SSNV192 - Test-tube with central crack with XFEM

Summary

This test sets up a central crack in a test-tube with X-FEM . There are thus two distinct funds of crack. The objective is to validate the separate taking into account several funds of crack, and the relevance of the results on K_I on the various funds.

This test comprises two modelings 3D:

- modeling a: with linear elements X-FEM

- modeling b: with quadratic elements X-FEM, which appreciably improve the precision of the results.

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1 Problem of reference

1.1 Geometry

The structure is a plate $3D$ dimensions $L_X = B = 1\,m$, $L_Y = 2.W = 10\,m$ and $L_Z = 2.L = 20\,m$, comprising a crack central length planes $2.a = 2\,m$, centered compared to the test-tube according to Y and Z and emerging of the two with dimensions ones according to X (see Figure 1.1-1).

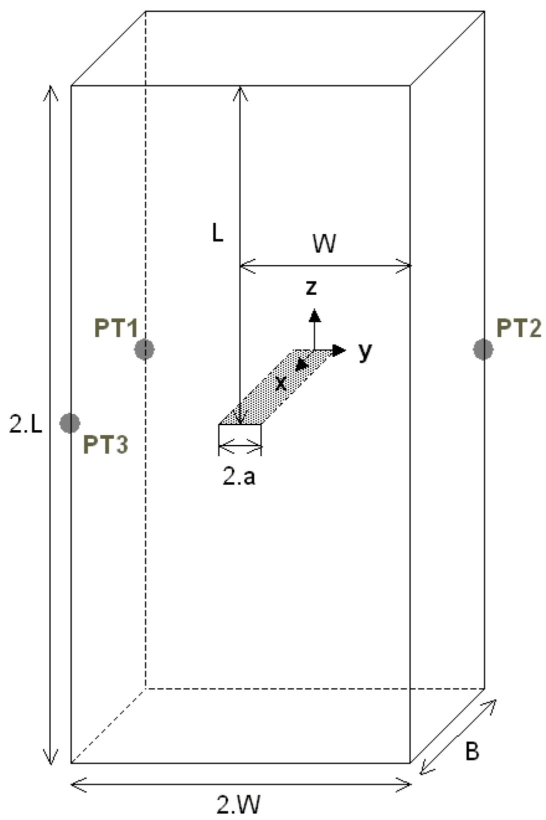

Figure 1.1-1 : Test-tube with emerging central crack

One will make use of the points $PT1(0;-W;0)$, $PT2(0;W;0)$ and $PT3(B;-W;0)$ to block the rigid modes.

1.2 Properties of material

Young modulus: $E = 1\,MPa$
Poisson's ratio: $\nu = 0$

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2 Reference solution

2.1 Method of calculating

The analytical solution of the problem is:

$$K_I = \frac{P}{B\sqrt{W}} f\left(\frac{a}{W}\right)$$

with $$f\left(\frac{a}{W}\right) = \sqrt{\frac{\pi a}{4\mathrm{W}\cos\left(\frac{\pi a}{2W}\right)}}\left[1 - 0.025\left(\frac{a}{W}\right)^2 + 0{,}06\left(\frac{a}{W}\right)^4\right]$$

and $$P = \sigma \times 2\mathrm{W} \times B$$

2.2 Sizes tested and results

$$\left\{\begin{array}{l} \sigma = 1\,Pa \\ B = 1\,m \\ a = 1\,m \\ W = 5\,m \end{array}\right\}$$

$$f\left(\frac{a}{W}\right) = 0{,}406$$

$$K_I = 1{,}81584\,Pa\sqrt{m}$$

2.3 Uncertainties on the solution

Analytical solution.

2.4 Bibliographical references

[1] GENIAUT S., MASSIN P.: Method X-FEM, Handbook of reference of *Code_Aster*, [R7.02.12]

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3 Modeling A

It is a uniform case of traction. In this modeling, one seeks to validate the definition of multiple funds of crack with the operator `DEFI_FISS_XFEM` [`U4.82.08`] and the calculation of K_I in bottom of crack separately on a bottom and the other of the crack.
The central crack of half-length $a=1\text{m}$ is represented by the level sets:

$$\begin{cases} LSN=z \\ LST=|Y|-a \end{cases}$$

3.1 Characteristics of the grid

The structure is with a grid starting from elements `HEXA` and `PENTA`. The number of external elements is of 3 elements according to X, 10 elements according to Y, and 10 elements according to Z.
A central zone of dimension $1\times 3\times 2$ containing the crack ($-1{,}5<Y<1{,}5$ and $-1<Z<1$) is with a grid more finely exclusively with elements `HEXA` : 21 elements on Y, 15 elements on Z.
The full number of voluminal elements is: 564 `PENTA` and 2556 `HEXA20`.

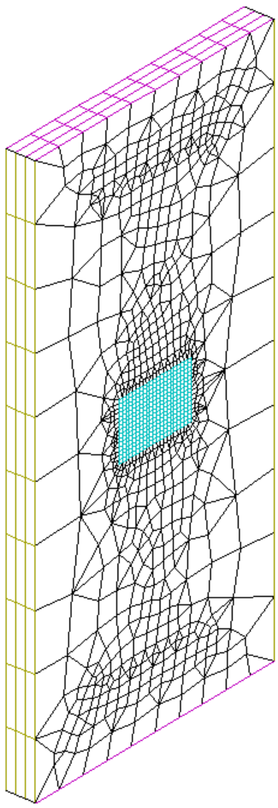

Figure 3.1-1 : Grid with central zone refined in `HEXA8`

3.2 Boundary conditions and loadings

One applies to the faces lower and higher a loading of traction by a left again pressure:

$$\sigma_{zz}=1\,\text{Pa}$$

The blocking of the rigid modes is applied to the points $PT1$, $PT2$ and $PT3$ (see Figure 1.1-1):

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$$PT_1 \begin{cases} DX_1=0 \\ DY_1=0 \\ DZ_1=0 \end{cases}, \quad PT_2 \begin{cases} DX_2=0 \\ DZ_2=0 \end{cases} \quad \text{and} \quad PT_3 \{ DZ_3=0$$

3.3 Sizes tested and results

One tests the values of K_I on the two funds of crack separately for various crowns of integration. The values of the lower and higher rays of the torus are the following ones:

	Crown 1	Crown 2	Crown 3	Crown 4	Crown 5	Crown 6
Rinf	0.1	0.2	0.3	0.1	0.1	0.2
Rsup	0.2	0.3	0.4	0.3	0.4	0.4

Table 3.1-1

To test all the nodes of the bottom of crack in only once, one tests the minimal and maximum values of K_I on all the nodes of the bottom of crack.

Fund of crack 1:

Identification	**Reference**	**% difference**
Crown 1 : MAX (K_I)	1.81584	1.0
Crown 1 : MIN (K_I)	1.81584	1.0
Crown 2 : MAX (K_I)	1.81584	1.0
Crown 2 : MIN (K_I)	1.81584	1.0
Crown 3 : MAX (K_I)	1.81584	1.0
Crown 3 : MIN (K_I)	1.81584	1.0
Crown 4 : MAX (K_I)	1.81584	1.0
Crown 4 : MIN (K_I)	1.81584	1.0
Crown 5 : MAX (K_I)	1.81584	1.0
Crown 5 : MIN (K_I)	1.81584	1.0
Crown 6 : MAX (K_I)	1.81584	1.0
Crown 6 : MIN (K_I)	1.81584	1.0

Fund of crack 2:

Identification	**Reference**	**% difference**
Crown 1 : MAX (K_I)	1.81584	1.0
Crown 1 : MIN (K_I)	1.81584	1.0
Crown 2 : MAX (K_I)	1.81584	1.0
Crown 2 : MIN (K_I)	1.81584	1.0
Crown 3 : MAX (K_I)	1.81584	1.0
Crown 3 : MIN (K_I)	1.81584	1.0
Crown 4 : MAX (K_I)	1.81584	1.0
Crown 4 : MIN (K_I)	1.81584	1.0
Crown 5 : MAX (K_I)	1.81584	1.0
Crown 5 : MIN (K_I)	1.81584	1.0
Crown 6 : MAX (K_I)	1.81584	1.0
Crown 6 : MIN (K_I)	1.81584	1.0

3.4 Comments

The results are stable for the various crowns, and the various points of the funds of crack. They are sufficiently close to the expected values.

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3.5 Remarks

In it CAS-test, tables resulting from DEFI_FISS_XFEM are printed in order to make sure that those are coherent with information of DEFI_FISS_XFEM in INFO=2. Thus tables FOND_FISS and NB_FOND_FISS are recovered while using RECU_TABLE and are then printed while using IMPR_TABLE. The value amongst funds of crack is recovered by EXTR_TABLE and is then used for the calculation of G (CALC_G) on all the funds of crack.

Moreover, impression of the grid of visualization X-FEM is also realized in order to make sure of the good construction of the nodes, meshs, groups of meshs and groups of nodes in bottom of cracks.

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4 Modeling B

Idem that modeling A, by transforming the linear elements into quadratic elements.

4.1 Characteristics of the grid

Identical to modeling A.

The full number of voluminal elements is: 564 `PENTA` and 2556 `HEXA20`.

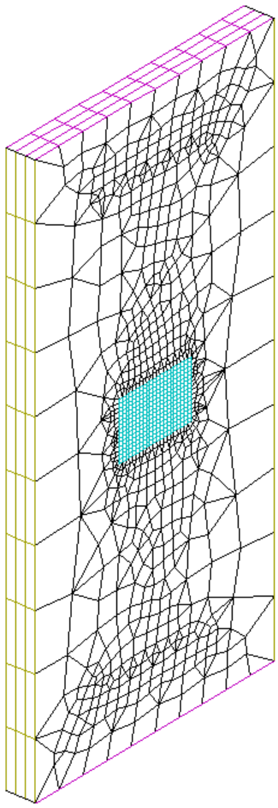

Figure 4.1-1 : Grid with central zone refined in `HEXA20`

4.2 Boundary conditions and loadings

Idem modeling A.

4.3 Sizes tested and results

Idem modeling A.

One tests the values of K_I on the two funds of crack separately for various crowns of integration. The values of the lower and higher rays of the torus are the following ones:

	Crown 1	Crown 2	Crown 3	Crown 4	Crown 5	Crown 6
Rinf	0.1	0.2	0.3	0.1	0.1	0.2
Rsup	0.2	0.3	0.4	0.3	0.4	0.4

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Table 3.1-1

To test all the nodes of the bottom of crack in only once, one tests the minimal and maximum values of K_I on all the nodes of the bottom of crack.

Fund of crack 1:

Identification	Reference	% difference
Crown 1 : `MAX (K_I)`	1.81584	0.01
Crown 1 : `MIN (K_I)`	1.81584	0.01
Crown 2 : `MAX (K_I)`	1.81584	0.01
Crown 2 : `MIN (K_I)`	1.81584	0.01
Crown 3 : `MAX (K_I)`	1.81584	0.01
Crown 3 : `MIN (K_I)`	1.81584	0.01
Crown 4 : `MAX (K_I)`	1.81584	0.01
Crown 4 : `MIN (K_I)`	1.81584	0.01
Crown 5 : `MAX (K_I)`	1.81584	0.01
Crown 5 : `MIN (K_I)`	1.81584	0.01
Crown 6 : `MAX (K_I)`	1.81584	0.01
Crown 6 : `MIN (K_I)`	1.81584	0.01

Fund of crack 2:

Identification	Reference	% difference
Crown 1 : `MAX (K_I)`	1.81584	0.01
Crown 1 : `MIN (K_I)`	1.81584	0.01
Crown 2 : `MAX (K_I)`	1.81584	0.01
Crown 2 : `MIN (K_I)`	1.81584	0.01
Crown 3 : `MAX (K_I)`	1.81584	0.01
Crown 3 : `MIN (K_I)`	1.81584	0.01
Crown 4 : `MAX (K_I)`	1.81584	0.01
Crown 4 : `MIN (K_I)`	1.81584	0.01
Crown 5 : `MAX (K_I)`	1.81584	0.01
Crown 5 : `MIN (K_I)`	1.81584	0.01
Crown 6 : `MAX (K_I)`	1.81584	0.01
Crown 6 : `MIN (K_I)`	1.81584	0.01

4.4 Comments

The results are stable for the various crowns, and the various points of the funds of crack. They are sufficiently close to the expected values.

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5 Summary of the results

The objective was to validate the separate taking into account several funds of crack, and the relevance of the results on K_I on the various funds. The test is conclusive.

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