HPLV103 - Computation of KI and G thermoelastic 3D for a circular crack

Abstract

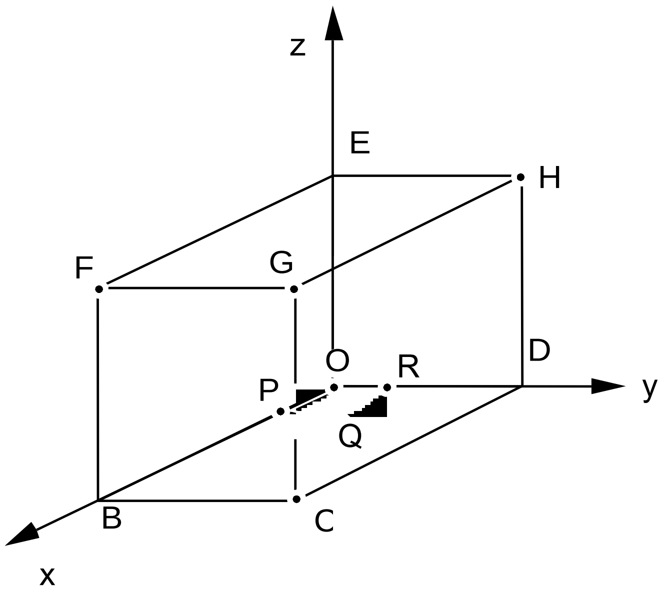
It acts of a test of fracture mechanics into thermomechanical for a three-dimensional problem. One considers a circular crack plunged in a thermoelastic medium. One imposes a uniform temperature on the lips of crack. This test makes it possible to calculate total rate of energy restitution G and the factor of intensity of the stresses room K_I in various points of the crack tip.

The interest of the test is invariance of G and of K_I according to various contours and the comparison with an analytical solution.

1 Problem of reference

1.1 Geometry

One considers a circular crack plunged in a thermoelastic medium. Taking into account symmetries of the problem, only a eighth of structure is represented:



Dimensions of crack are the following ones:

$OP = \mathrm{OR} = 1.0$

The medium is modelled by a parallelepiped of dimensions:

$OB = OD = OC = 30.0$

1.2 Material properties

thermal Conductivity: $\lambda = 1.$
Thermal coefficient of thermal expansion: $\alpha = 10^{-6} / ° C$

Young modulus: $E = 2.10^5\ MPa$
Poisson's ratio: $\nu = 0.3$

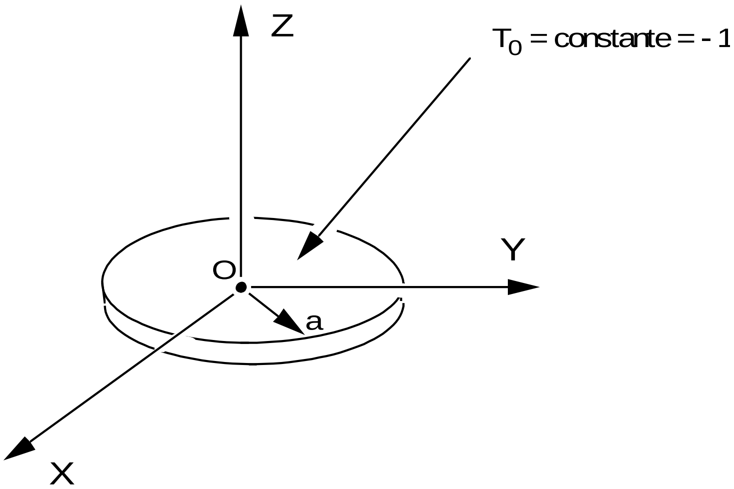
1.3 Boundary conditions and loadings

- Mechanics: displacements imposed (DDL_IMPO) on the following mesh groups:
  - $DX = 0$ on $ODHE$;
  - $DY = 0$ on $OEFB$;
  - $DZ = 0$ on $PBCDRQ$ (i.e lower face of the parallelepiped, without the lip of crack). Thermal
- : temperature imposed (TEMP_IMPO) on the following mesh groups: on
  - $TEMP = 0$, $BCGH$ and $CDHG$ (outsides $EFGH$ of the parallelepiped); on
  - $TEMP = -1$. $OPQR$ Reference solution

2 Method of calculating

2.1 used for the reference solution

the reference solution is resulting from the collection of MURAKAMI [bib1]:



The statement of the rate of refund of energy is the following one: ,

$$G=\frac{\left(1-\nu^{2}\right)}{E}K_1^2 \text{ avec} K_1=\frac{\alpha E}{\pi(1-\nu)}\left|T_0\right|\sqrt{\pi a}F(\eta)$$ with and $\eta = a/b$.

$$F(\eta)=1-0.6366\eta-0.4053\eta^2+2.0163\eta^3-0.6773\eta^4-3.8523\eta^5+4.1687\eta^6+3.2741\eta^7$$ Note:

For

(infinite $\eta=0$ medium), the solution is exact. For a medium finished, uncertainty on the solution is unknown. In this test. $\eta=1/30$ Result

2.2 of reference

result of reference is thus: and $K_I=157.73\,10^3\,Pa\,m^{1/2}$ bibliographical $G=1.132\,10^{-1}\,J/m^2$

2.3 References Stress

1) intensity factors Handbook (Y. MURAKAMI), box 11.39, pp. 1089 - 1090, the Society of Material Science, Japan, Pergamon Near, 1987. Modelization

3 A Characteristic

3.1 of the modelization It

acts of a three-dimensional modelization. The mesh was realized using procedure GIBI of fissured block [feeding-bottle $3D$ 1]. One represented only the eighth of structure (and thus a quarter of the front of crack), the quarter of this front being discretized in 16 sectors. Characteristics

3.2 of the mesh The mesh

is composed of quadratic elements Number of meshes

and types: 624 PENTA 15,5600 HEXA20 Quantities

3.3 tested and results

the values tested are those of the total rate of refund of energy G and the rate of refund of energy room at the points and A from B various integration contours and of the two methods of definition of the fields: θ Identification

Reference	total	*Aster*	% difference
G **Crowns**			
1 8.8910 G	−8 8.66	10 −8 2.53	Contour
2 8.8910 G	−8 8.68	10 −8 2.31	Contour
3 8.8910 G	−8 8.69	10 −8 2.17	Contour
4 8.8910 G	−8 8.68	10 −8 2.31	Lagrange
G **room – Legendre (degree 7) local**			
G 1 in 5.66 A	10 −8 6.13	10 −8 8.31	room
G 2 in 5.66 A	10 −8 6.19	10 −8 9.37	room
G 3 in 5.66 A	10 −8 6.42	10 −8 13.46	Lagrange
G **room – Legendre (degree 7) local**			
G 1 in 5.66 B	10 −8 5.50	10 −8 2.75	local
G 2 in 5.66 B	10 −8 5.51	10 −8 2.62	room
G 3 in 5.66 B	10 −8 5.50	10 −8 2.84	room
G **Legendre – Legendre (degree 7) local**			
G 1 in 5.66 A	10 −8 5.54	10 −8 2.07	room
G 2 in 5.66 A	10 −8 5.58	10 −8 1.39	room
G 3 in 5.66 A	10 −8 5.71	10 −8 1.01	Legendre
G **room – Legendre (degree 7) local**			
G 1 in 5.66 B	10 −8 5.51	10 −8 2.62	room
G 2 in 5.66 B	10 −8 5.52	10 −8 2.46	room
G 3 in 5.66 B	10 −8 5.52	10 −8 2.52	Contour

1: Crown $Rinf=0.07$ $\text{Rsup}=0.2$
2: Crown $Rinf=0.2$ $\text{Rsup}=0.4$
3: Crown $Rinf=0.4.$ $\text{Rsup}=0.6.$
4: $Rinf=0.07$ $\text{Rsup}=0.6$

The supports of the local field θ correspond to the first three contours of the global field. Remarks

3.4

- the value of reference is the value of the rate of refund of energy room: . $G_{réf}=5.66\,10^{-8}\,J/m^2$ The total rate of refund of energy provided by Code_Aster *is* : ,

  $G_{Aster}=G_{réf}\times\frac{2\Pi a}{8}$ since by reason of symmetry one models only one quarter of the plane of crack and only one lip.

- The results of the room G are given only for the points and A respectively B located on a symmetry plane and crack front. The results concerning the point (medium B of the front) reveal a variation of approximately compared to 3% result of reference. The results concerning the point are A less good (the variation is between and 3%), 13.5% which is a usual report for the estimate of the room G for the points located on a symmetry plane. Summary

4 of the results

- the transition of a quadratic mesh to a linear mesh for mechanical computation decreases the accuracy of result: the total ones G have a variation of on average 4.8% with the reference for the linear mesh against for 2.2% the quadratic mesh.
- Lissage LEGENDRE – `LEGENDRE led` , on this case test, with the most precise results for the local values of. G For the computation of the buildings K , one advises lissage LAGRANGE – `LAGRANGE`.
- The accuracy on the computation of room K_I is satisfactory, the average deviation being restricted with. 2.3%