SSNV511 – Block cut out by two interfaces intersected with X-FEM

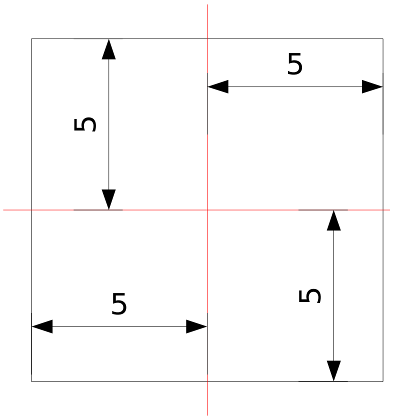
Summarized:

This test makes it possible to validate the approach intersection with X-FEM. It is about a case test where three cracks are introduced. The first crack cuts the field completely. The two other cracks are defined by the same level-set norm. They are connected on both sides of the first via key word JONCTION of operator DEFI_FISS_XFEM . The double junction forms an intersection then. One tests the approach with or without contact.

1 Problem of reference

1.1 Geometry

the structure is a healthy square into which one introduces two interfaces, in red on the figure 1.1-a. The two interfaces cross, dimensions of structure as well as the position of the interfaces are given on this figure.



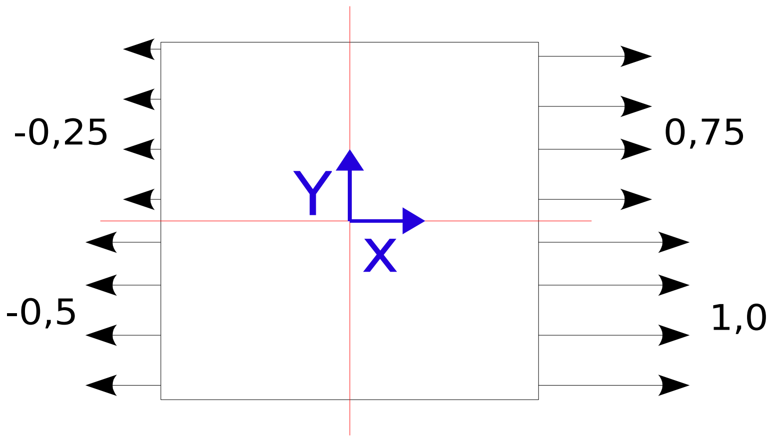
Appear 1.1-a: Geometry of structure and positioning of the interfaces.

1.2 Properties of the material

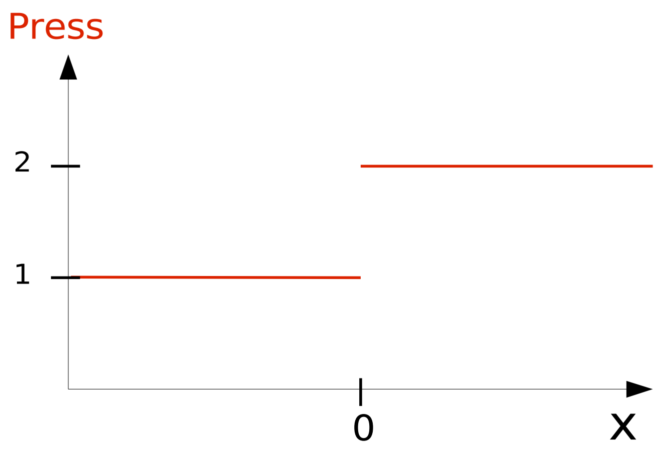
the material has an isotropic elastic behavior whose properties are:
Young modulus: $100\,MPa$
Poisson's ratio: 0.3

1.3 Boundary conditions and loadings

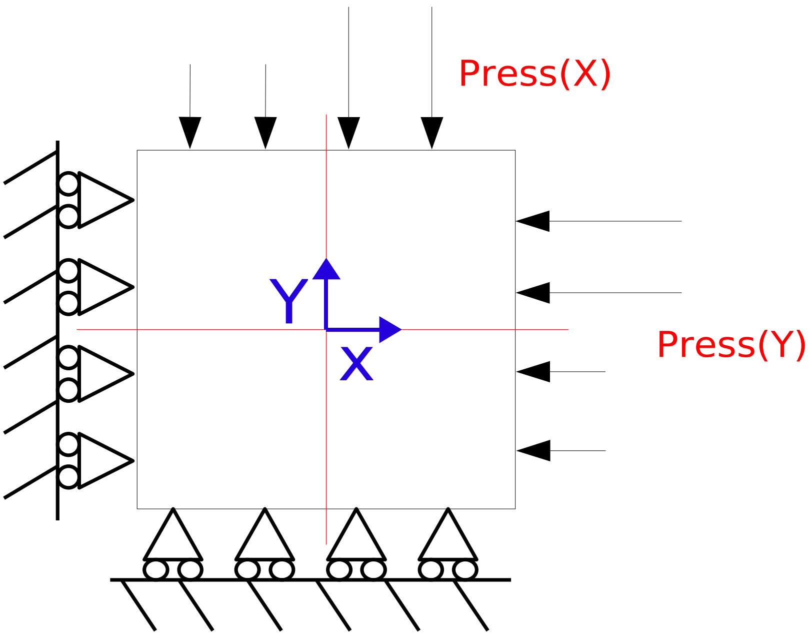
In the case without contact (modelizations A with D), one applies conditions in displacement to the edges left and right of structure, so that each of the 4 zones has a displacement different from the others according to X. This loading is represented figure 1.3-a. One blocks displacements in Y (and in Z for the modelizations $3\mathrm{D}$) on these same edges. One then obtains displacements of rigid modes for the 4 blocks.
In the case of the contact (modelizations E with H), one imposes conditions of roller on the edges left and low and one applies the pressure in staircase of the figure 1.3-b to flat rims and high. This loading is represented figure 1.3-c. Each block is then compressed in a uniform way according to X and Y.



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



Appear 1.3-b: Pressure imposed according to X on high edge and according to Y flat rim, (in MPa).



Appear 1.3-c: Illustration of the boundary conditions and the loadings, cases with contact.

2 Reference solution

Without contact, each zone must undergo a rigid body motion 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 the displacement of structure in the following way :

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

éq 2.1-1

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

éq 2.1-2

3 Modelization A

3.1 Characteristic of the modelization

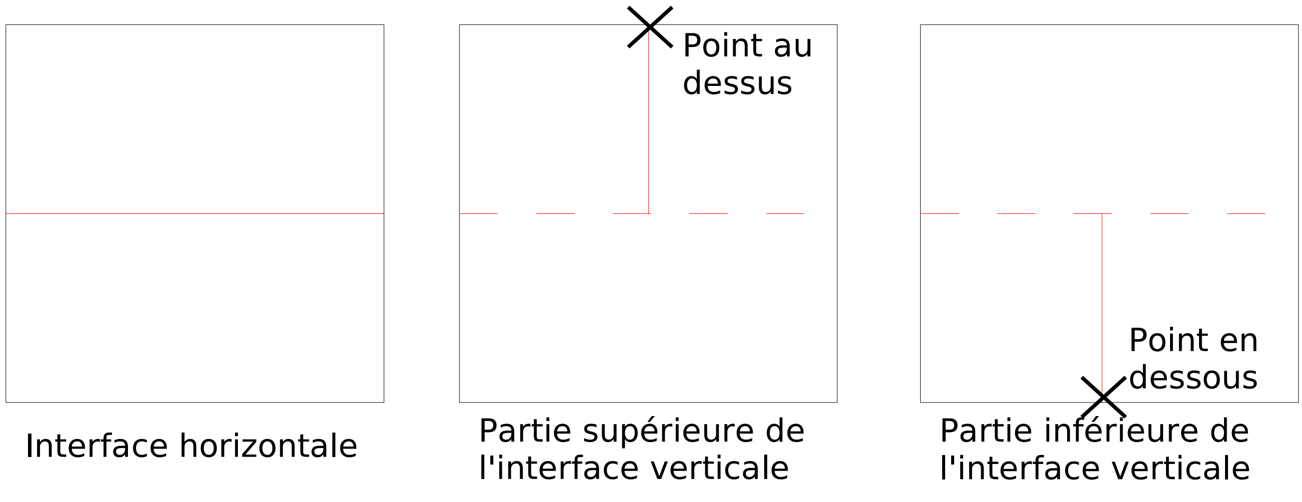
It acts of a modelization X-FEM, in plane strains. The interfaces are defined by functions of levels (level sets noted norms LN).

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

$$\mathrm{LN}1=Y$$ éq 3.1-1

$$\mathrm{LN}2=X$$ éq 3.1-2

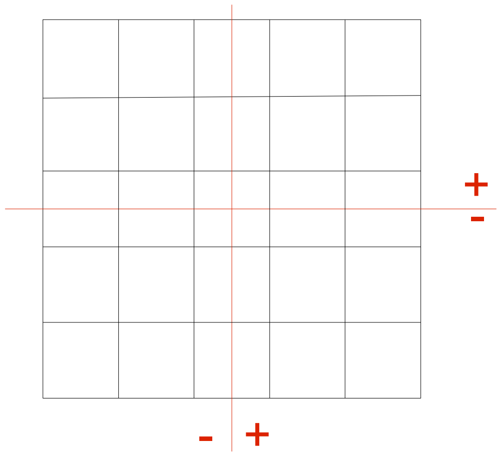
the horizontal interface is defined in a classical way by means of operator `DEFI_FISS_XFEM` with the level set norm $\mathrm{LN1}$.
To define the vertical interface, one proceeds in two stages. One calls for the first time operator `DEFI_FISS_XFEM` with the level set norm $\mathrm{LN2}$, by defining a point "in the top" of horizontal crack for key word `JONCTION` (the point is not obligatorily on the level set). This stage makes it possible to define the upper part of the vertical interface (see figure 3.1-a in the center). One for the second time calls operator `DEFI_FISS_XFEM` in the same way, but by defining a point "in lower part" of crack (see figure 3.1-a on the right).
One thus invited on the whole 3 times `DEFI_FISS_XFEM` (creation of 3 cracks objects) to define the two interfaces which are intersected. From a theoretical point of view, each object fissures addition an enrichment of the Heaviside type. What makes a total of three Heaviside degrees of freedom besides the classical degrees of freedom. There are thus well 4 degree of freedom on the level of the intersection, which makes it possible to move of way independent the 4 zones generated by the 2 interfaces.



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

3.2 Characteristics of the mesh

The mesh which comprises 25 meshes type `QUAD4`, is represented on the figure 3.2-a.
One notices on this figure that the central mesh is cut by the two interfaces. This test thus makes it possible to validate multiple cutting. Let us note that 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 $H3Y$.



Appear 3.2-a: The mesh of modelization A.

3.3 Fonctionnalités tested

One tests operator DEFI_FISS_XFEM with the use of the key word JONCTION, which makes it possible to define crack connections in X-FEM. One in the case of tests also operator MODI_MODELE_XFEM meshes which is cut by several cracks. Multi-Heaviside and the multi-storage of data structures X-FEM are of course activated.
One tests the assembly of the Heavisides degrees of freedom on the level of the matrixes and the second members of the elements connected to intersection for the option COMP_ELAS in STAT_NON_LINE.
One in the case of validates also X-FEM postprocessing multi-cutting, with operators POST_MAIL_XFEM and POST_CHAM_XFEM.

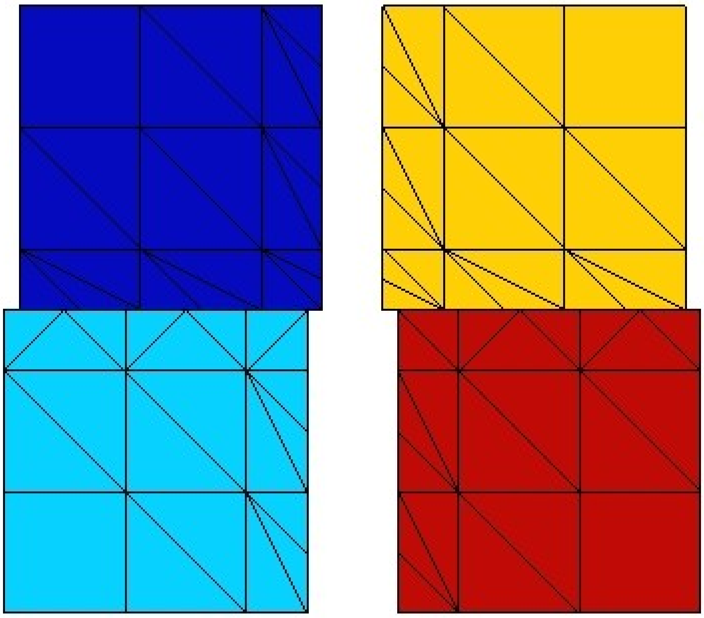
3.4 Quantities tested and results

One tests displacements on the level of the lips of 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 min and the max on the lips of each zone.

Identification			*Reference*
DEPZON_1	DX	MIN	-0.25
		MAX	-0.25
	DY	MIN	0
		MAX	0
DEPZON_2	DX	MIN	-0.5
		MAX	-0.5
	DY	MIN	0
		MAX	0
DEPZON_3	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0
DEPZON_4	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0

Table 3.4-1

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



Appear 3.4-a: Deformed shape of structure.

3.5 Remarks

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

4 Modelization B

4.1 Characteristic of the modelization

It is acted of the same modelization as the modelization A, but as plane stresses. The intersection is built same way.

4.2 Characteristics of the mesh

The mesh which comprises 54 meshes type `TRIA3` is represented on the figure 4.2-a.

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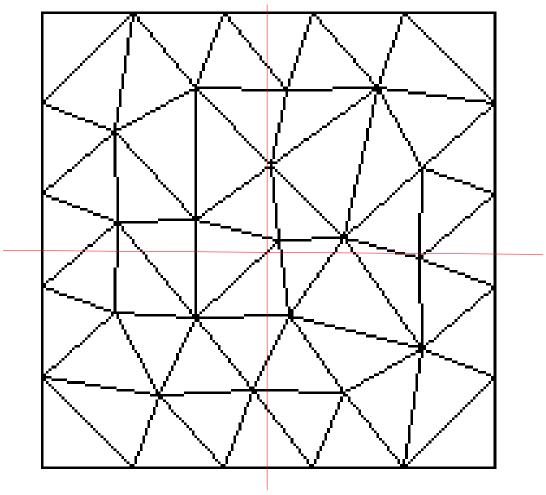


Figure 4.2-a : The mesh of the modelization B.

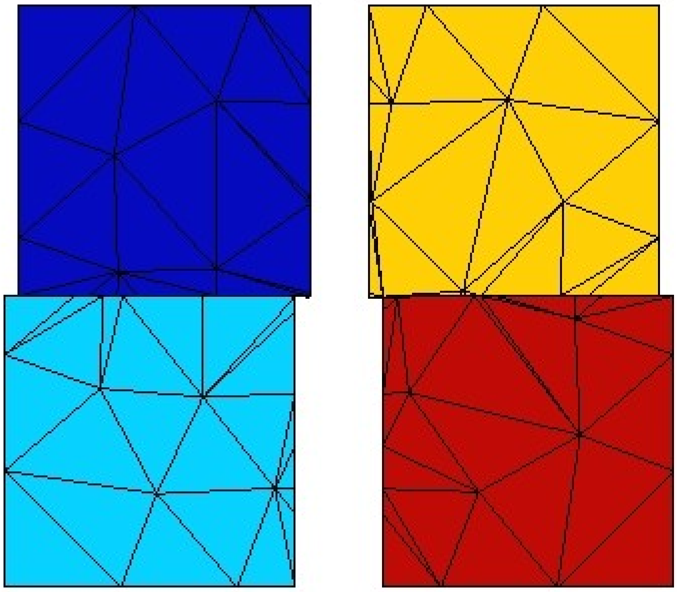
4.3 Quantities tested and results

the quantities tested are identical to those presented for modelization A.

Identification			*Reference*
DEPZON_1	DX	MIN	-0.25
		MAX	-0.25
	DY	MIN	0
		MAX	0
DEPZON_2	DX	MIN	-0.5
		MAX	-0.5
	DY	MIN	0
		MAX	0
DEPZON_3	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0
DEPZON_4	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0

Table 4.3-1

the deformed shape is represented on the figure 4.4-a.



Appear 4.4-a: Deformed shape of structure.

4.4 Remarks

the remarks are identical to those formulated for modelization A.

5 Modélisation C

5.1 Characteristic of the modelization

It acts of the same modelization as the modelization A, but in $3D$. The intersection is built same way.

5.2 Characteristics of the mesh

The mesh which comprises 25 meshes type `HEXA8` is represented on the figure 5.2-a.

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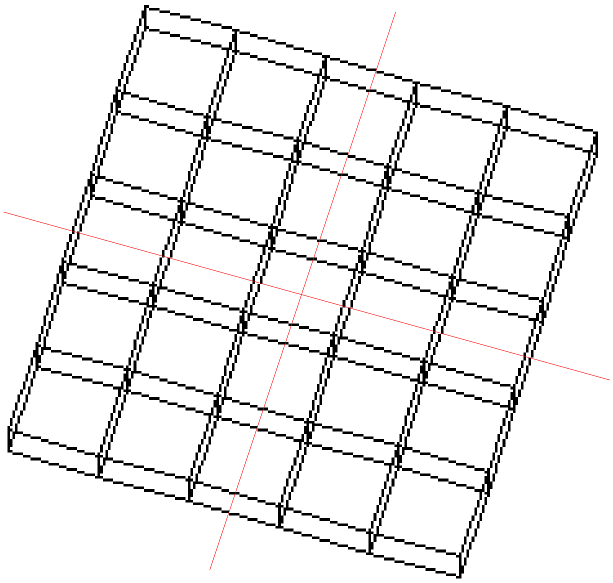


Figure 5.2-a : The mesh of the modelization C.

5.3 Quantities tested and results

the quantities tested are identical to those presented for modelization A. One adds tests on `DZ`.

Identification			***Reference***
DEPZON_1	DX	MIN	-0.25
		MAX	-0.25
	DY	MIN	0
		MAX	0
DEPZON_2	DX	MIN	-0.5
		MAX	-0.5
	DY	MIN	0
		MAX	0
DEPZON_3	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0
DEPZON_4	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0

Table 5.3-1

the deformed shape is represented on the figure 5.4-a.

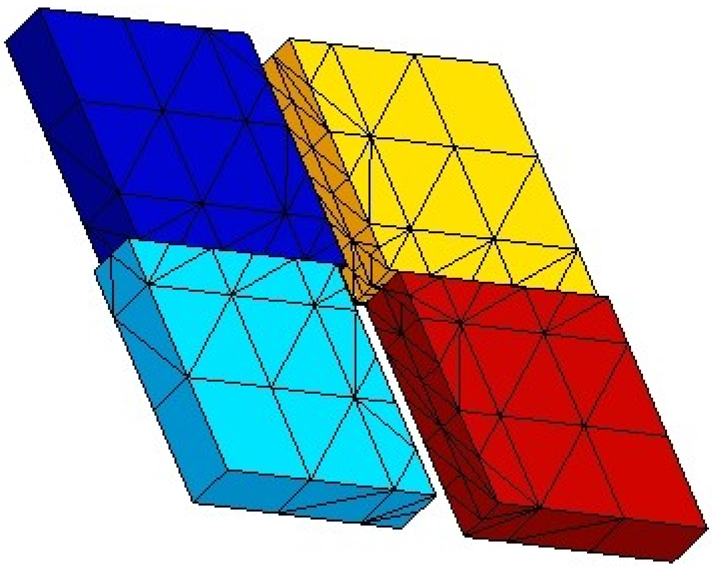


Figure 5.4-a : Deformed shape of structure.

5.4 Remarks

the remarks are identical to those formulated for modelization A.

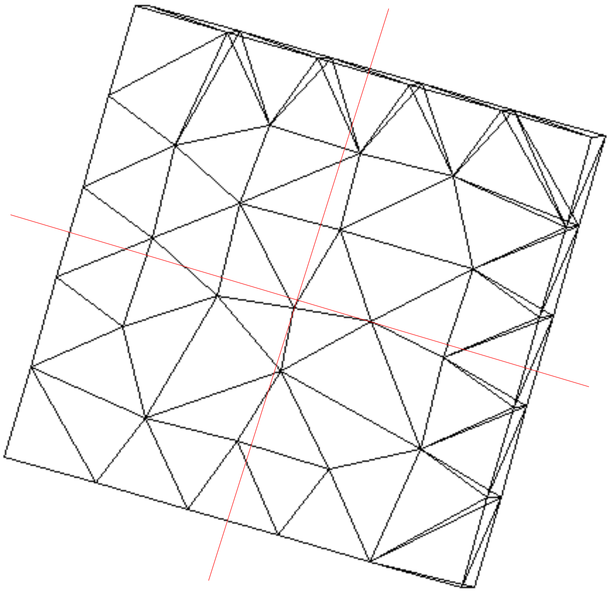
6 Modélisation D

6.1 Characteristic of the modelization

It acts of the same modelization as the modelization C.

6.2 Characteristic of the mesh

The mesh which comprises 162 meshes type TETRA4 is represented on the figure 6.2-a.



Appear 6.2-a: The mesh of modelization D.

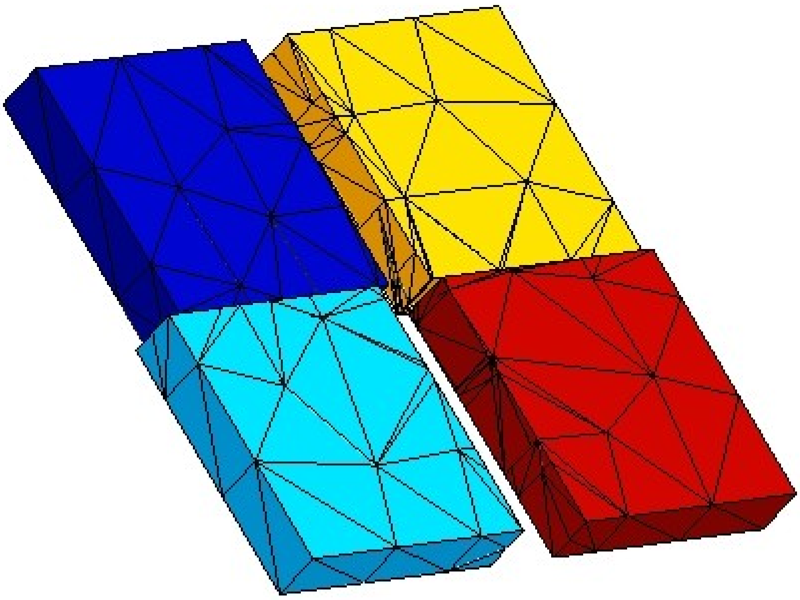
6.3 Grandeurs tested and results

the quantities tested are identical to those presented for the modelization C.

Identification			Reference
DEPZON_1	DX	MIN	-0.25
		MAX	-0.25
	DY	MIN	0
		MAX	0
DEPZON_2	DX	MIN	-0.5
		MAX	-0.5
	DY	MIN	0
		MAX	0
DEPZON_3	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0
DEPZON_4	DX	MIN	0.75
		MAX	0.75
	DY	MIN	0
		MAX	0

Table 6.3-1

the deformed shape is represented on the figure 6.4-a.



Appear 6.4-a: Deformed shape of structure.

6.4 Remarks

the remarks are identical to those formulated for modelization A.

7 Modélisation E

7.1 Characteristic of the modelization

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

7.2 Caractéristiques of the mesh

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

7.3 Features tested

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

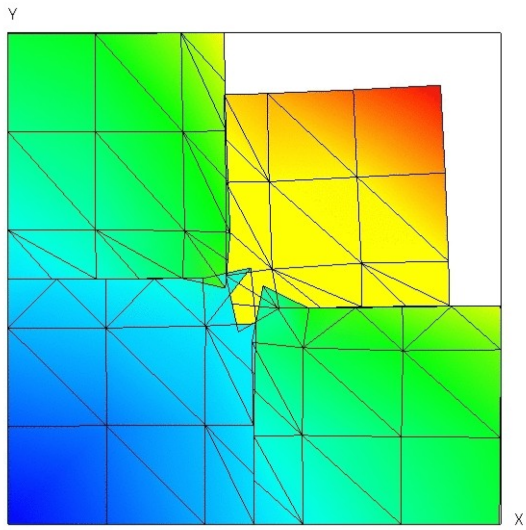
7.4 Quantities tested and results

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

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

Table 7.4-1

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



Appear 7.4-a: Deformed shape 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 forces of contact on these facets are not taken into account in computation. The zone affected relates to in particular the point of intersection of the cracks (which one does not test) as well as the element the container. Let us note that the results are clearly to improve when the mesh is refined.

8 Modelization F

8.1 Characteristic of the modelization

It is acted of the same modelization as the modelization E, but as plane stresses. The intersection is built same way.

8.2 Characteristics of the mesh

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

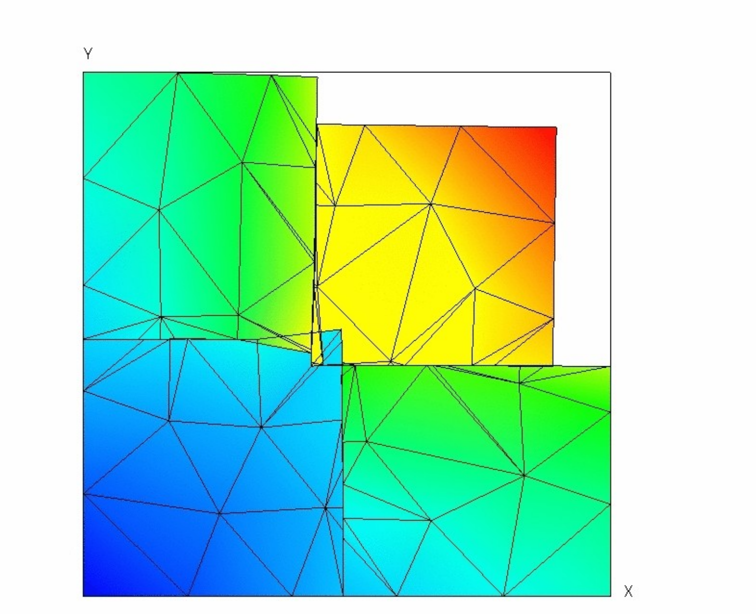
8.3 Quantities tested and results

the quantities tested are identical to those presented for the modelization E.

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

Table 8.3-1

the deformed shape is represented on the figure 8.4-a.



Appear 8.4-a: Deformed shape of the structure (exaggeration 10).

8.4 Remarks

the remarks are identical to those formulated for the modelization E.

9 Modelization G

9.1 Characteristic of the modelization

It acts of the same modelization as the modelization E, but in $3D$. The intersection is built same way.

9.2 Characteristics of the mesh

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

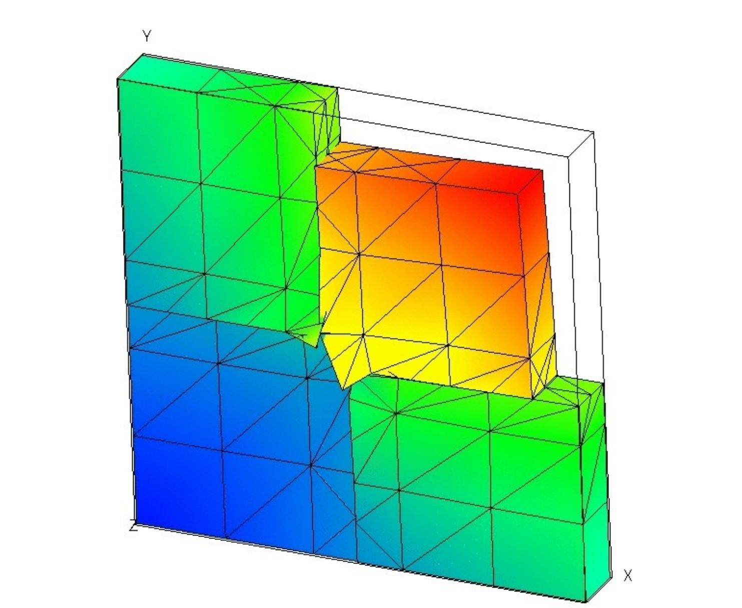
9.3 Quantities tested and results

the quantities tested are identical to those presented for the modelization E. One adds tests on DZ.

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

Table 9.3-1

the deformed shape is represented on the figure 9.4-a.



Appear 9.4-a: Deformed shape of the structure (exaggeration 10).

9.4 Remarks

the remarks are identical to those formulated for the modelization E.

10 Modelization H

10.1 Characteristic of the modelization

It acts of the same modelization as the modelization G.

10.2 Characteristic of the mesh

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

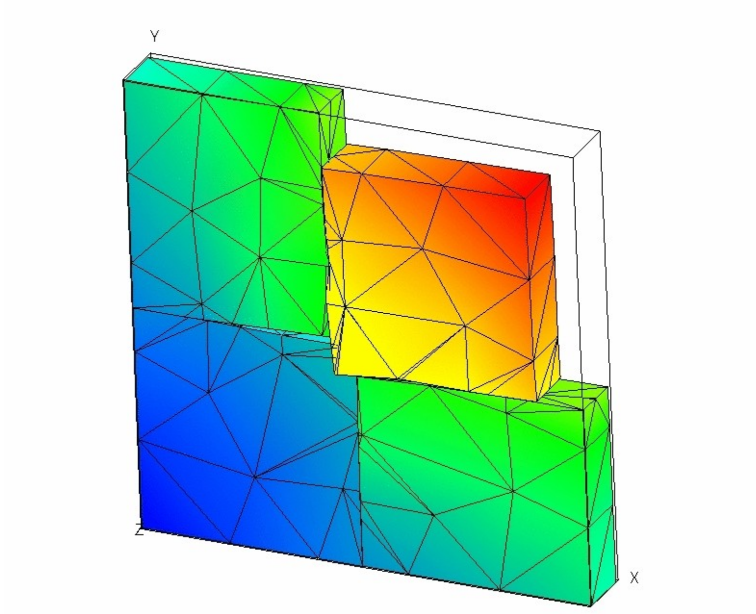
10.3 Quantities tested and results

the quantities tested are identical to those presented for the modelization G.

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

Table 10.3-1

the deformed shape is represented on the figure 10.4-a.



Appear 10.4-a: Deformed shape of the structure (exaggeration 10).

10.4 Remarks

the remarks are identical to those formulated for the modelization E.

11 Summary of the results

the representation of junctions with X-FEM makes it possible to model the kinematics of opening of the intersection of two interfaces. It is also possible to make the same thing with crack tips on both sides of the junction, but it is necessary to take care to move away the bottom from the intersection (approximately 2 meshes for a topological enrichment because one cannot manage yet the presence of the additional Heaviside for elements Ace-tip. An element Ace-tip cannot currently "see" more than one crack at the same time).

The approach was validated in 2D for modelizations C_PLAN and D_PLAN and the elements of the type QUAD4 and TRIA3. One also validated the approach in 3D for elements HEXA8 and TETRA4, with or without contact.