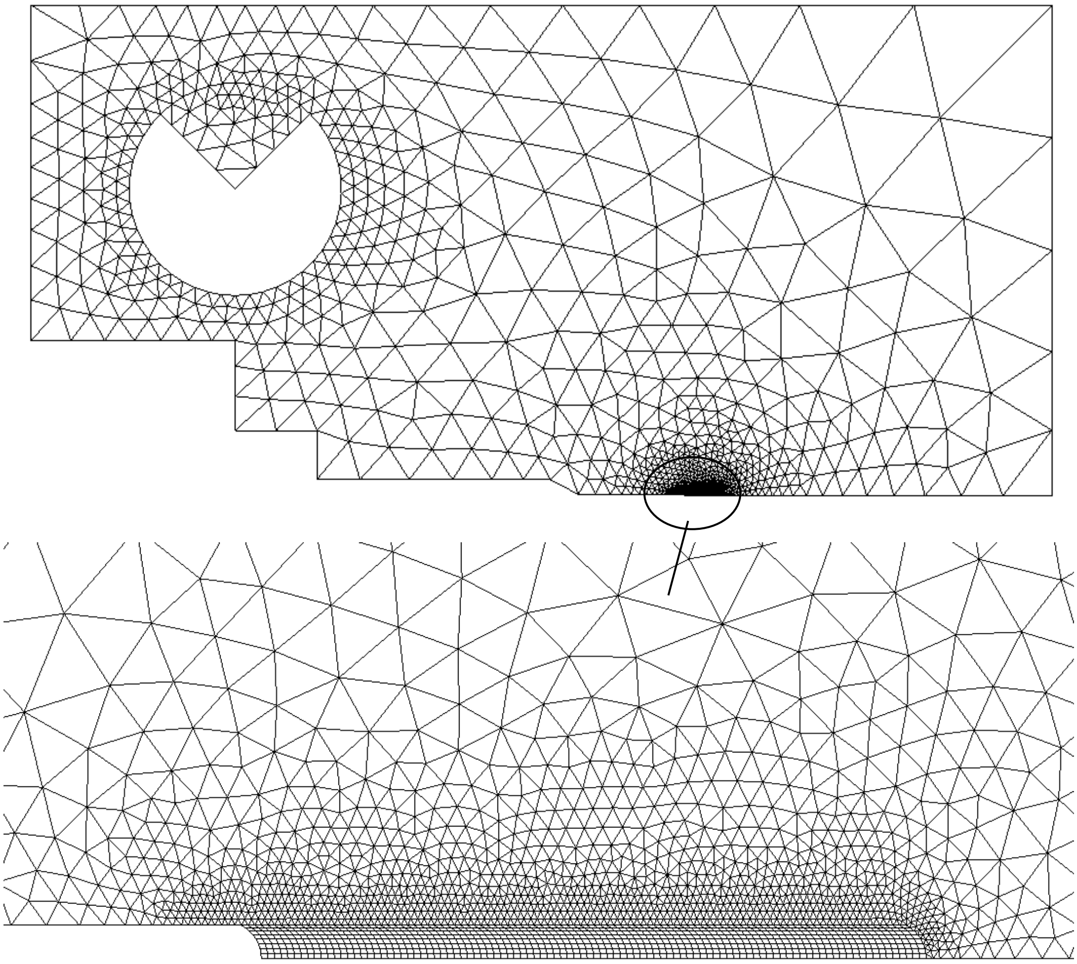
2.3 Bibliographical references

1) WADIER Y.: "Brief Presentation of the energy approach of the elastoplastic fracture applied to the cleavage fracture", EDF Notes R & D HT-64/03/001/A, January 2003.

2) WADIER Y., LORENTZ E.: "Fracture mechanics in the presence of plasticity: modelization of crack by a notch". C.R.A.S.T. 332, IIb series, 2004. Modelization

3 A Characteristic

3.1 of the modelization the crack



is modelled by a notch of radius 100 microns. The zone Ze length $2\,mm$ is divided into layers of 20 microns thickness elements (also called "chips"). Characteristics

3.2 of the mesh Many

nodes: 9368 Number of meshes

and types: 3350 SORTED 6,800 QUADS 8 Quantities

3.3 tested and Values results

3.3.1 tested With

the operator CALC `_GP and definition` of the chips by mesh: Identification

Reference	*Aster Tolerance*	*(%) to*
G_P time 4 with the chip 8 0.023662413	0.010	at
G_P time 40 with the chip 3 0.727738207	0.010	With

the operator CALC `_GP and automatic` definition of the chips Identification

Reference	*Aster Tolerance*	*(%) to*
G_P time 4 with the chip 8 0.0234148559	0.010	at
G_P time 40 with chip 3 0.674949376	0.010	Remark

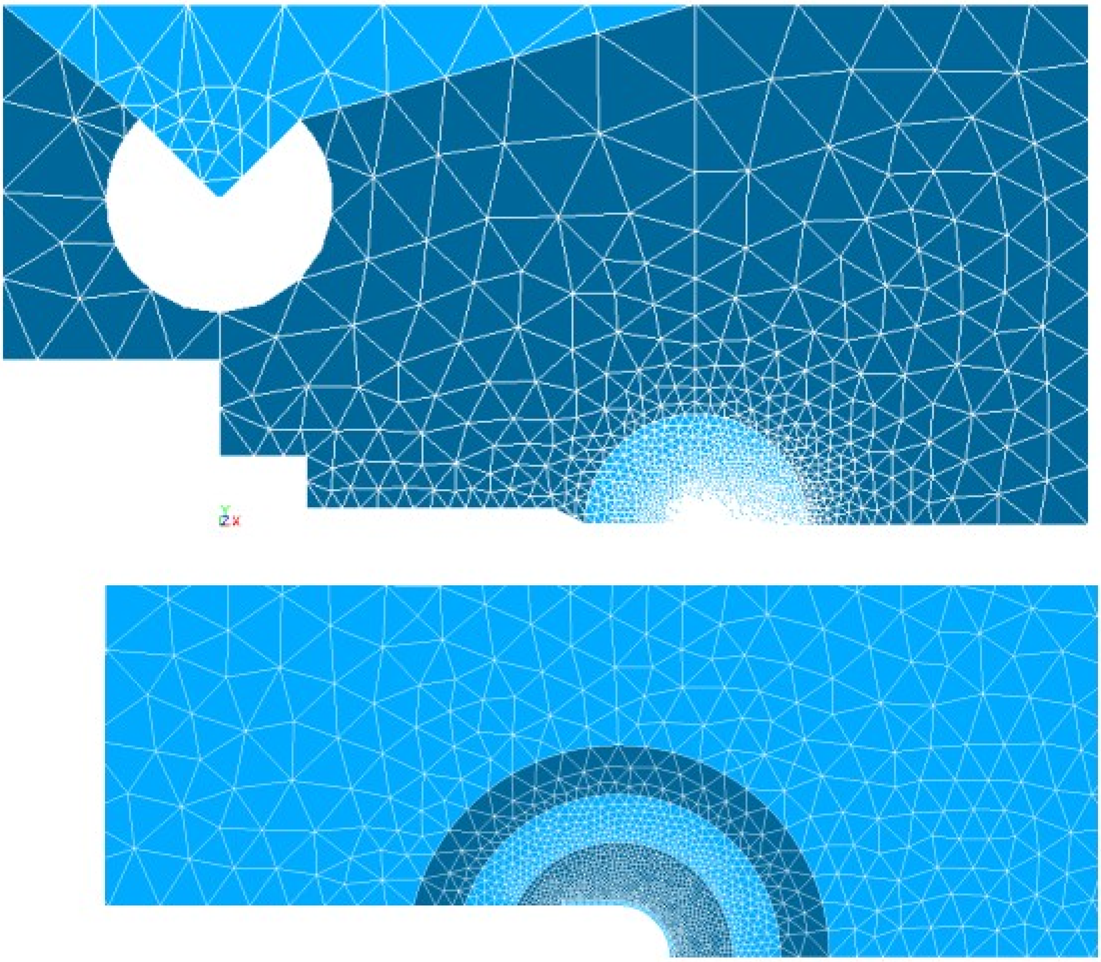
3.3.2

the results observed to make sure of the NON-regression of the code are the breaking values of the energy parameter corresponding to the values of following critical tenacities: ; ; $Kjc_1=27{,}2\ MPa\sqrt{m}$. $Kjc_2=34\,MPa\sqrt{m}$ A $Kjc_3=40\,MPa\sqrt{m}$ these

values correspond of the critical loadings identified by calculating the quantity by G the method Theta which is connected to tenacity via the formula D" Irwin: . $G=\frac{1-\nu^2}{E}K^2$ Contours chosen for the field Theta are: $[0.25\,mm\,;0.5\,mm]$ $[0.5\,mm\,;1.0\,mm]$ $[1.0\,mm\,;2.0\,mm]$. $[2.0\,mm\,;5.0\,mm]$ A $[5.0\,mm\,;10.0\,mm]$ these critical loadings correspond the breaking values of the parameter whose Gp values are tested with the §3.3.1. Modelization

4 B Characteristic

4.1 of the modelization Figure



4.1 4.1 of the modelization B. the crack

is modelled by a notch of radius 100 microns. Characteristics

4.2 of the mesh Many

nodes: 11514 Number of meshes

and types: 4296 SORTED `6,886` QUADS `8 Quantities`

4.3 tested and results With

the operator CALC `_GP and automatic` definition of the chips by mesh: Identification

Reference	*Aster Tolerance*	*(%) to*

G_P time 4 with the chip 8 0.02443105	0.010	at
G_P time 40 with the chip the 3 0.740216439	0.010	

differences noticed between the various possibilities of computation, although rather weak, are due to the geometry different from the zones of computation and with the singularity created by means of the geometry of the mesh of modelization A. For more details, the competent people will be able to consult the CR-AMA.12-272. Summary

5 of the results In

both cases (and $2D$), $3D$ the tests are validated with a lower deviation than 2nd-04%. One notes
moreover one great coherence of the results and $2D$. $3D$