SSNV513 – Block cut out by three interfaces sequentially connecting with X-FEM

Summary:

This test makes it possible to validate the approach junction with X-FEM. It is about a case test where three cracks are introduced. The first crack cuts the field completely. The second connects on the first via the keyword `JUNCTION` of the operator `DEFI_FISS_XFEM`. The third connects on the second. One tests the approach with and without contact.

1 Problem of reference

1.1 Geometry

The structure is a healthy square into which one introduces three interfaces, in red on the figure 1.1-a. First is oblique and entirely cuts the field. Second is vertical. It connects on the first. Third is horizontal. It connects on the second. Dimensions of the structure as well as the position of the interfaces are given on the figure 1.1-a and are expressed in meters, $[\mathrm{m}]$.

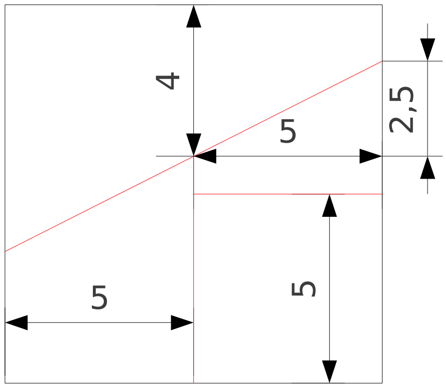

Figure 1.1-a: Geometry of the structure and positioning of the interfaces.

1.2 Properties of material

The material has an isotropic elastic behavior defined by the parameters material following:
Young modulus: $100\,\mathrm{MPa}$
Poisson's ratio: 0.3

1.3 Boundary conditions and loadings

In the case without contact (modelings A with D), one applies conditions in displacement to the edges left and right of the structure, so that each of the 4 zones has a displacement different from the others according to X . This loading is represented figure 1.3-a. One blocks displacements in Y (and in Z for modelings 3D) on these same edges.

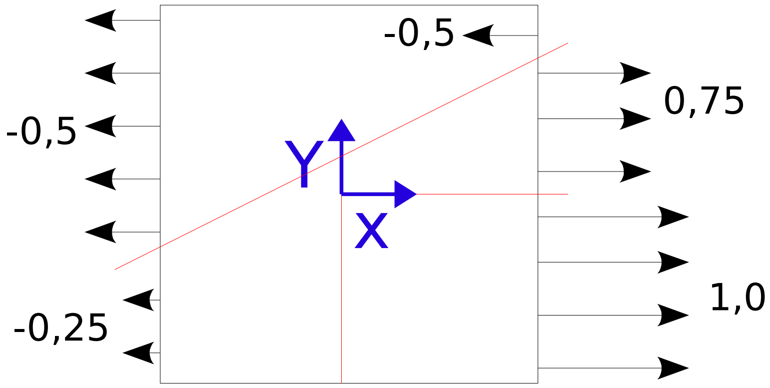

Figure 1.3-a: Illustration of the boundary conditions and the loadings, cases without contact.

In the case of the contact (modelings E with H), one imposes conditions of roller on the edges left and low and one applies a homogeneous pressure to the flat rims and high of $1\ \text{MPa}$. This loading is represented figure 1.3-b. Each block is then compressed in a uniform way according to X and Y.

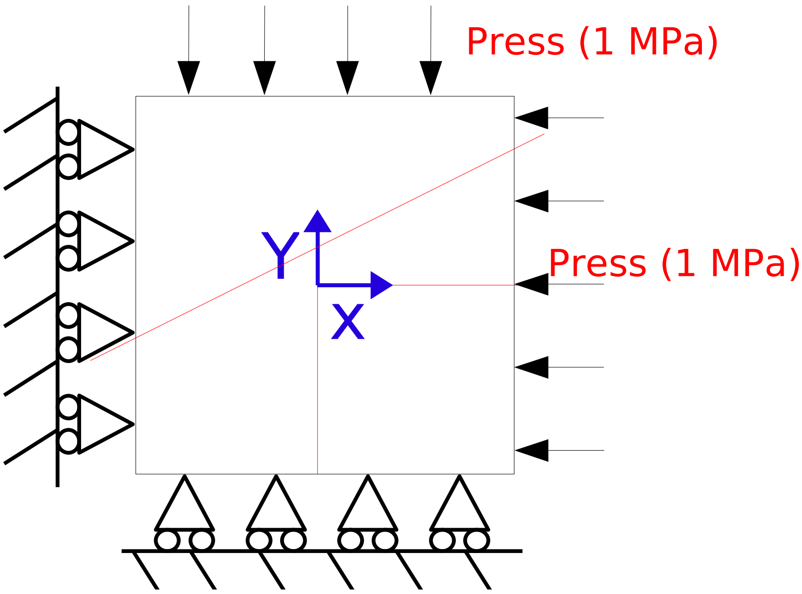

Figure 1.3-b: Illustration of the boundary conditions and the loadings, cases with contact.

2 Reference solution

Without contact, each zone must undergo a rigid movement of body corresponding to the limiting condition imposed on its edge (right or left).

With contact, the 4 blocks undergo a uniform compression according to X and Y. One can express displacement structure in the following way :

$$Depl_X(X) = -(5+X)\frac{Press}{E}$$

éq 2.1-1

$$Depl_Y(Y) = -(5+Y)\frac{Press}{E}$$

éq 2.1-2

3 Modeling A

3.1 Characteristics of modeling

It is about a modeling X-FEM, in plane deformations (D_PLAN). The interfaces are defined by functions of levels (level sets noted normals LN).

The equations of the functions of levels for the oblique interfaces, horizontal and vertical are the following ones:

$$\mathrm{LN}\,1 = Y - 1 - \frac{X}{2}$$

éq 3.1-1

$$LN2=Y$$ éq 3.1-2

$$LN3=X$$ éq 3.1-3

The oblique interface is defined in a classical way by using the operator DEFI_FISS_XFEM with the level set normal $LN1$. To define the vertical interface, the operator is invited DEFI_FISS_XFEM with the level set normal $LN2$, by defining a connection with the crack obliques via the keyword JUNCTION, and by choosing a point "in lower part" of the interface obliques in the operand NOT. This stage makes it possible to define crack 2 in the field below the first (see figure 3.1-a in the center).
To define the horizontal interface, the operator is invited DEFI_FISS_XFEM with the level set normal $LN3$, by defining a connection with the vertical crack via the keyword JUNCTION, and by choosing a point "on the right" in the operand NOT. This stage makes it possible to define crack 3 in the field on the right of the second crack (see figure 3.1-a on the right).

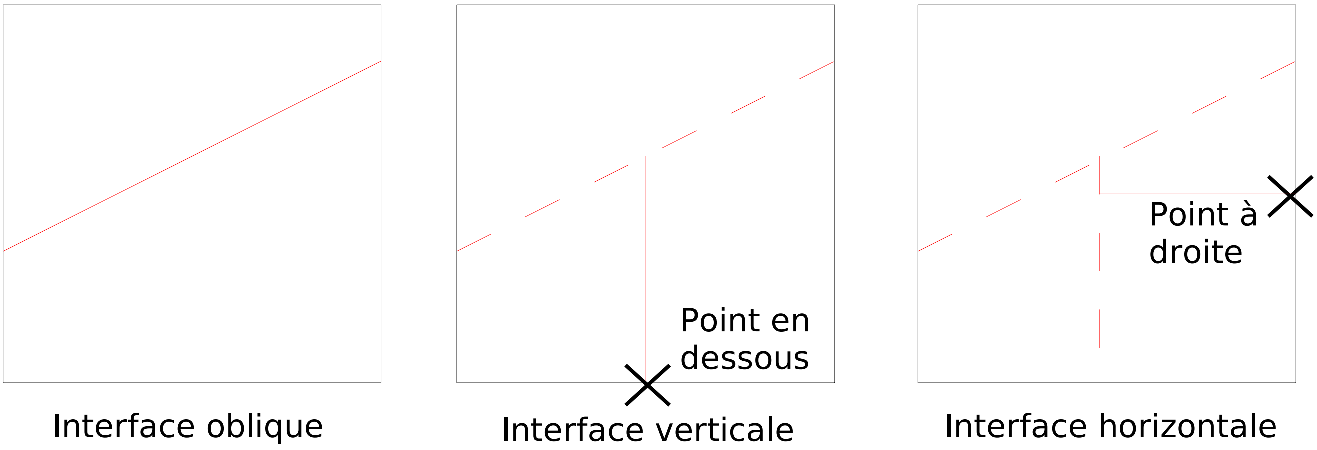

Figure 3.1-a: Stages of construction of the intersection.

3.2 Characteristics of the grid

The grid which comprises 25 meshs of the type QUAD4 is represented on the figure 3.2-a.
One notices on this figure that the central mesh is cut by the three interfaces. This test thus makes it possible to validate multiple cutting. The nodes of this mesh are nouveau riches 3 times: they thus have the degrees of freedom DX, DY, H1X, H1Y, H2X, H2Y, H3X and H3Y.

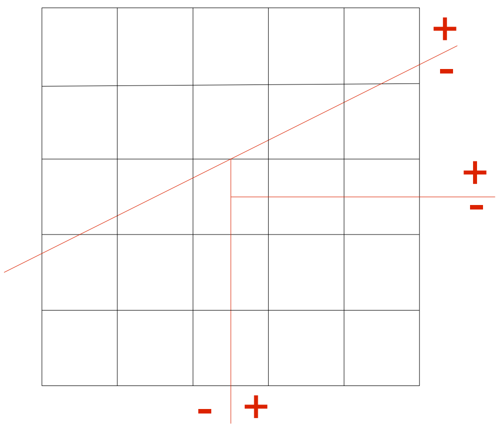

Figure 3.2-a: Grid of modeling A.

The interest of this test is to check Que the addition of 3 functions of discontinuity to the function of form standard for each node of the central mesh makes it possible to represent the kinematics of displacement of the 4 fields generated by the two connections (even figure 3.2-b).

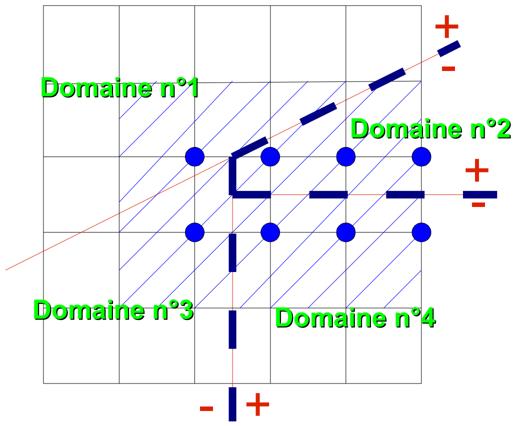

Figure 3.2-b: multi-Heaviside nodes and fields of discontinuity represented.

3.3 Features tested

The operator is tested DEFI_FISS_XFEM with the use of the keyword JUNCTION, which makes it possible to define connections of cracks in X-FEM. One tests also the operator MODI_MODELE_XFEM in the case of the meshs which are cut by several cracks. Multi-Heaviside and multi-storage remove the structure from Data (SD) X-FEM is of course activated. One checks the attribution of the Heaviside functions under elements of integration of the support of the horizontal crack (in blue on the figure 3.2-b).
One tests the assembly of ddegrés of Heavisides freedom on the level of the matrices and the second members of the elements connected to the intersection for the option BEHAVIOR in STAT_NON_LINE.
One validates also postprocessing X-FEM in the case of multi-cutting, with the operators POST_MAIL_XFEM and POST_CHAM_XFEM.

3.4 Sizes tested and results

Displacements are tested on the level of the lips of the cracks after having carried out the operations of postprocessings relative to X-FEM (`POST_MAIL_XFEM` and `POST_CHAM_XFEM`). Displacement `DX` must correspond to the loading imposed of the figure 1.3-a on each zone and `DY` must be null. One tests the values minimum and maximum on the lips of each zone.

Identification			Reference	% tolerance
DEPZON_1	DX	MIN	-0.25	1.00E-11
		MAX	-0.25	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_2	DX	MIN	-0.5	1.00E-11
		MAX	-0.5	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_3	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_4	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11

Table 3.4-1

The deformation is represented on the figure 3.4-a. The code color represents the field of displacement.

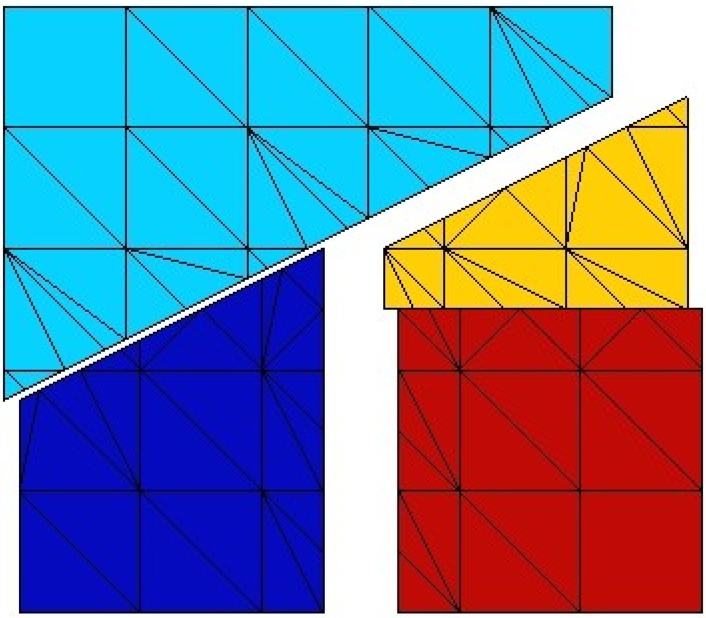

Figure 3.4-a: Deformation of the structure.

3.5 Remarks

One gets very good results for this test, the raised error corresponding to the digital residue.

4 Modeling B

4.1 Characteristics of modeling

It is acted of the same modeling as modeling A, but as plane constraints (C_PLAN). The junctions are built same manner.

4.2 Characteristics of the grid

The grid which comprises 54 meshs of the type TRIA3 is represented on the figure 4.2-a. The grid is refined sufficiently little to be found in the same situation as for modeling A (figure 4.2-b).

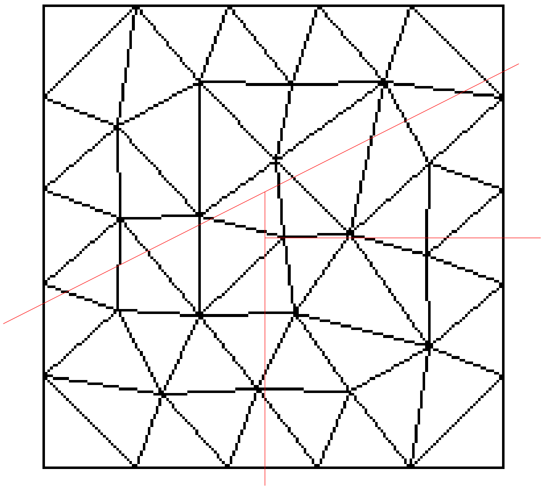

Figure 4.2-a: Grid of modeling B.

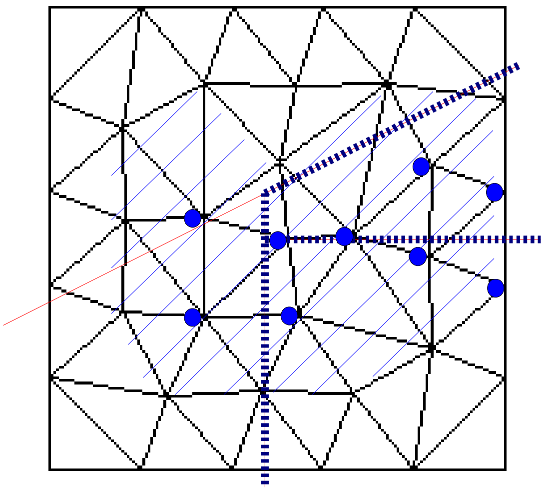

Figure 4.2-b: Value of the Heaviside function for the horizontal crack and its support.

4.3 Sizes tested and results

The sizes tested are identical to those presented for modeling A.

Identification			*Reference*	*% tolerance*
DEPZON_1	DX	MIN	-0.25	1.00E-11
		MAX	-0.25	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_2	DX	MIN	-0.5	1.00E-11
		MAX	-0.5	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_3	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_4	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11

Table 4.3-1

The deformation is represented on the figure 4.4-a.

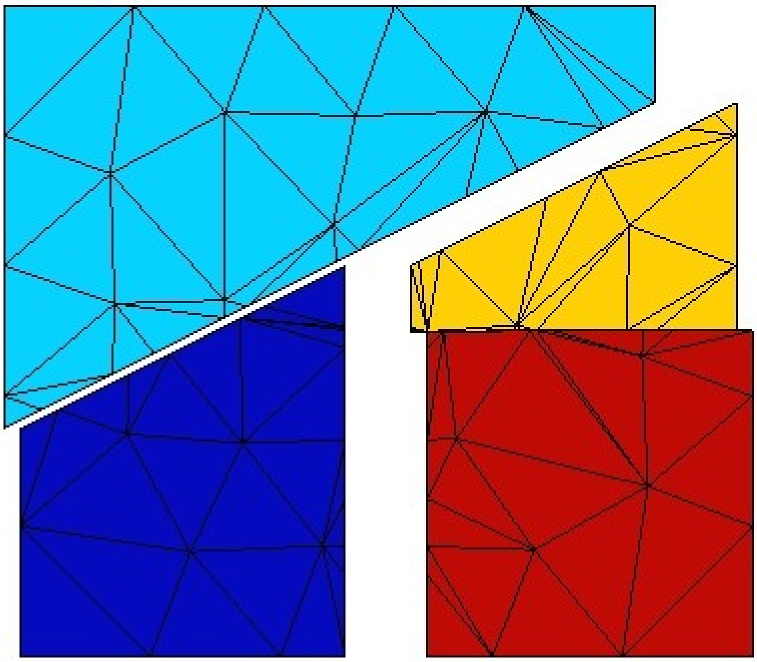

Figure 4.4-a: Deformation of the structure.

4.4 Remarks

The remarks are identical to those specified for modeling A.

5 Modeling C

5.1 Characteristics of modeling

It is the same modeling as modeling A, but in 3D. The intersection is built same manner.

5.2 Characteristics of the grid

The grid which comprises 25 meshs of the type HEXA8 is represented on the figure 5.2-a. The grid is refined sufficiently little to be found in the same situation as in the case of modeling A.

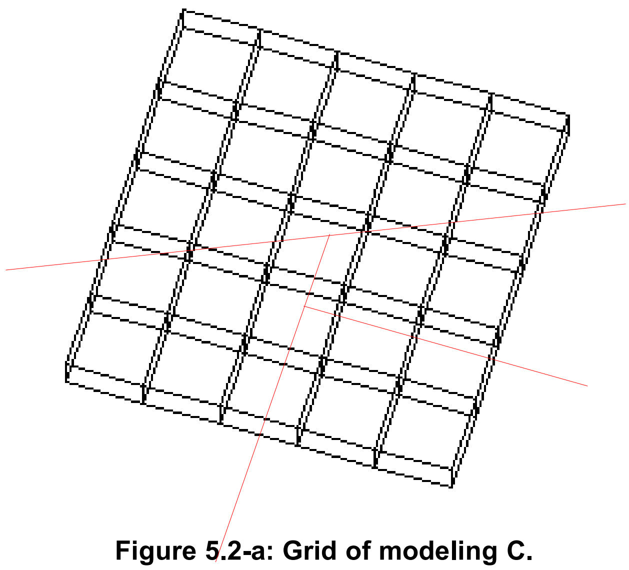

Figure 5.2-a: Grid of modeling C.

5.3 Sizes tested and results

The sizes tested are identical to those presented for modeling A and one adds tests on DZ.

Identification			***Reference***	***% tolerance***
DEPZON_1	DX	MIN	-0.25	1.00E-11
		MAX	-0.25	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_2	DX	MIN	-0.5	1.00E-11
		MAX	-0.5	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_3	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_4	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11

Table 5.3-1

The deformation is represented on the figure 5.4-a.

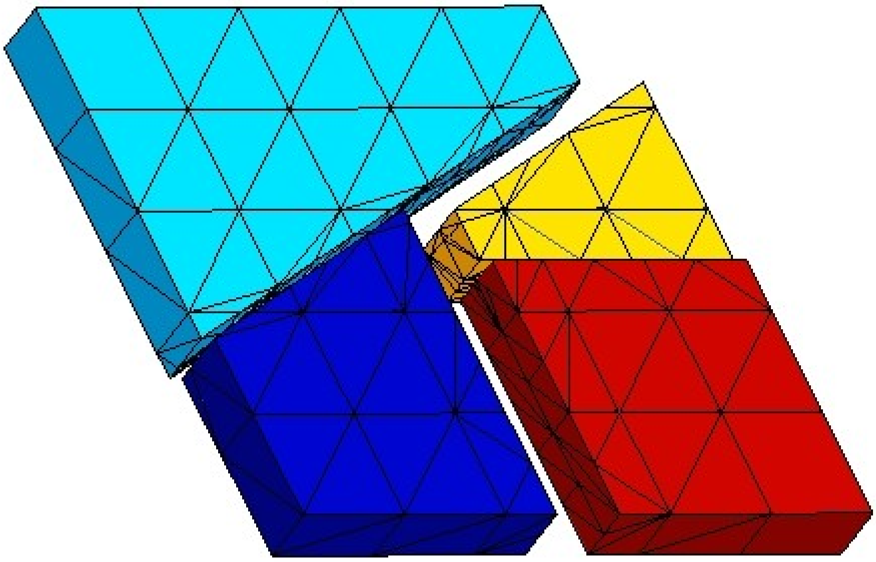

Figure 5.4-a: Deformation of the structure.

5.4 Remarks

The remarks are identical to those specified for modeling A.

6 Modeling D

6.1 Characteristics of modeling

It is the same modeling as modeling C.

6.2 Characteristics of the grid

The grid which comprises 162 meshs of the type `TETRA4` is represented on the figure 6.2-a. The grid is refined sufficiently little to be found in the same situation as in modeling A.

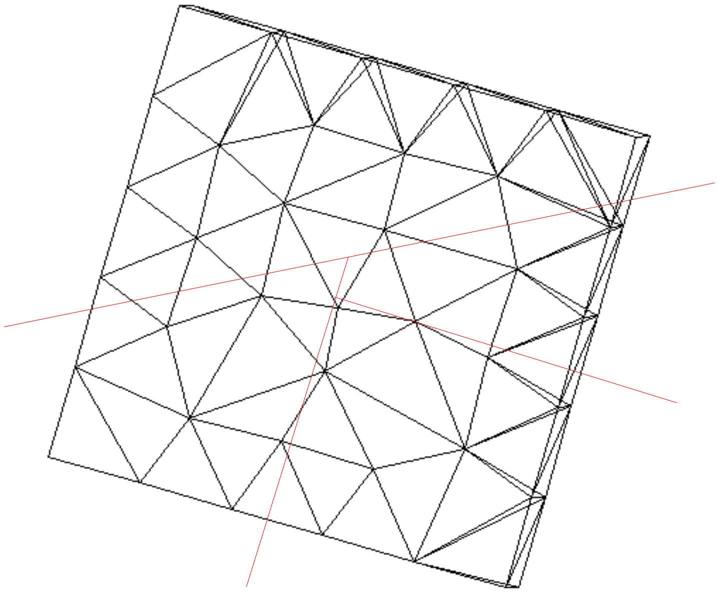

Figure 6.2-a: Grid of modeling D.

6.3 Sizes tested and results

The sizes tested are identical to those presented for modeling C.

Identification			***Reference***	***% tolerance***
DEPZON_1	DX	MIN	-0.25	1.00E-11
		MAX	-0.25	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_2	DX	MIN	-0.5	1.00E-11
		MAX	-0.5	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_3	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11
DEPZON_4	DX	MIN	0.75	1.00E-11
		MAX	0.75	1.00E-11
	DY	MIN	0	1.00E-11
		MAX	0	1.00E-11

Table 6.3-1

The deformation is represented on the figure 6.4-a.

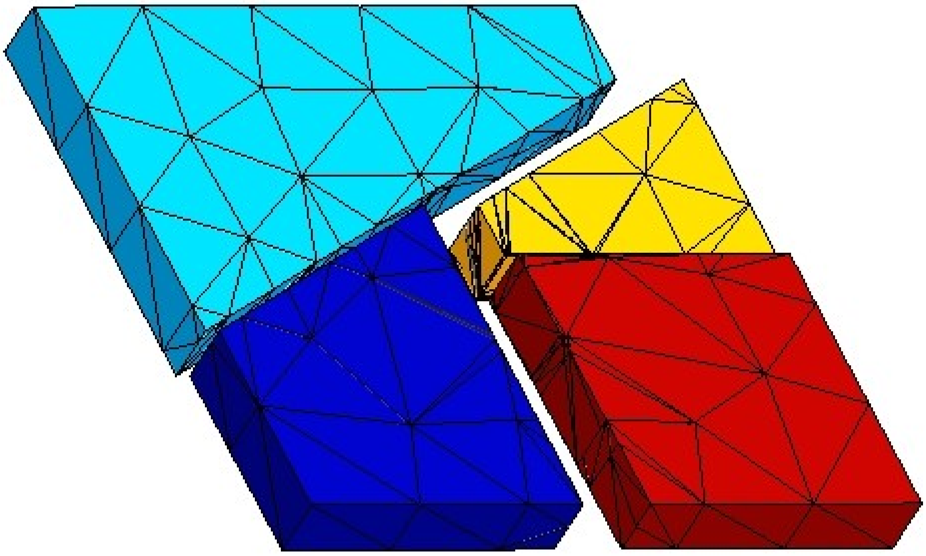

Figure 6.4-a: Deformation of the structure.

6.4 Remarks

The remarks are identical to those specified for modeling A.

7 Modeling E

7.1 Characteristics of modeling

It is the same modeling that modeling A, but the conditions of loading in contact are applied. The junctions are built with X-FEM and the functions of levels in the same way as for modeling A.

7.2 Characteristics of the grid

The grid identical to that of modeling A, is represented figure 3.2-a. Let us note that the nodes of the mesh cut by the 3 cracks are nouveau riches 3 times, they thus have the degrees of freedom of contact LAGS_C , LAG2_C and LAG3_C besides degrees of freedom kinematics.

7.3 Features tested

One tests the functionality already presented for modeling A. One in the case of tests also contact X-FEM junctions with X-FEM via the operator DEFI_CONTACT.

7.4 Sizes tested and results

Displacements are tested on the level of the lips of the cracks after having carried out the operations of postprocessings relative to X-FEM (POST_MAIL_XFEM and POST_CHAM_XFEM). Displacement DX must follow the function $Depl_X$ equation 2.1-1. Displacement DY must follow the function $Depl_Y$ equation 2.1-2. One obtains the deformation of the figure 7.4-a.

Identification			Reference	tolerance
DEPZON_1	DX- $Depl_X$	MIN	0	0.06
		MAX	0	0.06
	DY $Depl_Y$	MIN	0	0.06
		MAX	0	0.06
DEPZON_2	DX- $Depl_X$	MIN	0	0.06
		MAX	0	0.06
	DY $Depl_Y$	MIN	0	0.06
		MAX	0	0.06
DEPZON_3	DX- $Depl_X$	MIN	0	0.06
		MAX	0	0.06
	DY $Depl_Y$	MIN	0	0.06
		MAX	0	0.06
DEPZON_4	DX- $Depl_X$	MIN	0	0.06
		MAX	0	0.06
	DY $Depl_Y$	MIN	0	0.06
		MAX	0	0.06

Table 7.4-1

The deformation is represented on the figure 7.4-a. The code color represents the field of displacement.

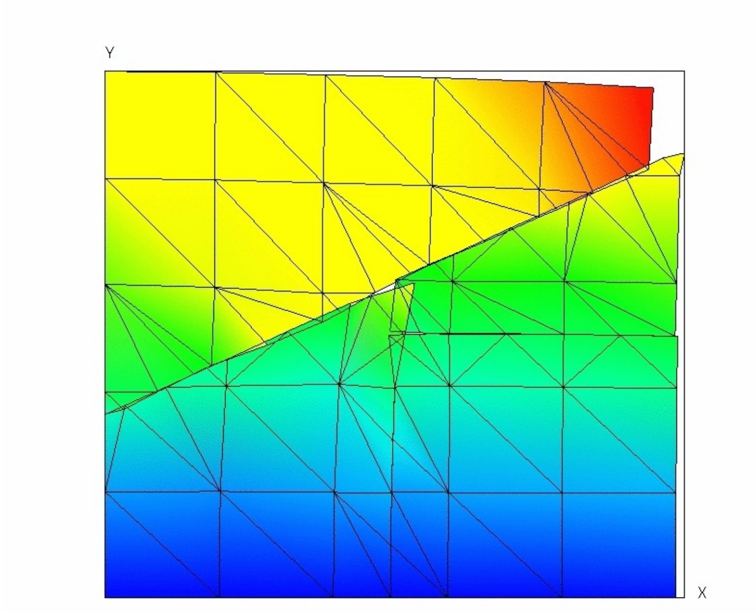

Figure 7.4-a: Deformation of the structure (exaggeration 10).

7.5 Remarks

A high error is obtained. Indeed the implementation of the recutting of the facets of contact was not implemented. The efforts of contact on these facets are not taken into account in calculation. The zone affected relates to in particular the junction points (which one does not test) as well as the elements the container. Let us note that the results are clearly to improve when the grid is refined.

8 Modeling F

8.1 Characteristics of modeling

It is acted of the same modeling as modeling E, but as plane constraints. The junctions are built same manner.

8.2 Characteristics of the grid

The grid identical to that of modeling B, is represented on the figure 4.2-a.

8.3 Sizes tested and results

The sizes tested are identical to those presented for modeling E.

Identification			Reference	tolerance
DEPZON_1	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05
DEPZON_2	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05
DEPZON_3	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05
DEPZON_4	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05

Table 8.3-1

The deformation is represented on the figure 8.4-a.

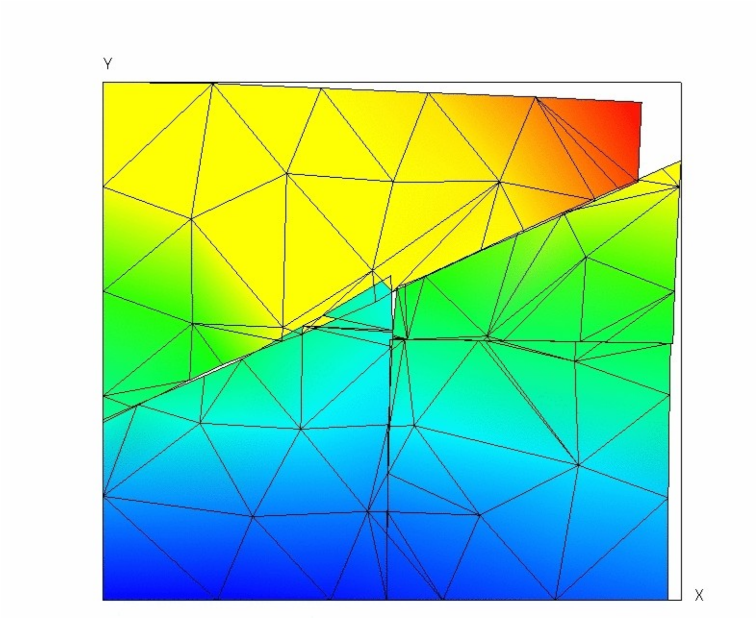

Figure 8.4-a: Deformation of the structure (exaggeration 10).

8.4 Remarks

The remarks are identical to those formulated for modeling E.

9 Modeling G

9.1 Characteristics of modeling

It is the same modeling as modeling E, but in $3D$. The junctions are built same manner.

9.2 Characteristics of the grid

The grid identical to that of modeling C, is represented on the figure 5.2-a.

9.3 Sizes tested and results

The sizes tested are identical to those presented for modeling E. One adds tests on DZ.

Identification			Reference	tolerance
DEPZON_1	DX- $Depl_X$	MIN	0	0.07
		MAX	0	0.07
	DY $Depl_Y$	MIN	0	0.07
		MAX	0	0.07
DEPZON_2	DX- $Depl_X$	MIN	0	0.07
		MAX	0	0.07
	DY $Depl_Y$	MIN	0	0.07
		MAX	0	0.07
DEPZON_3	DX- $Depl_X$	MIN	0	0.07
		MAX	0	0.07
	DY $Depl_Y$	MIN	0	0.07
		MAX	0	0.07
DEPZON_4	DX- $Depl_X$	MIN	0	0.07
		MAX	0	0.07
	DY $Depl_Y$	MIN	0	0.07
		MAX	0	0.07

Table 9.3-1

The deformation is represented on the figure 9.4-a.

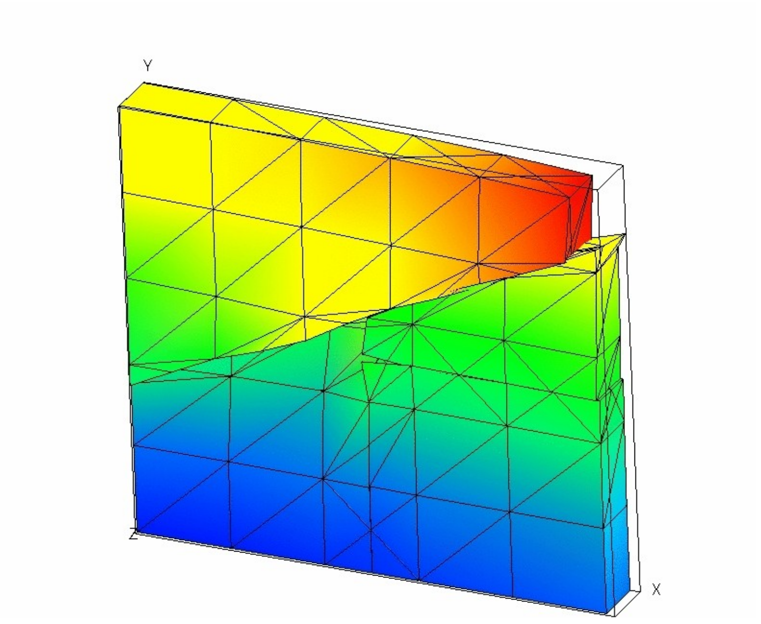

Figure 9.4-a: Deformation of the structure (exaggeration 10).

9.4 Remarks

The remarks are identical to those formulated for modeling E.

10 Modeling H

10.1 Characteristics of modeling

It is the same modeling as modeling G.

10.2 Characteristics of the grid

The grid identical to that of modeling D, is represented on the figure 6.2-a.

10.3 Sizes tested and results

The sizes tested are identical to those presented for modeling G.

Identification			Reference	tolerance
DEPZON_1	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05
DEPZON_2	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05
DEPZON_3	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05
DEPZON_4	DX- $Depl_X$	MIN	0	0.05
		MAX	0	0.05
	DY $Depl_Y$	MIN	0	0.05
		MAX	0	0.05

Table 10.3-1

The deformation is represented on the figure 10.4-a.

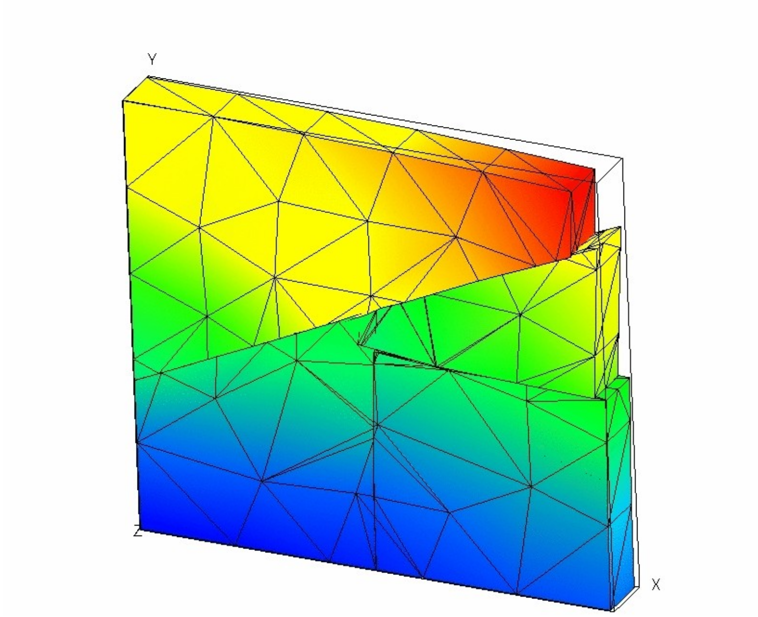

Figure 10.4-a: Deformation of the structure (exaggeration 10).

10.4 Remarks

The remarks are identical to those formulated for modeling E.

11 Summary of the results

It is possible to represent the junction of a crack for a crack already resulting from a junction. The two junctions can be close and it is not necessary to refine the grid in the zone which contains the 2 junctions.
The approach was validated in $2D$ for modelings `C_PLAN` and `D_PLAN` and for the elements of the type `QUAD4` and `TRIA3`. One also validated the approach in $3D$ for the elements `HEXA8` and `TETRA4` with and without contact.