ZZZZ255 - Validation of the option `TEST_MAIL` in `PROPA_FISS`

Summary:

This test validates the keyword `TEST_MAIL` of the operator `PROPA_FISS`. This keyword makes it possible to check if the grid and/or the auxiliary grid used for the representation of the level sets of a crack X-FEM are sufficiently refined.
It acts several propagations in mode I of a circular crack of form. If the keyword `TEST_MAIL` is used, the operator `PROPA_FISS` impose the same projection on all the points which form the bottom of the crack. Consequently, the form of the bottom does not change during the propagation but its dimension (the ray 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 ray is equal to the expected value. It is only when the grid is sufficiently refined that the two properties are checked.

1 Problem of reference

1.1 Geometry

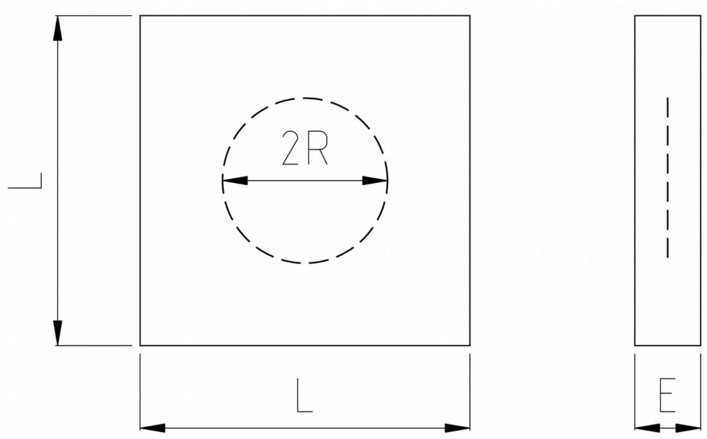

Figure 1.1-a: geometry of the fissured plate

Geometrical dimensions of the fissured plate:

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

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

1.2 Properties of material

No material is used.

1.3 Boundary conditions and loadings

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

2 Reference solution

2.1 Method of calculating

Three propagations of the crack are calculated. With each propagation the crack advances $\Delta a=25\,mm$. The distance between the new bottom of crack 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 the initial crack, one always finds the value d_i calculated.

2.2 Sizes and results of reference

For the three propagations calculated in the tests, the distance between the new bottom of crack and the initial crack are the following one:

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

Table 2.1

3 Modeling A

3.1 Characteristics of modeling

Method UPWIND is used by PROPA_FISS to solve the equations of propagation of the crack.
No auxiliary grid is not used. That is possible because the grid of the structure is very regular.

3.2 Characteristics of the grid

The structure is modelled by a grid made up of 6400 elements HEXA8 (see Figure 3.2-a).

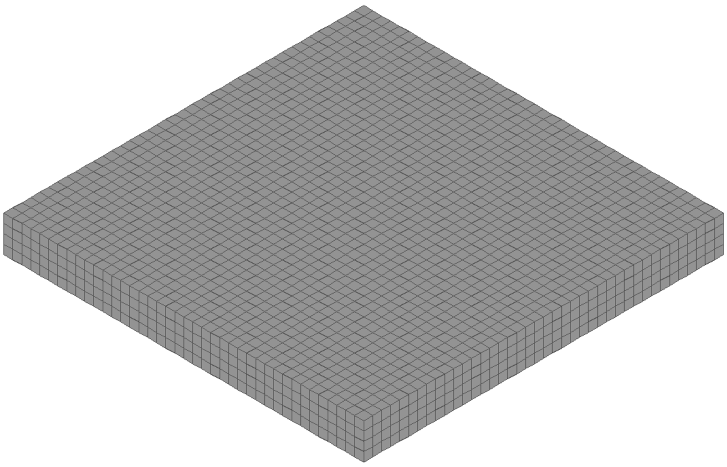

Figure 3.2-a: grid of the structure

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

3.3 Features tested

The operator PROPA_FISS calculate the minimal and maximum distance between the new bottom of crack 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 grid, 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 maximum distance 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 grid or grid used for the representation of the level sets ($25\,mm$ in this CAS-test).
One chose to calculate the relative error compared to l_{min} because one expects that the precision of the representation of the level sets is related to this size. Theoretically the error must be equal to zero and the new bottom of crack 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 bottom of crack after the propagation is not regular and one can obtain oscillations, which must be limited to have a good representation of the bottom. One thus decided to use one limiting

value calculated like percentage length l_{min} , who expresses the precision with which the grid 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 allow to correctly manage the checking of the form of the bottom because the tolerated oscillation $(d_{calculée} - d_{référence})$ increase with the number of the propagation considered (see the values of d_i in Table 2.1).

Under the keyword TEST_MAIL of the operator PROPA_FISS, a maximum relative error of 5% is accepted.

Propagation	d_i reference [mm]	d_{min} [mm]	Error relative [%]	d_{max} [mm]	Error relative [%]
1	25.0	24.78	-1.3	25.0167	0.1
2	50.0	49.55	-2.7	50	0
3	75.0	74.34	-3.9	74.99	0

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

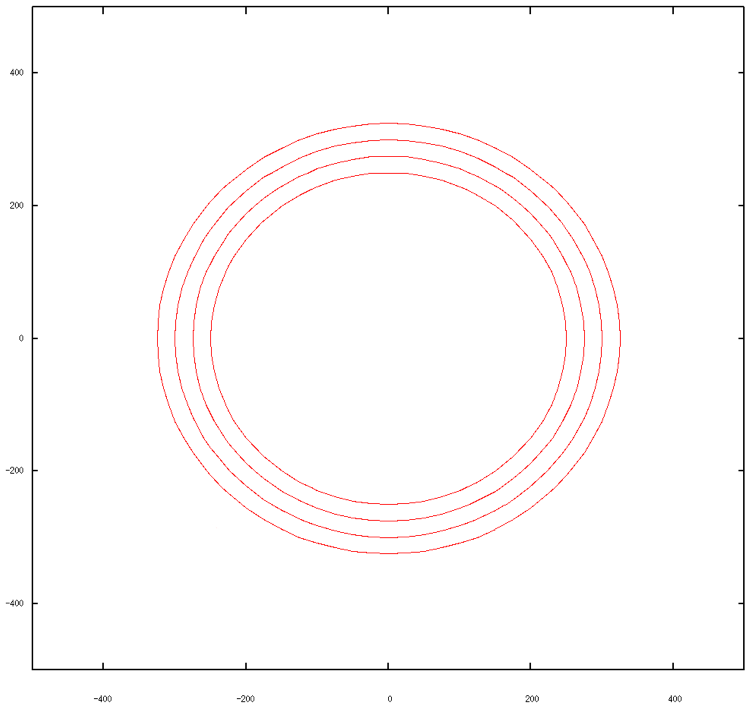

Figure 3.3-a: bottom of the initial crack and bottom after each propagation

It is seen 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 grid used for the representation of the level sets is sufficiently refined because it makes it possible to represent the bottom of the crack well.
If the values tested are looked at, it is seen that all are in the tolerance used. The use of the keyword TEST_MAIL thus allows to conclude that the grid used for the representation of the level sets is sufficiently refined. That shows that the keyword TEST_MAIL function correctly.

3.4 Sizes tested and results

This CAS-test is a data-processing validation of the keyword TEST_MAIL. The not-satisfaction of the intrinsic conditions to this keyword returns simply an alarm to the user.
In order to feed a file result, one proposes to add to this CAS-test, one 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 face of crack. 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	$500\sqrt{2}-(R+3\times25)$	5

4 Modeling B

4.1 Characteristics of modeling

Method SIMPLEX is used by PROPA_FISS to solve the equations of propagation of the crack. **No auxiliary grid** is not used.

4.2 Characteristics of the grid

One uses the same grid as that of modeling A .

4.3 Features tested

Under the keyword TEST_MAIL of the operator PROPA_FISS, a maximum relative error of 5% is accepted.

Propagation	d_i reference [mm]	d_{min} [mm]	Error relative [%]	d_{max} [mm]	Error relative [%]
1	25.0	24.88	-0.7	25	0
2	50.0	49.71	-1.7	50	0
3	75.0	74.61	-2.3	75	0

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

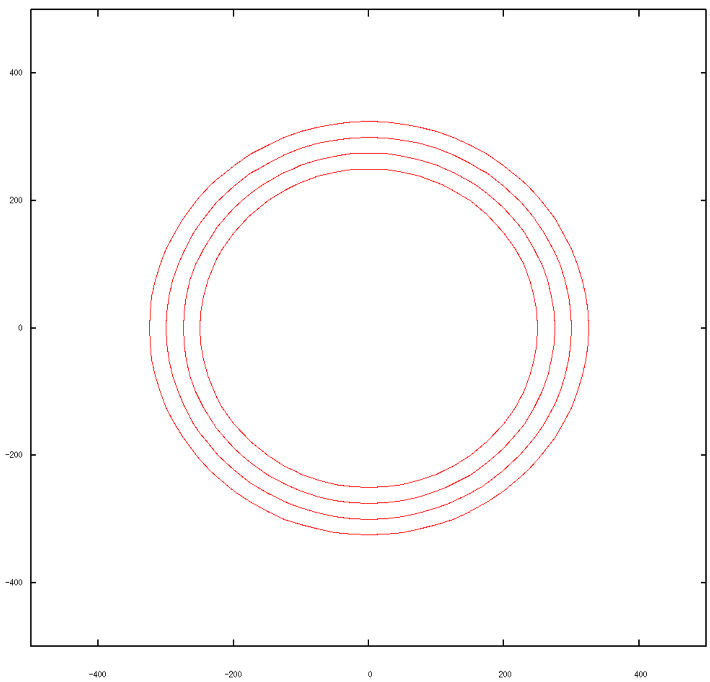

Figure 4.3-a: bottom of the initial crack and bottom after each propagation

It is seen 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 grid used for the representation of the level sets is sufficiently refined because it makes it possible to represent the bottom of the crack well.

If the values tested are looked at, it is seen that all are in the tolerance used. The use of the keyword TEST_MAIL allows to conclude that the grid used for the representation of the level sets is sufficiently refined. That shows that the keyword TEST_MAIL function correctly.

4.4 Sizes tested and results

This CAS-test is a data-processing validation of the keyword TEST_MAIL. The not-satisfaction of the intrinsic conditions to this keyword returns simply an alarm to the user.
In order to feed a file result, one proposes to add to this CAS-test, one 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 face of crack. 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	$500\sqrt{2}-(R+3\times25)$	5

5 Modeling C

5.1 Characteristics of modeling

Method GRID is used by PROPA_FISS.

5.2 Characteristics of the grid

One uses the same grid as that of modeling A .

5.3 Features tested

TEST_MAIL is irrelevant for this method of propagation. The use of this keyword is thus not authorized.
One decides nevertheless to use this CAS-test in order to check the good initialization and circular propagation of crack with this method of propagation.

5.4 Sizes 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 face of crack to 5% near.

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

6 Summary of the results

One tested a grid by using the keyword 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 grid is sufficiently refined for representing well the circular crack definite on the grid.
By representing the bottom of the initial crack and the funds obtained after each propagation, one checked that the calculated funds are correct.
One can thus conclude that the keyword TEST_MAIL allows to make a checking of grid in the automatic and very fast way.
In addition, the distances calculated with the face of crack are coherent with the theoretical values whatever the method of propagation of PROPA_FISS ('UPWIND', 'SIMPLEXE' or 'MAILLAGE')