SSNP110 - Crack of edge in a rectangular plate finished in elastoplasticity

Summary:

This test is a CAS-test in nonlinear breaking process.

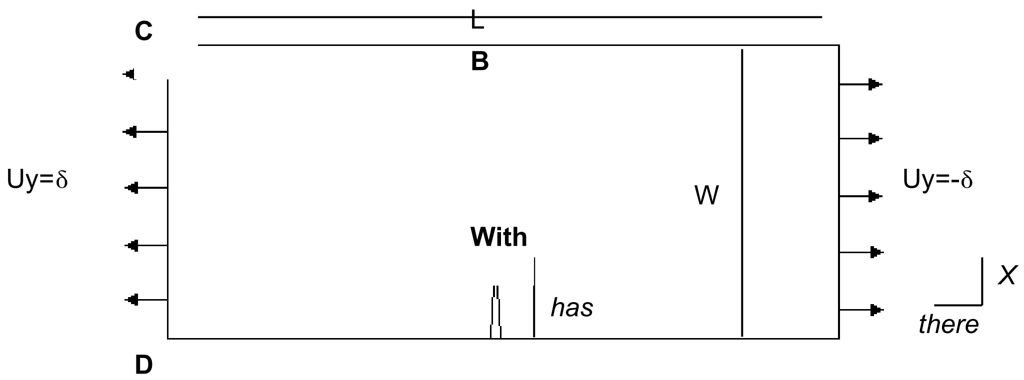
One considers a rectangular plate finished, fissured and subjected to a loading of traction. The law of behavior used is an elastoplastic law of Von Mises.

This CAS-test understands five modelings in 2D:

- modelings A and B, in plane constraints, aim at studying the influence of the taking into account or not of the terms of second order of the deformations (DEFORMATION = 'PETIT' or 'GROT_GDEP' in the operator STAT_NON_LINE) on the calculation of the rate of refund of energy G ;
- modelings C and D, in plane constraints, aim at testing method X-FEM (crack nonwith a grid) in nonlinear elasticity and elastoplasticity for calculation of the field of displacement;
- modeling E, in plane deformations, validates the calculation of G for the various methods of definition of the curve of work hardening.

1 Problem of reference

1.1 Geometry



Length	$L=50\,mm$
Width	$W=16\,mm$
Depth of crack	$a=6\,mm$

1.2 Properties of material

The material is elastoplastic of type Von Mises. For modelings A with D, there is no work hardening. For modeling E, various laws of work hardening are compared (linear work hardening or power). The properties of material are the following ones:

Young modulus	$E=2{,}0601\,10^5\,MPa$
Poisson's ratio	$\nu=0.3$
Yield stress	$\sigma_y=808{,}34\,MPa$
Module of work hardening	$H=0$ (modeling A with D) or $H=6{,}867\ \ 10^4\,MPa$ (modeling E)

1.3 Boundary conditions and loading

For modelings A, B and E, the model is limited to half of the structure, the plan of the vertical crack being a symmetry plane. For modelings C and D, the totality of the structure is represented.

Boundary conditions

Vertical displacement $UX=0$ at the point B

Horizontal displacement $UY=0$ in the ligament AB (condition of symmetry for modelings A, B and E)

Loading

Horizontal displacement imposed on the segment CD : $UY=\delta$

2 Reference solution

Pas de reference solution. This is a test of not-regression.

3 Modeling A

3.1 Characteristics of modeling

It is about a calculation in elastoplasticity under the assumption of small displacements, in plane constraints.

3.2 Characteristics of the grid

Grid, built with an automatic procedure gibi, consists of 400 quadratic elements (1000 nodes). Tori are defined in bottom of crack in order to improve the precision of calculation in breaking process, cf [Figure 3.2-a] below. The ray of the largest torus is of $1{,}5\ mm$.

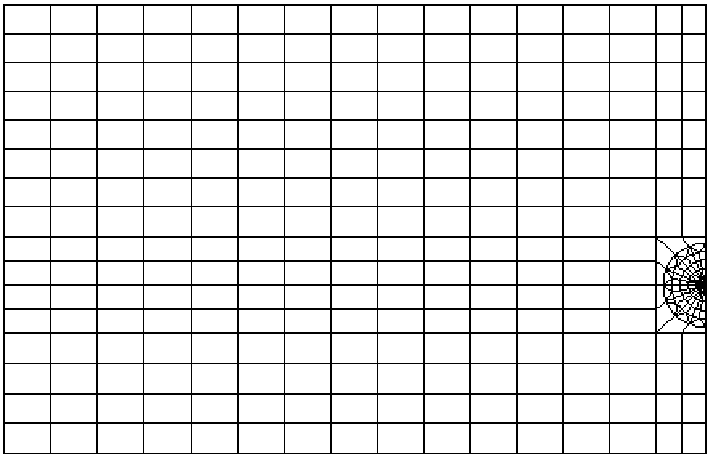


Figure 3.2-a: Grid of the fissured rectangular plate

3.3 Features tested

Calculation of the rate of refund of energy by the method $G-\theta$ in elastoplasticity.

3.4 Sizes tested and results

The values of the rate of refund are tested for five values of imposed horizontal displacement δ . One compares the results got for three different crowns of integration:

- crown 1: $R_{inf}=0{,}15\ mm$; $R_{\sup}=0{,}6\ mm$
- crown 2: $R_{inf}=0{,}3\ mm$; $R_{\sup}=0{,}9\ mm$
- crown 3: $R_{inf}=0{,}9\ mm$; $R_{\sup}=1{,}5\ mm$

Imposed displacement δ **(** mm **)**	$G(N/mm)$ **crown 1**	$G(N/mm)$ **crown 2**	$G(N/mm)$ **crown 3**
0.02	3.29	3.20	3.20
0.04	13.60	13.24	13.24
0.06	31.97	31.22	31.24
0.08	58.99	57.74	57.76

0.1	91.42	89.64	89.71

The results are satisfactory: the maximum variation enters the values of G obtained on the three crowns of integration is lower than 2%.

4 Modeling B

4.1 Characteristics of modeling

It is about a calculation in elastoplasticity under the assumption of great displacements, in plane constraints.

The objective of this CAS-test is to examine the influence of the taking into account of great deformation in mechanical calculation on the parameters of mechanics rupture.

4.2 Characteristics of the grid

The grid is identical to that of modeling A.

4.3 Features tested

Calculation of the rate of refund of energy by the method $G-\theta$ in elastoplasticity.

4.4 Sizes tested and results

The values of the rate of refund are tested for the same crowns of integration as in modeling A.

Imposed displacement δ **(** mm **)**	$G(N/mm)$ **crown 1**	$G(N/mm)$ **crown 2**	$G(N/mm)$ **crown 3**
0.02	3.26	3.17	3.18
0.04	13.36	13.03	13.07
0.06	31.02	30.50	30.67
0.08	56.33	55.90	56.51
0.1	85.84	85.91	87.47

The results are satisfactory: the maximum variation enters the values of G obtained on the three crowns of integration is lower than 2%.

The effect of the terms of second order in the deformation is relatively weak: the difference between the results of two modelings is increasing with imposed displacement δ and is worth to the maximum 6%, cf [Figure 4.4-a].

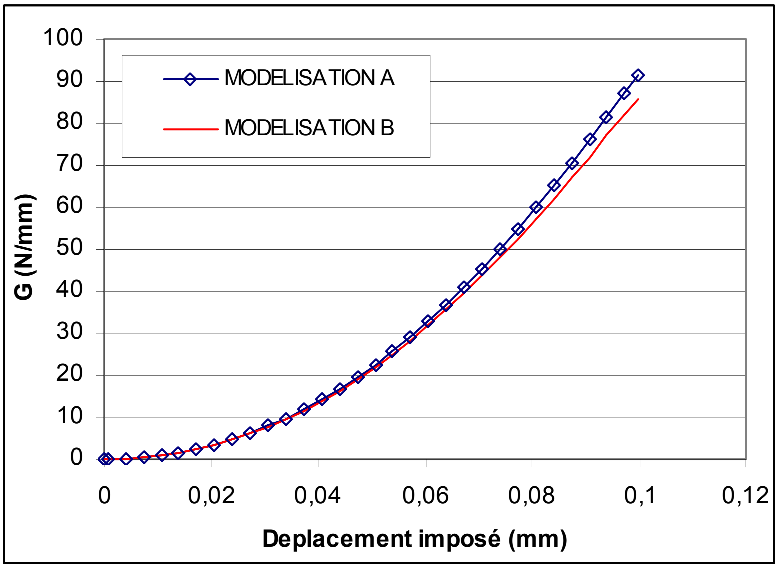


Figure 4.4-a: Comparison of the rates of refund of energy of two modelings

5 Modeling C

5.1 Characteristics of modeling

It is about a calculation in nonlinear elasticity under the assumption of small displacements, with method X-FEM (crack nonwith a grid). Modeling is in plane constraints.

5.2 Characteristics of the grid

The grid is composed of linear elements (560 meshs QUA6 - 600 nodes). The refinement of the grid is uniform (18 elements according to x and 31 elements according to y).

5.3 Features tested

Calculation of displacement for a model X-FEM in nonlinear elasticity.

5.4 Sizes tested and results

Several types of sizes are tested: indicator of radiality of the loading, displacements, and rate of refund of energy.

5.4.1 Indicator of radiality of the loading

The maximum of component is tested DCHA_V field DERA_ELGA on all the points of Gauss. It is a test of regression.

Identification	Type of reference	Value of reference	Tolerance
MAX (DCHA_V)	'NON-REGRESSION'	0,58	10^{-6}%

5.4.2 Displacements

The component is tested DY displacement at the two points where the crack emerges (points of each lip), at the last moment of calculation (imposed displacement $0,1\,mm$). This test is carried out on the field of displacement created by the operator POST_CHAM_XFEM.
The value of reference is the solution obtained in modeling A.

Identification	Type of reference	Value of reference	Tolerance
Lip $y>0$	'AUTRE_ASTER'	$9.876\ 10^{-2}$	2,00%
Lip $y<0$	'AUTRE_ASTER'	$-9.876\ 10^{-2}$	2,00%

5.4.3 Rate of refund of energy

One tests the calculation of the rate of refund of energy G with 2 different crowns:

- crown n°1 enters h and $4h$,
- crown n°2 enters $2h$ and $6h$

where h is the size of an element.

Identification	Type of reference	Value of reference	Tolerance
Crown n°1: G with t=0,02	'AUTRE_ASTER'	3.29	4,00%

Crown n°1: G with t=0,04	'AUTRE_ASTER'	13.60	4,00%
Crown n°1: G with t=0,06	'AUTRE_ASTER'	31.97	4,00%
Crown n°1: G with t=0,08	'AUTRE_ASTER'	58,99	4,00%
Crown n°1: G with t=0,10	'AUTRE_ASTER'	91,42	4,00%
Crown n°2: G with t=0,02	'AUTRE_ASTER'	3.29	4,00%
Crown n°2: G with t=0,04	'AUTRE_ASTER'	13.60	4,00%
Crown n°2: G with t=0,06	'AUTRE_ASTER'	31.97	4,00%
Crown n°2: G with t=0,08	'AUTRE_ASTER'	58,99	4,00%
Crown n°2: G with t=0,10	'AUTRE_ASTER'	91,42	4,00%

6 Modeling D

6.1 Characteristics of modeling

It is about a calculation in elastoplasticity under the assumption of small displacements, with method X-FEM (crack nonwith a grid). One represents the opening of the crack and his closing by activating the contact on the lips.

Compared to modeling C one replaces non-linear elasticity by elastoplasticity. Until the moment $0{,}1$ the loading is monotonous and the results are thus identical between modelings C and D. In modeling D, one carries out then a discharge and one applies an opposed loading, thus activating the contact to the lips of the crack.

6.2 Characteristics of the grid

The grid is identical to that of modeling C.

6.3 Features tested

Calculation of displacement for a model X-FEM in elastoplasticity.

6.4 Sizes tested and results

Two sizes are tested:

- the component DY displacement at the two points where the crack emerges (points of each lip), at moment 0.1 of calculation (imposed displacement $0{,}1\,mm$) and at the last moment $0{,}3$ (imposed displacement $-0{,}1\,mm$);
- values of the effective plastic deformation ($V1$) on the mesh $M277$, in item 10 and at the moments $0{,}1$, $0{,}14$ and $0{,}3$.

For the moment $0{,}1$, the value of reference of displacement is the solution obtained in modeling A. For the rest, the tests are of not-regression.

Displacement	**Reference (mm)**	**Code_Aster (mm)**	**Difference**
Lip $y>0$, $t=0.1$	9,876.10 $^{-2}$	9,532.10 $^{-2}$	-3,5%
Lip $y<0$, $t=0.1$	-9,876.10 $^{-2}$	-9,533.10 $^{-2}$	-3,5%
Lip $y>0$, $t=0.3$	1,782.10 $^{-2}$	*Not-regression*	
Lip $y<0$, $t=0.3$	-1,782.10 $^{-2}$	*Not-regression*	
Effective plastic deformation ($V1$ on $M277$)			
$t=0.1$	1.270.10 $^{-2}$	*Not-regression*	
$t=0.14$	1.270.10 $^{-2}$	*Not-regression*	
$t=0.3$	2.451.10 $^{-2}$	*Not-regression*	

This test validates calculation in elastoplasticity for models X-FEM.

7 Modeling E

7.1 Characteristics of modeling

It is about a calculation in nonlinear elasticity under the assumption of small displacements, in plane deformations.

7.2 Characteristics of the grid

The grid is identical to that of modeling A.

7.3 Features tested

Calculation of the rate of refund of energy by the method THETA in nonlinear elasticity. One compares the three methods to define work hardening: `TRACTION`, `ECRO_LINE` and `ECRO_PUIS`.

7.4 Sizes tested and results

The size tested is the rate of refund G, calculated for the first crown of integration defined in modeling A and for ten values of imposed horizontal displacement δ. (δ varying 0 with $0{,}2\,mm$).

Two series distinct from calculations are carried out:
initially, one takes a law of behaviour to linear work hardening. Three calculations are carried out with the various methods available to define the same curve of work hardening (`TRACTION`, `ECRO_LINE` and `ECRO_PUIS`). One compares between them the solutions obtained by these three calculations;
then one chooses a law of behaviour with work hardening in law power and one compares the got results enters `ELAS_VMIS_TRAC` and `ELAS_VMIS_PUIS`.

The test is of standard not-regression. It is checked that:
three various calculations in linear work hardening lead exactly to the same result on G ;
two calculations in work hardening in law power lead to very close results (lower deviation than 0,3%). The variation decreases if the step of time of calculation is decreased.

Imposed displacement δ (mm)	$G(N/mm)$ - linear work hardening: `ELAS_VMIS_TRAC`	$G(N/mm)$ - linear work hardening: `ELAS_VMIS_LINE`	$G(N/mm)$ - linear work hardening: `ELAS_VMIS_PUIS`
0.02	3.59	3.59	3.59
0.04	14.47	14.47	14.47
0.06	32.88	32.88	32.88
0.08	59.42	59.42	59.42
0.10	94.50	94.50	94.50
0.12	134.98	134.98	134.98
0.14	178.95	178.95	178.95
0.16	226.24	226.24	226.24
0.18	276.47	276.47	276.47
0.20	329.61	329.61	329.61

Imposed displacement δ (mm)	$G(N/mm)$ - work hardening power: `ELAS_VMIS_TRAC`	$G(N/mm)$ - work hardening power: `ELAS_VMIS_PUIS`
0.02	3.59	3.59
0.04	14.44	14.44
0.06	32.76	32.76
0.08	58.99	58.98
0.10	93.76	93.77
0.12	136.14	136.18
0.14	184.04	184.09
0.16	236.31	236.38
0.18	292.38	292.46
0.20	351.82	351.90

This test validates the calculation of G in linear elasticity for the various methods of definition of the curve of work hardening.

8 Summary of the results

This case test aims at validating the calculation of the rate of refund of the constraints in elastoplasticity:

- modelings A and B make it possible to make sure of the invariance of the calculation of the rate of refund of energy by the method theta according to the crowns of integration for laws of perfectly plastic behavior of the elastic type -. One also notes the weak contribution of the terms of second order in the deformation;
- modeling E validates the various methods of definition of the curve of work hardening.

Modelings C and D make it possible to validate the calculation of the field of displacement for models X-FEM.