SSLV319 - Propagation planes of a semi-elliptic crack

Summary:

The purpose of this test is to validate the plane propagation of a crack by observing the displacement of the bottom of crack at the time of propagation.

This test brings into play a paving stone with an emerging crack semi-elliptic planes, subjected to a force of traction.

The crack is represented by the method X-FEM and the propagation simulated using the order PROPA_FISS.

We will compare the results with an experimental solution.

This test contains four modelings:

Modeling A uses the method GRID of the operator PROPA_FISS.
Modeling B uses the method GEOMETRICAL of the operator PROPA_FISS.
Modeling C uses the method GEOMETRICAL of the operator PROPA_FISS, with cohesive elements. The operation is used DETECT_COHESIF for the determination of the projection of the face.
Modeling D uses the method SIMPLEX of the operator PROPA_FISS .

1 Problem of reference

1.1 Geometry

One considers a three-dimensional bar having for dimensions:

- height: LZ = 4 mm,
- dimensioned: LX = LY = 1 mm.

This bar comprises a plane, semi-elliptic crack. The crack is located in the plan Oxy . The characteristics of the cracks are the following ones:

- Demi-large axis: a = 119 µm
- half-small axis: b = 100 µm.

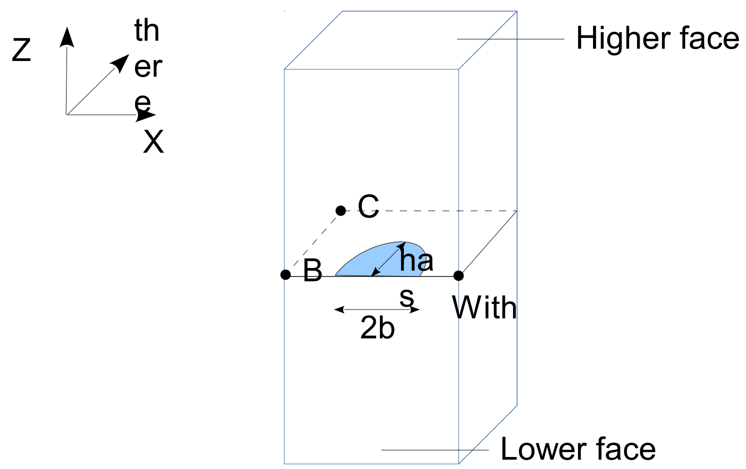


Figure 1.1-1: Geometry of the initial crack

1.2 Material properties

The material is elastic isotropic whose properties are:

$E=200\,000\,MPa$

$\nu=0{,}3$

1.3 Boundary conditions and loadings

1.3.1 Cyclic loading for study of tiredness

The structure is subjected to a loading of tiredness under constant amplitude: traction $\sigma_{max}=220\,MPa$ and a ratio $R=0{,}1$. The temperature is the room temperature. The frequency of loading is of $40\,Hz$. A loading of 4000 cycles is applied.

The tractive effort is applied to faces higher and lower.

The blocking of the rigid modes is carried out in the following way:

- the point A is blocked in the directions Oy and Oz ,
- the point B is blocked in the directions Oy and Oz ,
- the point C is blocked in the directions Ox and Oz .

1.3.2 Modeling with cohesive zones: monotonous loading

For this modeling, the loading is monotonous instead of being cyclic: the structure is subjected to a traction $\sigma_{max}=220\ MPa$. The tractive effort is applied to the faces higher and lower.

The blocking of the rigid modes is carried out in the following way:

- the point A is blocked in the directions Oy and Oz,
- the point B is blocked in the directions Oy and Oz ,
- the point C is blocked in the directions Ox and Oz .

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution was obtained by vexperimental goose 4. In this article, a digital simulation is also carried out.

2.2 Results of reference

The law of propagation in fatigue of the type Paris exits of the tests is the following one: $\frac{da}{dN}=C(\Delta K)^m$ with $C=10^{-9,2}$ and $m=3,5$. The values of the coefficients of the law of Paris are given for ΔK in $MPa.\sqrt{m}$ and a speed $\frac{da}{dN}$ in $m/cycle$.

After 4000 cycles, the major point of the bottom of crack reached the coast in experiments $y=173\,\mu m$. 1 present the experimental and numerically calculated bottom of crack after 4000 cycles.

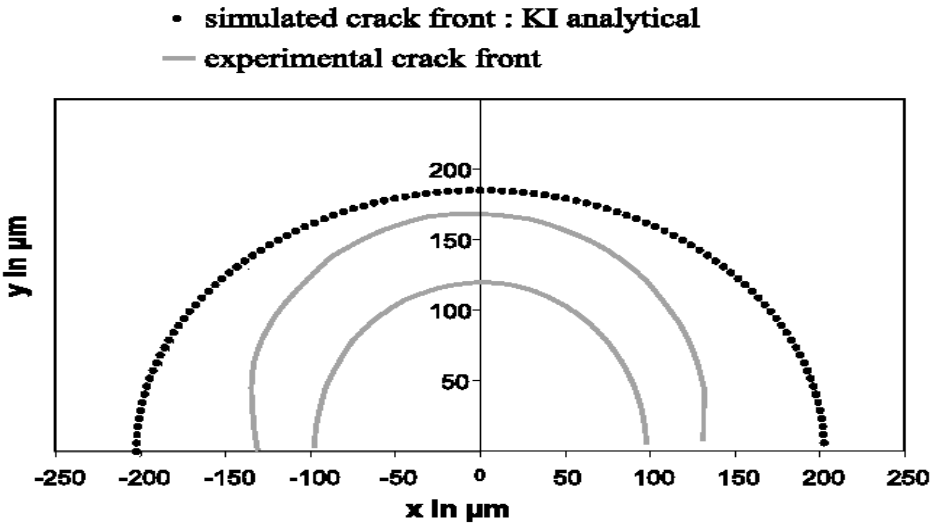


Figure2.1 1: Fund of crack

2.3 Bibliographical references

[1] E. Ferrié, J.Y. Buffière, W. Ludwig, A. Gravouil, L. Edwards, Tiredness ace propagation: In situ visualistion using X-Ray microtomography and 3D simulation using the extend finite element method, Recorded Materialia 54, pp. 1111-1122, 2006

3 Modeling a: Method `GRID`

3.1 Characteristics of modeling

In this modeling, the crack is not with a grid. One uses method X-FEM and a representation of the crack by level sets. The update of the level sets is carried out by the operator `PROPA_FISS`, method `GRID`.

3.2 Characteristics of the grid

The initial grid as of the structure is relatively coarse. It was carried out in module SMESH of Salomé, with Blsurf and GHS3D. The size defined for the surface grid Blsurf is $2\,mm$.

unit of the grid: meters

Many nodes: 2268
Number of meshs and type: 10690 `TETRA4`

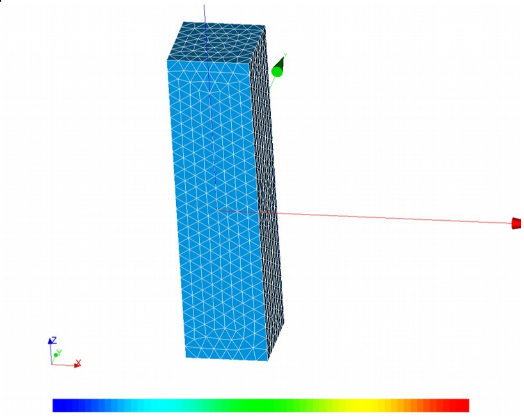
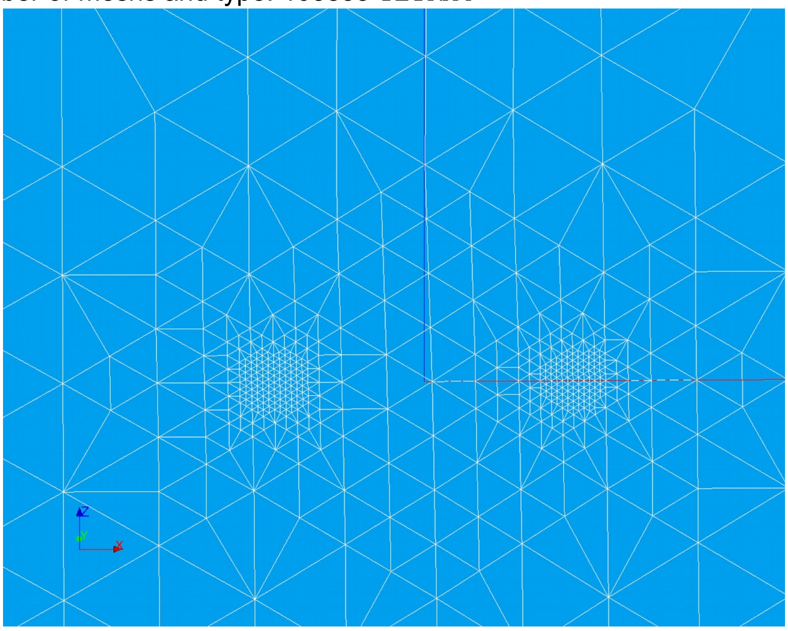
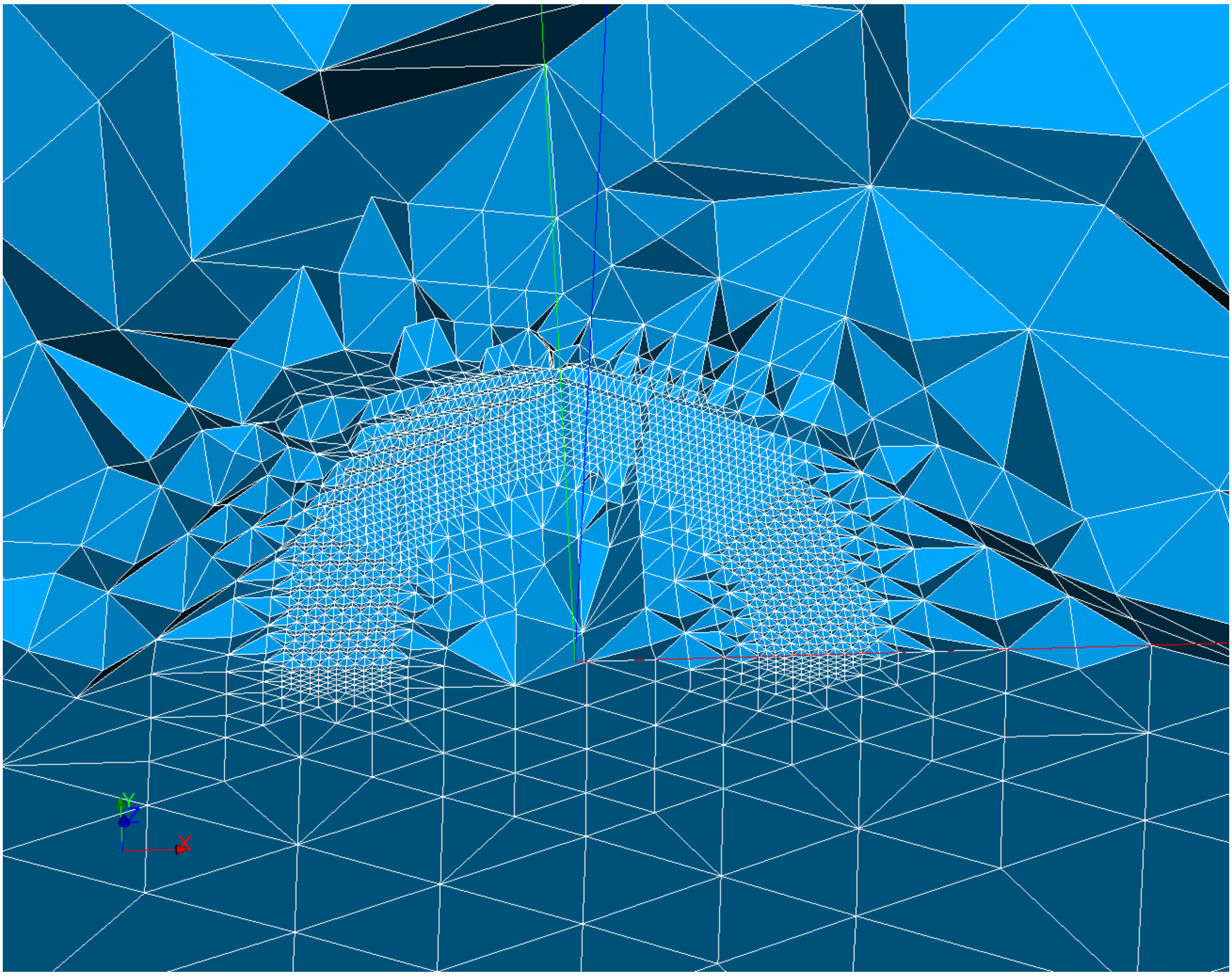


Figure 3.2-1:

An automatic procedure of refinement is installation. After refinement around the bottom of crack, the length characteristic of an element close to the bottom to crack is of $5\,\mu m$.
The refined grid has the following characteristics:

- Many nodes: 18325
- Number of meshs and type: 103853 `TETRA4`





3.3 Boundary conditions and loadings

- A tractive effort is applied to the faces higher and lower and that of right-hand side;
- One blocks the rigid modes in the following way:
  node A : $DY=DZ=0$, node B : $DY=DZ=0$, and node C : $DX=DZ=0$

3.4 Sizes tested and results

One tests the position of the point of the major bottom of crack. That amounts testing the maximum coordinate along the axis Y points of the bottom of crack after a step of propagation.

Identification	Type of reference	Value of reference	% Tolerance
$max(Y)$	'SOURCE_EXTERNE'	173.3 10^{-6}	5%

4 Modeling b: Method GEOMETRICAL

4.1 Characteristics of modeling

In this modeling, the crack is not with a grid. One uses method X-FEM and a representation of the crack by level sets. The update of the level sets is carried out by the operator PROPA_FISS, method GEOMETRICAL.

The initial grid, the boundary conditions and the loadings are identical to those of modeling A.

4.2 Sizes tested and results

One tests the position of the point of the major bottom of crack. That amounts testing the maximum coordinate along the axis Y points of the bottom of crack after a step of propagation.

Identification	Type of reference	Value of reference	% Tolerance
$max(Y)$	'SOURCE_EXTERNE'	173.3 10^{-6}	5%

5 Modeling C: validation of DETECT_COHESIF

5.1 Characteristics of modeling

In this modeling, the initial crack is with a grid. It is prolonged in its plan by a zone of cohesive cracking, represented by level sets and whose discontinuity is described by the method XFEM. The law CZM_LIN_MIX is introduced into the model XFEM by the order DEFI_CONTACT.

A load of traction *monotonous* is applied : the cohesive zone opens, thus propagating the crack. At the end of calculation, a detection of the new face of propagation is carried out, which determines the limiting upstream of the cohesive zone. It is carried out by the operator PROPA_FISS, with the method GEOMETRICAL, by specifying the operation DETECT_COHESIF (OPERATION = 'DETECT_COHESIF').

5.2 Characteristics of the grid

The grid rather coarse, but is refined on the level of the point of initial crack. For more regularity of the detected face, it is about a grid radiating around the point.
Many nodes: 18167
Number of meshs and type: 15120 HEXA8 and 2440 PENTA6

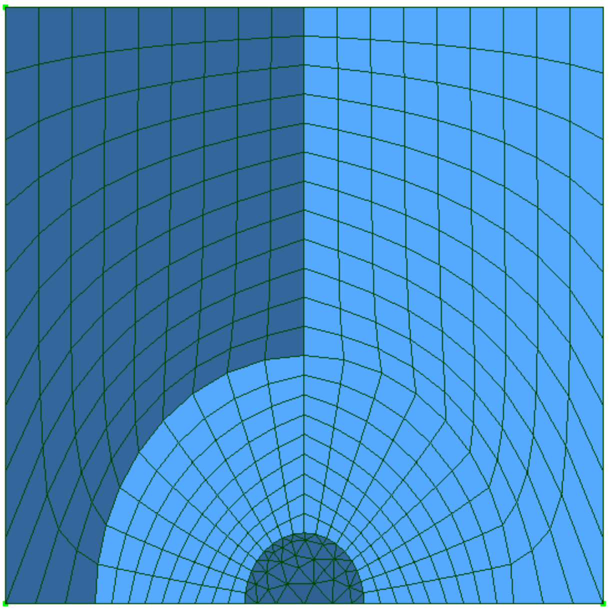


Figure 5.2-1: sight in plan of cut of fissured surface and radiant grid

5.3 Sizes tested and results

The validation is done on the projection of the face detected after this first step of propagation. For lack of experimental data for a monotonous loading, it acts of a test of nonregression. We represented in figure 5.3-1 make of crack initial and the face detected after the first step of propagation. Although we do not have a quantitative reference, we notice that the qualitative pace of the face is similar to that of the experiments of tiredness.

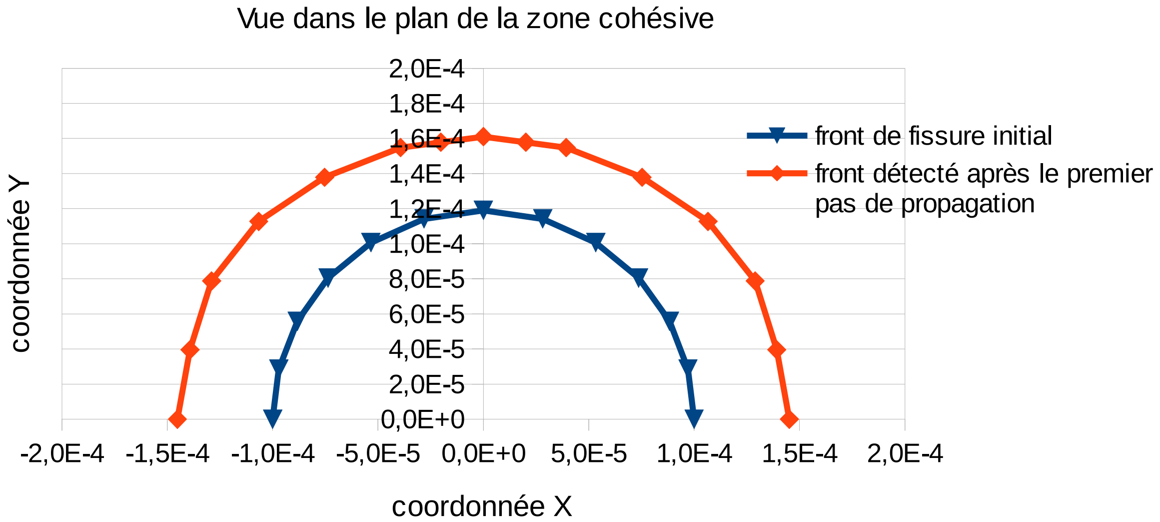


Figure 5.3-1: initial face and face detected after the first step of propagation

One tests the position of the point of the major bottom of crack. That amounts testing the maximum coordinate along the axis Y points of the bottom of crack after a step of propagation.

Identification	Type of reference	Value of reference	% Tolerance
$max(Y)$	'NON_REGRESSION'	$1.61048\ 10^{-4}$	0.1%

6 Modeling D: Method SIMPLEX

6.1 Characteristics of modeling

In this modeling, the crack is not with a grid. One uses method X-FEM and a representation of the crack by level sets. The update of the level sets is carried out by the operator PROPA_FISS, method SIMPLEX.
The initial grid, the boundary conditions and the loadings are identical to those of modeling A.

6.2 Sizes tested and results

One tests the position of the point of the major bottom of crack. That amounts testing the maximum coordinate along the axis Y points of the bottom of crack after a step of propagation.

Identification	Type of reference	Value of reference	% Tolerance
$max(Y)$	'SOURCE_EXTERNE'	$173.3\ 10^{-6}$	5%

7 Summary of the results

This CAS-test validates the update of the level sets following a step of plane propagation with the method GRID, method GEOMETRICAL and method SIMPLEX.