ZZZZ255 - Validation of option TEST_MAIL in PROPA_FISS

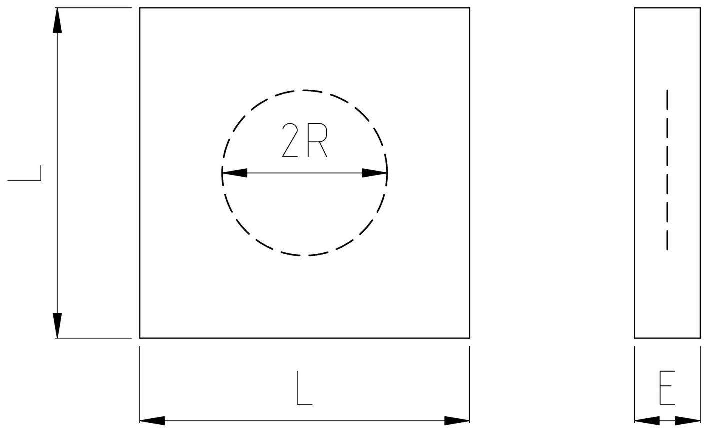
Summarized:

This test validates key word TEST_MAIL of operator PROPA_FISS. This key word makes it possible to check if the mesh and/or auxiliary grid used for the representation of the level sets of a crack X-FEM are sufficiently refined.

It is several propagations in mode I about a circular crack of form. If key word TEST_MAIL is used, operator PROPA_FISS imposes the same projection on all the points which form the bottom of crack. Consequently, the form of the bottom does not change during the propagation but its dimension (the radius of the circle) increases by a quantity equal to the imposed projection. After each propagation, the operator checks if the form of the new bottom is changed and if its radius is equal to the expected value. It is only when the mesh is sufficiently refined that the two properties are checked.

1 Problem of reference

1.1 Geometry



Appears 1.1-a: geometry of the fissured plate

geometrical Dimensions of the fissured plate:

width $L=1000\,mm$
thickness $E=100\,mm$

initial Radius of circular crack: $R=250\,mm$.
The crack is positioned in the middle of the thickness of the plate ($E/2$).

1.2 Properties of the material

No material is used.

1.3 Boundary conditions and loadings

No boundary condition nor no loading is applied. Indeed, key word TEST_MAIL makes it possible to simulate a propagation by imposing the same projection, given by the user, at all the points of the bottom of crack and the resolution of the model is not necessary (confer to the documentation [U4.82.11]).
The imposed projection is equal to $25\,mm$.

2 Reference solution

2.1 Method of calculating

Three propagations of crack are calculated. With each propagation the crack advances $\Delta a=25\,mm$. The distance between the new crack tip and the initial crack can thus be calculated: $d_i=i\cdot\Delta a$. If one calculates the distance between each point of the new bottom and the bottom of initial crack, one always finds the computed value d_i .

2.2 Quantities and results of reference

For the three propagations calculated in the tests, the distance between the new crack tip and the initial crack is the following one:

Propagation i	d_i [mm]
1	25.0
2	50.0
3	75.0

Table 2.1

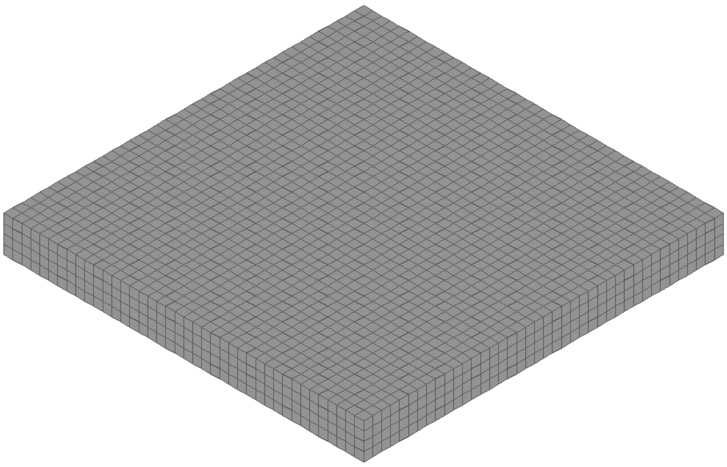
3 Modelization A

3.1 Characteristic of the modelization

method UPWIND is used by PROPA_FISS to solve the equations of propagation of crack.
No auxiliary grid is used. That is possible because the mesh of structure is very regular.

3.2 Characteristics of the mesh

the structure is modelled by a mesh made up of 6400 elements HEXA8 (see Appear 3.2-a).



Appear 3.2-a: mesh of structure

The mesh is very regular and the dimension of the elements is equal to $25\times25\times25\,mm$.

3.3 Features tested

operator PROPA_FISS calculates the minimal and maximum distance between the new crack tip after the propagation and the bottom at the beginning of the propagation. Theoretically the values of the two calculated distances are equal between them. On the other hand, the representation of the level sets by a grid, or a mesh, introduced approximations and thus the computed values are not equal between them, nor with the expected value of reference (Table 2.1). Consequently, a tolerance is used. It is applied to the relative error between the calculated distance and reference outdistances it. This error is calculated like this:

$$erreur=\frac{d_{calculée}-d_{référence}}{l_{min}}$$

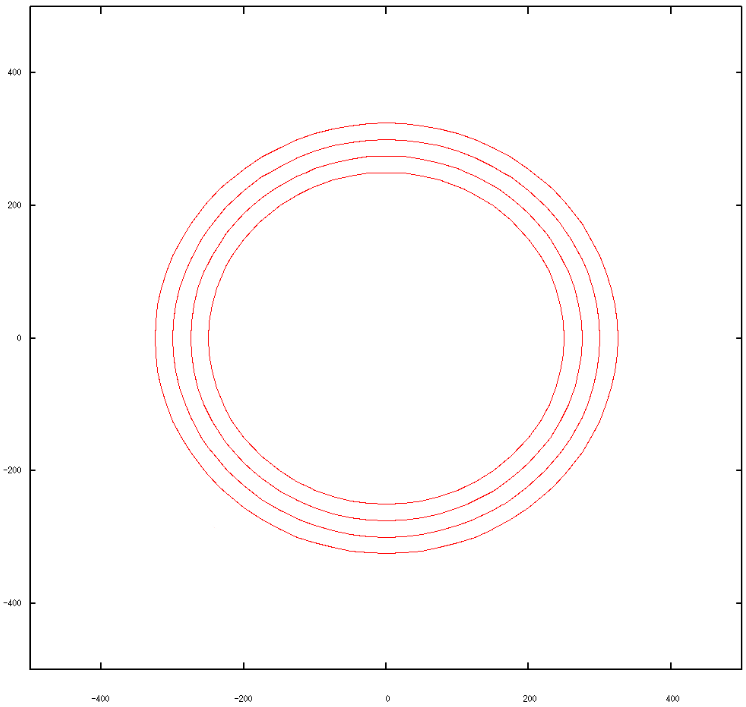
where $d_{calculé}$ is the distance maximum d_{max} or minimal d_{min} calculated by PROPA_FISS after the propagation, $d_{référence}$ is the distance from expected reference (Table 2.1) and l_{min} is the length of the smallest edge of the mesh or the grid used for the representation of the level sets ($25\,mm$ in this benchmark).
One chose to calculate the relative error compared to l_{min} because one expects that the accuracy of the representation of the level sets is related to this quantity. Theoretically the error must be equal to zero and the new crack tip after the propagation must be homothetic at the bottom at the beginning of the propagation. Very small differences however are tolerated. Because of these differences, the form of the crack tip after the propagation is not regular and one can obtain oscillations, which must be restricted to have a good representation of the bottom. One thus decided to use a limiting value

calculated like percentage the length l_{min} , which expresses the accuracy with which the mesh or the grid used can represent the level sets. It is noticed that the limiting value used is independent of the value $d_{référence}$. That makes it possible to identify the oscillations of the form of the bottom even if the value of reference $d_{référence}$ is large. The use of a relative error calculated compared to $d_{référence}$ does not make it possible to correctly manage the checking of the form of the bottom because the tolerated oscillation $(d_{calculée} - d_{référence})$ increases with the number of the propagation considered (see the values of d_i in Table 2.1).

Under key word TEST_MAIL of operator PROPA_FISS, a maximum relative error of 5% is accepted.

Propagation	d_i **reference** **[** mm **]**	d_{min} **[** mm **]**	**relative Error [%]**	d_{max} **[** mm **]**	**relative Error [%]**
1	25.0	24.7383	-1.0	25.2018	0.8
2	50.0	49.4396	-2.2	50.3049	1.2
3	75.0	74.2634	-2.9	75.1643	0.7

One can represent the bottom of initial crack and the bottom obtained after each propagation:



Appear 3.3-a: melts of initial crack and bottom after each propagation

One sees immediately that the three propagated funds are homothetic at the initial bottom and that the distance between two consecutive funds is the same one. That makes it possible to check immediately that the mesh used for the representation of the level sets is sufficiently refined because it makes it possible to represent the bottom of crack well.
If the values tested are looked at, it is seen that all are in the tolerance used. The use of the key word TEST_MAIL thus makes it possible to conclude that the mesh used for the representation of the level sets is sufficiently refined. That shows that key word TEST_MAIL functions correctly.

3.4 Quantities tested and results

This benchmark is a data-processing validation of key word TEST_MAIL. The non-satisfaction of the intrinsic conditions to this key word returns simply an alarm to the user.
In order to supply a results file, one proposes to add to this benchmark, a TEST_RESU carrying out an operation similar to TEST_MAIL. It consists in calculating, with the last step of propagation, the distance between each corner of the plate and the crack front. One thus records the tangential value of the level-set of each one of these nodes and one checks that the minimal and maximum value found values are quite equal to the theoretical value to 5% near.

Propagation	d_i **reference** **[** mm **]**	**Tolerance [%]**
3	$500\sqrt{2}-(R+3\times 25)$	5

4 Modelization B

4.1 Characteristic of the modelization

method SIMPLEXE is used by PROPA_FISS to solve the equations of propagation of crack. **No auxiliary grid** is used.

4.2 Characteristics of the mesh

One uses the same mesh as that of the modelization A.

4.3 Functionalities tested

Under key word TEST_MAIL of operator PROPA_FISS, a maximum relative error of 5% is accepted.

Propagation	d_i reference [mm]	d_{min} [mm]	relative Error [%]	d_{max} [mm]	relative Error [%]
1	25.0	24.7383	-1.0	25.2018	0.8
2	50.0	49.4014	-2.4	50.2463	1.0
3	75.0	74.0372	-3.9	75.1664	0.7

One can represent the bottom of initial crack and the bottom obtained after each propagation:

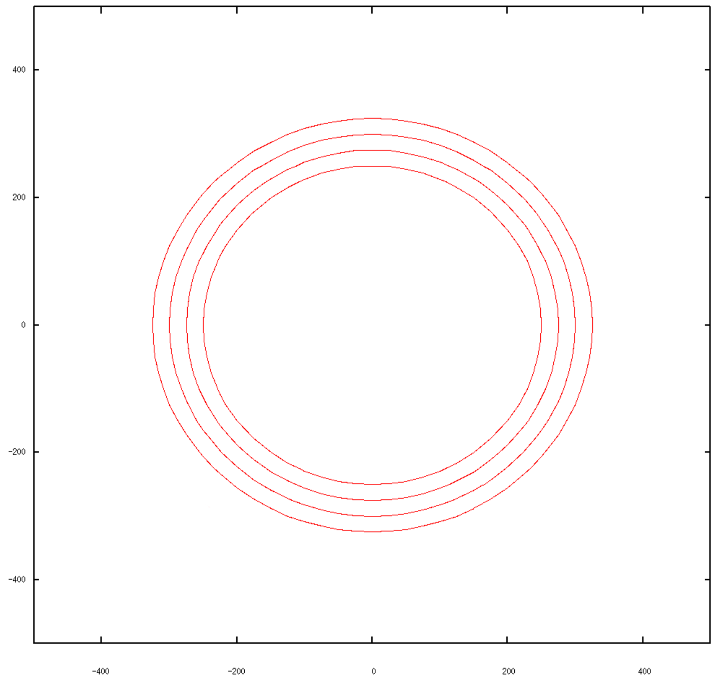


Figure 4.3-a : 4.3-a melts of initial crack and bottom after each propagation

One sees immediately that the three propagated funds are homothetic at the initial bottom and that the distance between two consecutive funds is the same one. That makes it possible to check that the mesh used for the representation of the level sets is sufficiently refined because it makes it possible to represent the bottom of crack well.

If the values tested are looked at, it is seen that all are in the tolerance used. The use of the key word TEST_MAIL makes it possible to conclude that the mesh used for the representation of the level sets is sufficiently refined. That shows that key word TEST_MAIL functions correctly.

4.4 Quantities tested and results

This benchmark is a data-processing validation of key word TEST_MAIL. The non-satisfaction of the intrinsic conditions to this key word returns simply an alarm to the user.
In order to supply a results file, one proposes to add to this benchmark, a TEST_RESU carrying out an operation similar to TEST_MAIL. It consists in calculating, with the last step of propagation, the distance between each corner of the plate and the crack front. One thus records the tangential value of the level-set of each one of these nodes and one checks that the values minimal and maximum found values are quite equal to the theoretical value to 5% near.

Propagation	d_i **reference** **[** mm **]**	**Tolerance [%]**
3	$500\sqrt{2}-(R+3\times 25)$	5

5 Modelization C

5.1 Characteristic of the modelization

the method MAILLAGE is used by PROPA_FISS.

5.2 Characteristics of the mesh

One uses the same mesh as that of the modelization A .

5.3 Functionalities tested

TEST_MAIL is without interest for this method of propagation. The use of this key word is thus not authorized.
One decides nevertheless to use this benchmark in order to check the good initialization and circular propagation of crack with this method of propagation.

5.4 Quantities tested and results

One records the tangential value of the level-set of each corner of the plate and one checks that the values minimal and maximum found values are quite equal to the theoretical value of the distance to the crack front to 5% near.

Propagation	d_i **reference** **[** mm **]**	**Tolerance [%]**
3	$500\sqrt{2}-(R+3\times25)$	5

6 Summary of the results

One tested a mesh by means of key word TEST_MAIL and two different methods (UPWIND', "SIMPLEXE") to solve the equations of propagation. In both cases, a positive response was obtained, i.e. the mesh is sufficiently refined for representing well circular crack definite on the mesh.
By representing the bottom of initial crack and the funds obtained after each propagation, one checked that the calculated funds are correct.
One can thus conclude that key word TEST_MAIL makes it possible to make a checking of mesh in the automatic and very fast way.
In addition, the distances calculated at the crack front are coherent with the theoretical values whatever the method of propagation of PROPA_FISS ("UPWIND", "SIMPLEXE" or "MAILLAGE")