SSLP115 - Calculation of the rate of refund of energy of a disc fissured in the presence of initial constraints

Summary

This test makes it possible to validate the calculation of the rate of refund of energy by the method theta in the presence of a state of initial constraints.

Modeling a: UN embedded and fissured disc is subjected to one initial stress field opening the crack. This initial stress field is identical to that generated by a heat gradient. The solution is identical to that obtained in the case of the thermal loading only, validating the taking into account of an initial state of stresses.
Modeling b: it is similar to modeling A with a crack not-with a grid (X-FEM).
Modeling C : it is similar to modeling A. The coefficients materials are defined by constant functions of the temperature.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

1 Problem of reference

1.1 Geometry

A disc of ray is considered 100mm, embedded on its edges, and containing a horizontal crack of 23mm one of the points is in the center of the disc. Figure 1.1 present this geometry.

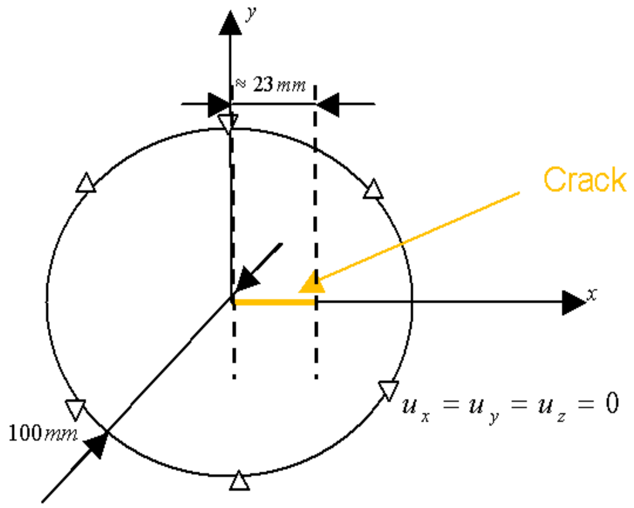

Figure 1.1 : Geometry of the disc.

.

1.2 Properties of material

Young modulus: $E=210000\,MPa$
Poisson's ratio: $\nu=0{,}3$
Thermal dilation coefficient: $\alpha=10^{-5}K^{-1}$

1.3 Boundary conditions and loadings

The disc is completely embedded on its edge.

It is subjected to an initial stress field obtained by application of a thermal loading presenting a strong gradient according to the horizontal direction (see Figure 1.2 and Figure 1.3).

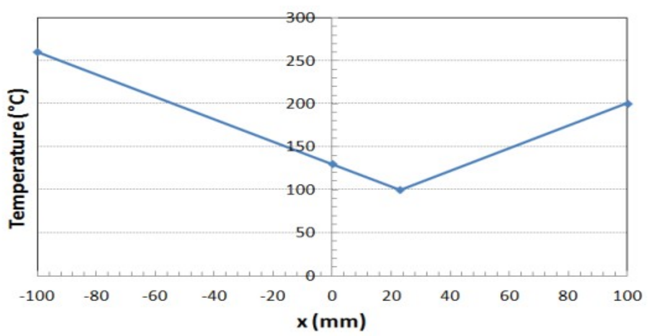

Figure 1.2 : Variation in temperature applied to the embedded disc.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

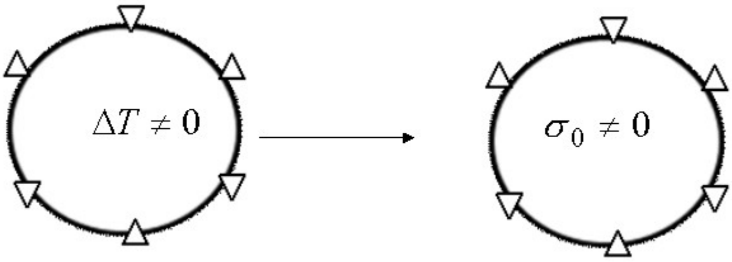

Figure 1.3 : Creation of the initial stress field.

1.4 Reference solution

The reference solution is that obtained by the application of the thermal loading directly on the disc fissured without initial state. Indeed, the behavior being elastic, the principle of superposition applies and the results in the presence of thermal loading without initial constraints and in absence of thermics with initial constraints are equivalent, as summarizes it Figure 1.4.

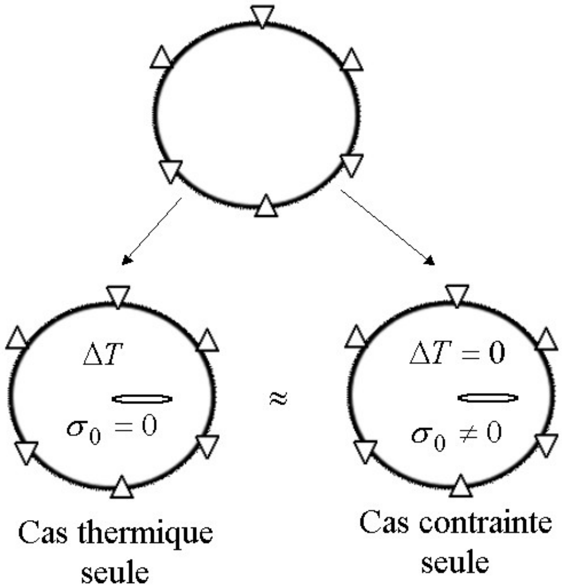

Figure 1.4 : Equivalence loadings.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

2 Modeling A

2.1 Characteristics of the grid

The grid is quadratic radiant around the crack; it is composed of 27670 nodes forming 9519 meshs including 100 triangles allowing déraffinement. Lbe meshs are quadratic. Elements of the type "Barsoum" are used at the 2 bottoms of the crack. Figure 2.1 and Figure 2.2 present the grid used.

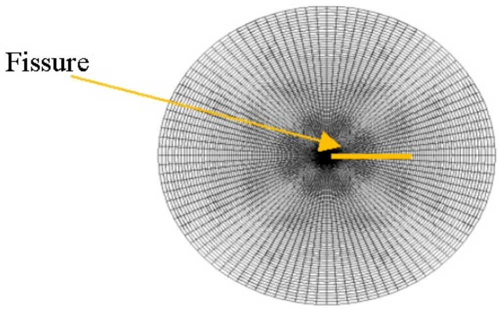

Figure 2.1 : Grid of the disc.

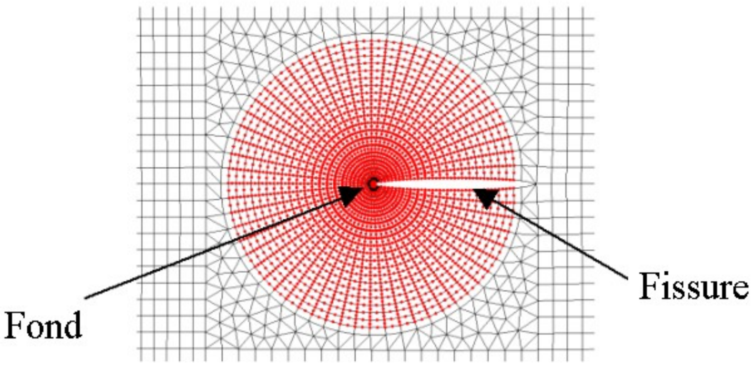

Figure 2.2 : Grid: zoom on the crack.

From the grid, one defines several crowns which will be used thereafter, during postprocessing in breaking process. Each crown is characterized by the data of a lower ray (R_INF) and of a higher ray (R_SUP). One gives also the correspondence in terms of many layers of elements.

	Value of R_INF (mm)	Value of R_SUP (mm)	Correspondence of many layers of elements[1]
Crown n°1	1.009	2.05	2:00 - 4h
Crown n°2	2.05	4.228	4:00 - 8h
Crown n°3	4.228	9.0	8:00 - 16h

2.2 Calculations carried out

It is pointed out that LE principle of this test of checking equivalence enters the taking into account of an initial state and a thermal loading are equivalent, during a postprocessing of breaking process.

1 H represents the "radial" size of an element

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

The sizes of interest are the rate of refund of energy (G) and factors of intensity of the constraints (limited here to K_I because the configuration requests only mode I because of symmetry). The paragraph §2.3.1 detail the various manners post-of treating these sizes which are used and tested.

Modeling : The configuration is bidimentionnelle. Mechanical calculations are carried out under assumption of Plane Deformations.

Calculation of reference:
The analytical solution not being known, the first stage consists in generating calculation serving as reference: i.e. calculation in linear thermoelasticity. One connect creation of the field of temperature then LE calculation thermO-rubber band liénaire, after which two types of postprocessings are carried out:
- a postprocessing in breaking process in order to determine the values of reference of the sizes of interest,
- an extraction of the stress field, which will be used as initial stress field.

Calculation with initial constraints:
A calculation in incremental linear elasticity with an initial state given in the shape of an initial stress field, with presence of the crack, is carried out. It is important to stress that **the initial state is well informed *via* an initial stress field**, and not by the data of a concept of type result (EVOL_NOLI) in the operator of resolution.
Then, postprocessings in breaking process are carried out. In order to test the various opportunities given by the order CALC_G, several configurations are put in work, which differ by the type of initial stress field provided to the order CALC_G : at the points of Gauss, with the nodes by element or the nodes.

2.3 Sizes tested and results

2.3.1 Sizes tested

One tests Lbe valueS rate of refund of energy (G) resulting from:
- the operator CALC_G , option CALC_G ,
- the operator CALC_G, option CALC_K_G.

One also tests the values of the factor of intensity of the constraints in mode I (K_I) exits of:
- the operator CALC_G, option CALC_K_G,
- the operator POST_K1_K2_K3.

For postprocessings with the operator CALC_G, 3 crowns previously defined are systematically tested.

Lastly, one compared with each time, values resulting from the calculation of reference to the values resulting from calculation with initial state, to Iso-condition (even representation of the initial stress field, even operator of postprocessing, even crown).

2.3.2 Results

Test of the rates of refund of energy (without special mention, G indicates G resulting from calculation with initial state :

Identification	Reference	Type of reference	Tolerance
CALC_G			
G resulting from thermal calculation (reference), crown n°3	-	'NON_REGRESSION'	-
G with definite initial state at the points of Gauss, crown n°1	55.3629	'AUTRE_ASTER'	0,01%

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

G with definite initial state at the points of Gauss, crown n°2	55.3649	'AUTRE_ASTER'	0, 01%
G with definite initial state at the points of Gauss, crown n°3	55.3651	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes by element, crown n°1	55.3629	'AUTRE_ASTER'	0,0%
G with initial state defined in the nodes by element, crown n°2	55.3649	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes by element, crown n°3	55.3651	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes, crown n°1	55.3629	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes, crown n°2	55.3649	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes, crown n°3	55.3651	'AUTRE_ASTER'	0, 01%

Identification	**Reference**	**Type of reference**	**Tolerance**
CALC_K_G			
G resulting from thermal calculation (reference), crown n°3	-	'NON_REGRESSION'	-
G with definite initial state at the points of Gauss, crown n°1	55.3629	'AUTRE_ASTER'	0,01%
G with definite initial state at the points of Gauss, crown n°2	55.3649	'AUTRE_ASTER'	0, 01%
G with definite initial state at the points of Gauss, crown n°3	55.3651	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes by element, crown n°1	55.3629	'AUTRE_ASTER'	0,01%
G with initial state defined in the nodes by element, crown n°2	55.3649	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes by element , crown n°3	55.3651	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes, crown n°1	55.3629	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes, crown n°2	55.3649	'AUTRE_ASTER'	0, 01%
G with initial state defined in the nodes, crown n°3	55.3651	'AUTRE_ASTER'	0, 01%

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

Test of the stress intensity factors:

Identification	Reference	Type of reference	Tolerance
CALC_K_G			
K_I resulting from thermal calculation (reference), crown n°3	-	'NON_REGRESSION'	-
K_I with definite initial state at the points of Gauss, crown n°1	3574,36	'AUTRE_ASTER'	0,005%
K_I with definite initial state at the points of Gauss, crown n°2	3574,43	'AUTRE_ASTER'	0.005%
K_I with definite initial state at the points of Gauss, crown n°3	3574,44	'AUTRE_ASTER'	0.005%
K_I with initial state defined in the nodes by element, crown n°1	3574,36	'AUTRE_ASTER'	0,005%
K_I with initial state defined in the nodes by element, crown n°2	3574,43	'AUTRE_ASTER'	0.005%
K_I with initial state defined in the nodes by element, crown n°3	3574,44	'AUTRE_ASTER'	0.005%
K_I with initial state defined in the nodes , crown n°1	3574,36	'AUTRE_ASTER'	0.005%
K_I with initial state defined in the nodes, crown n°2	3574,43	'AUTRE_ASTER'	0.005%
K_I with initial state defined in the nodes, crown n°3	3574,44	'AUTRE_ASTER'	0.005%

Identification	Reference	Type of reference	Tolerance
POST_K1_K2_K3			
K_I resulting from thermal calculation (reference)	-	'NON_REGRESSION'	-
K_I with initial state	3576,75	'AUTRE_ASTER'	0.005%

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

3 Modeling B

3.1 Characteristics of the grid

The geometry is identical to modeling A. LE grid represents the virgin part of any crack (it will be represented by method X-FEM); the grid is linear.

3.2 Calculations carried out

In order to test the various opportunities given by the order CALC_G, several configurations of calculations are put in work.

The first is the result of reference got by thermal loading without initial state.

The others result from calculation with initial state without thermal loading; they differ by the values from the rays from the crowns provided to the order CALC_G. As for modeling A, one also tests the factors of intensity of the constraints (the reference is obtained by POST_K1_K2_K3). It is noted that only the initial stress field with points of gauss was used, the definition of a stress field to the nodes not being available with X-FEM.

3.3 Sizes tested and results

3.3.1 Sizes tested

One tests the value of the rate of refund of energy result of the operator. They all must be equal except for a weak tolerance.

3.3.2 Results

Test of the rates of refund of energy and the stress intensity factors:

Identification	Reference	Type of reference	Tolerance
CALC_G			
G resulting from thermal calculation (CALC_G)	-	'NON_REGRESSION'	-
G with rays automatic (CALC_G)	55.36	'AUTRE_ASTER'	2.0%
G with R_INF = 2.4, R_SUP = 4.8 (CALC_G)	55.36	'AUTRE_ASTER'	2,0%
G with R_INF =4,228, R_SUP = 9 (CALC_G)	55.36	'AUTRE_ASTER'	3.5%
G with rays automatic (CALC_K_G)	55.36	'AUTRE_ASTER'	2.0%
G with R_INF = 2.4, R_SUP = 4.8 (CALC_K_G)	55.36	'AUTRE_ASTER'	2,0%
G with R_INF = 4.228, R_SUP = 49 (CALC_K_G)	55.36	'AUTRE_ASTER'	3.5%

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

K_I with rays automatic (CALC_K_G)	3574	'AUTRE_ASTER'	1.0%
K_I with R_INF = 2.4 R_SUP = 4.8 (CALC_K_G)	3574	'AUTRE_ASTER'	1.0%
K_I with R_INF =4,228, R_SUP = 9 (CALC_K_G)	3574	'AUTRE_ASTER'	1.5%

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

4 Modeling C

This modeling, added at ends of data-processing validation, test the possibility of using coefficients materials dependent on the temperature.
It is identical with modeling A. The only difference is that Lbe coefficients materials are defined by constant functions of the temperature.

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)

5 Summary of the results

The case test allows a confrontation of the results got starting from Chargement thermics and of a stress fieldS initialS. It shows that the results are appreciably equivalent.

More precisely in FEM (modeling A):

- Conclusions on G:
  - Excellent independence results of CALC_G with the crowns (maximum difference between crowns lower than 0.004%) , in all the cases,
  - Strictly identical results between an initial stress field provided to CALC_G of type ELGA and ELNO ,
  - Very close results with the reference, with identical crown (lower deviation than 0.01%) . The closest results are got when the initial constraint is given to the nodes to CALC_G ,
  - Strictly has ucune difference enters CALC_G and CALC_K_G (with 6 significant figures)
- Conclusions on K:
  - Same conclusions as on G, with each time, a precision doubles (maximum difference between crowns lower than 0.002% and variation with the reference lower than 0.005 %)

It will be added that this same case gives the same results with the Abaqus software in its version 6.11 (method FEM, calculation of G only).

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.
Copyright 2021 EDF R&D - Licensed under the terms of the GNU FDL (http://www.gnu.org/copyleft/fdl.html)