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

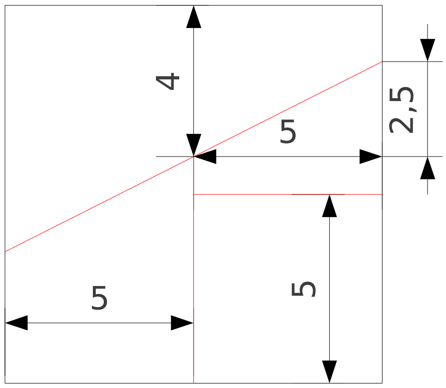
Summarized:

This test makes it possible to validate the approach junction with $\mathrm{X\text{-}FEM}$. 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 key word `JONCTION` of operator `DEFI_FISS_XFEM`. The third connects on the second. 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 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 structure as well as the position of the interfaces are given on the figure 1.1-a and are expressed in meters $[m]$.



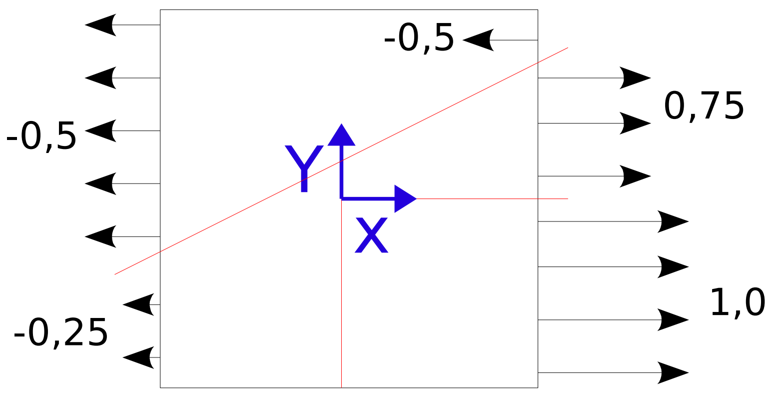
Appear 1.1-a: Geometry of structure and positioning of the interfaces.

1.2 Properties of the material

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

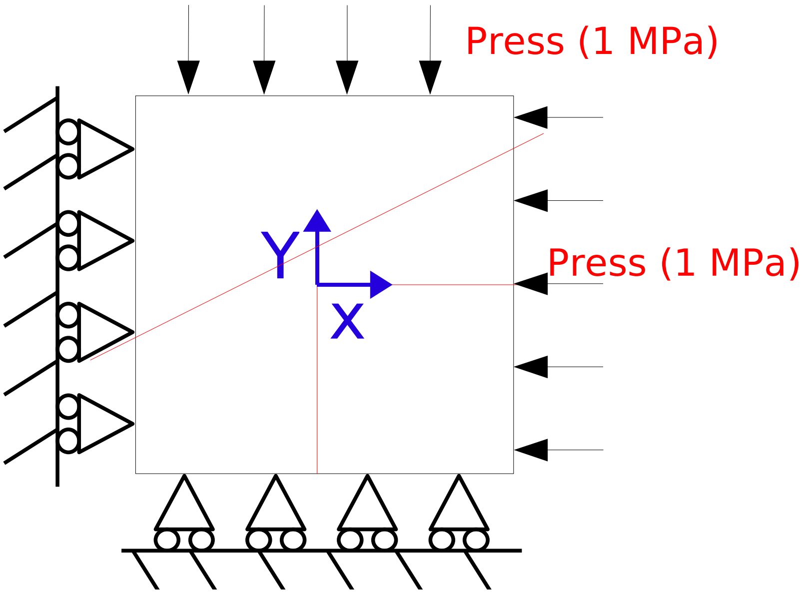
1.3 Boundary conditions and loadings

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 Z for the modelizations 3D) on these same edges.



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

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



Appear 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 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 :

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

éq 2.1-1

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

éq 2.1-2

3 Modelization A

3.1 Characteristic of the modelization

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

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

$$LN1 = Y - 1 - \frac{X}{2}$$

éq 3.1-1

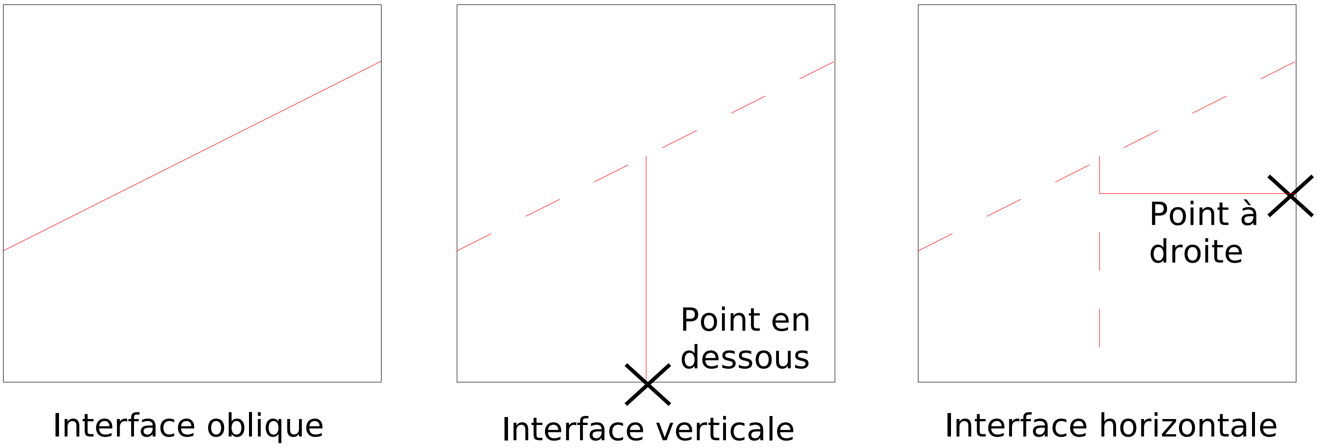
$$\mathrm{LN}2=Y$$

éq 3.1-2

$$\mathrm{LN}3=X$$

éq 3.1-3

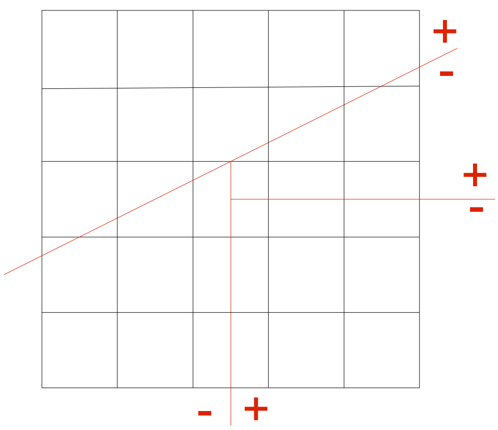
the oblique interface is defined in a classical way by means of operator `DEFI_FISS_XFEM` with the level set norm $\mathrm{LN1}$. To define the vertical interface, one invites operator `DEFI_FISS_XFEM` with the level set norm $\mathrm{LN2}$, by defining a connection with oblique crack via key word `JONCTION`, and by choosing a point “in lower part” of the oblique interface in the operand `POINT`. 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, one invites operator `DEFI_FISS_XFEM` with the level set norm $\mathrm{LN3}$, by defining a connection with vertical crack via key word `JONCTION`, and by choosing a point “on the right” in the operand `POINT`. This stage makes it possible to define crack 3 in the field on the right of second crack (see figure 3.1-a on the right).



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

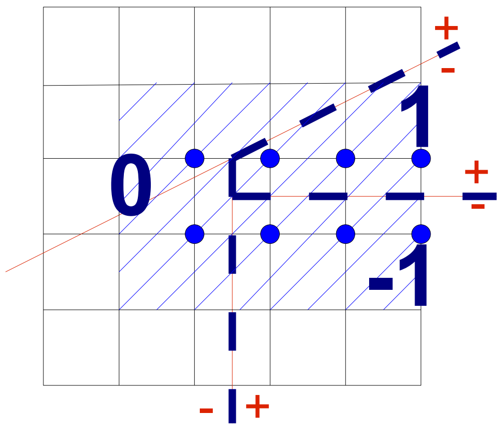
3.2 Characteristics of the mesh

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 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 DX `degrees of freedom`, `DY`, `H1X`, `H1Y`, `H2X`, `H2Y`, `H3X` and `H3Y`.



Appear 3.2-a: The mesh of modelization A.

the interest of this test is to check that one takes well into account the values of function Heaviside of the horizontal crack which must be worth $+1$, -1 or 0 according to the zone (see figure 3.2-b). The horizontal crack was connected on vertical crack: let us notice whereas the zone in which its Heaviside function is worth 0 is also delimited by the oblique crack, on which the horizontal crack is not directly connected.



Appear 3.2-b: Value of the Heaviside function for horizontal crack and its support.

3.3 Functionalities 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 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 horizontal crack (in blue on the figure 3.2-b).
One tests the assembly of ddegrés of Heavisides 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.

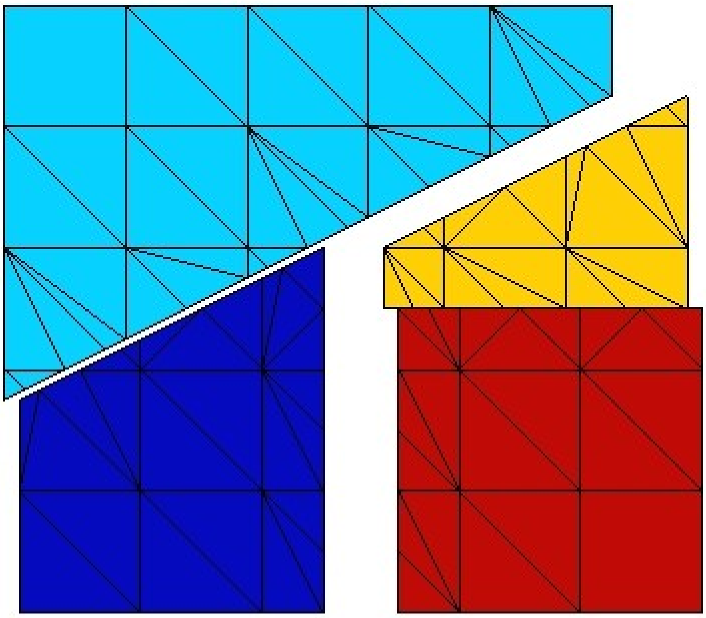
3.4 Quantities tested and results

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`). DX `displacement` 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 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 (C_PLAN). The junctions are 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. The mesh is refined sufficiently little to find itself in the same situation as for the modelization A (figure 4.2-b).

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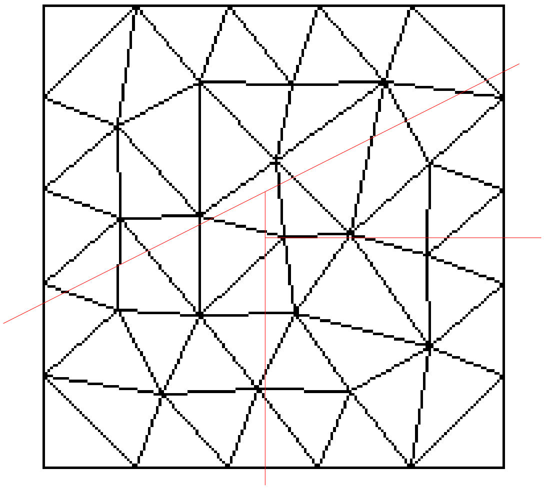

Figure 4.2-a : The mesh of the modelization B.

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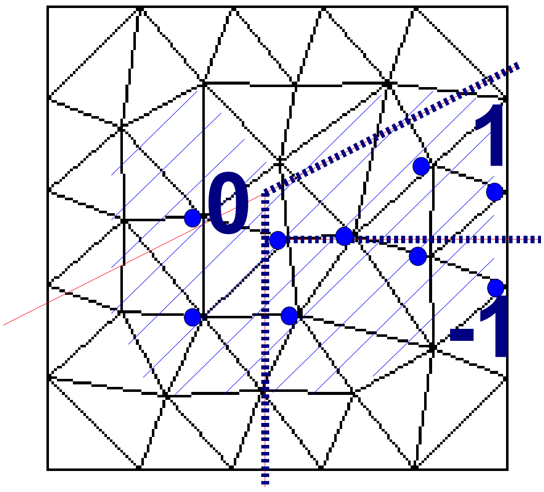


Figure 4.2-b: Value of the Heaviside function for horizontal crack and its support.

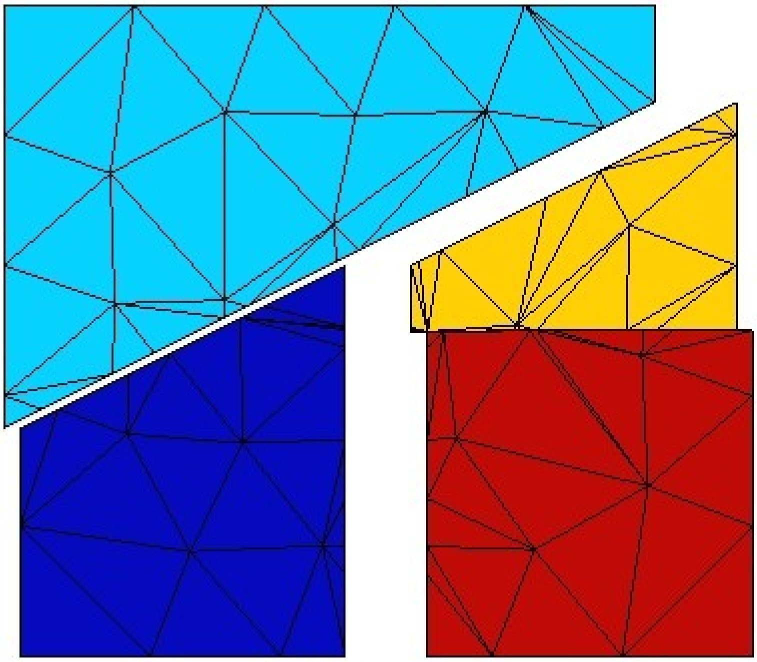
4.3 Quantities tested and results

the quantities tested are identical to those presented for modelization 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 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 specified 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. The mesh is refined sufficiently little to find itself in the same situation as in the case of modelization A.

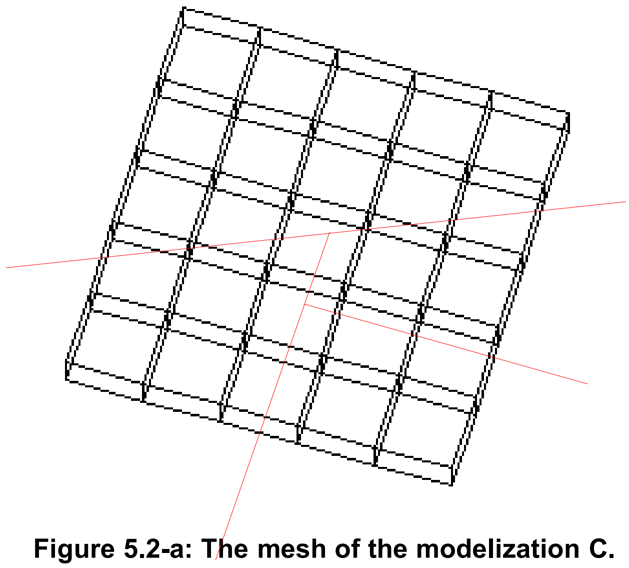


Figure 5.2-a: The mesh of the modelization C.

5.3 Quantities tested and results

the quantities tested are identical to those presented for the modelization 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 deformed shape is represented on the figure 5.4-a.

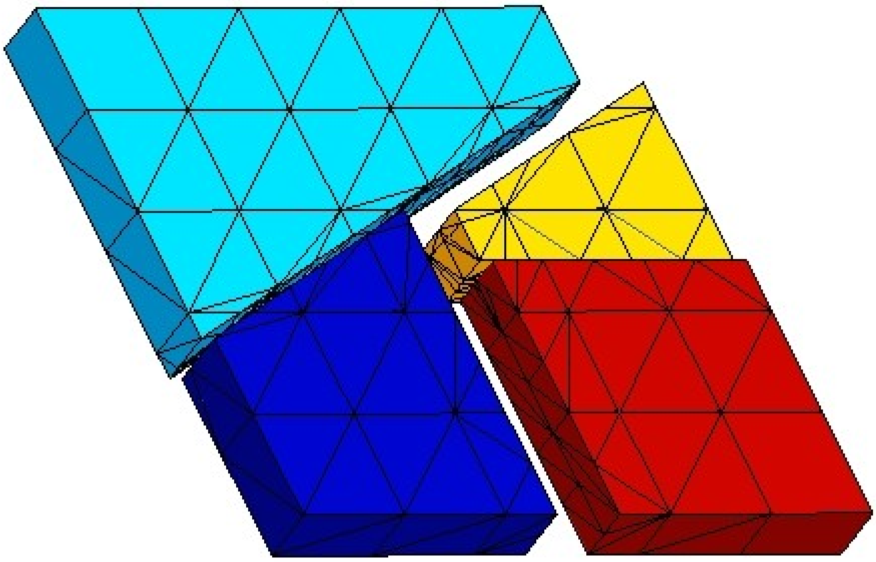


Figure 5.4-a : Deformed shape of structure.

5.4 Remarks

the remarks are identical to those specified 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. The mesh is refined sufficiently little to find itself in the same situation as in modelization A.

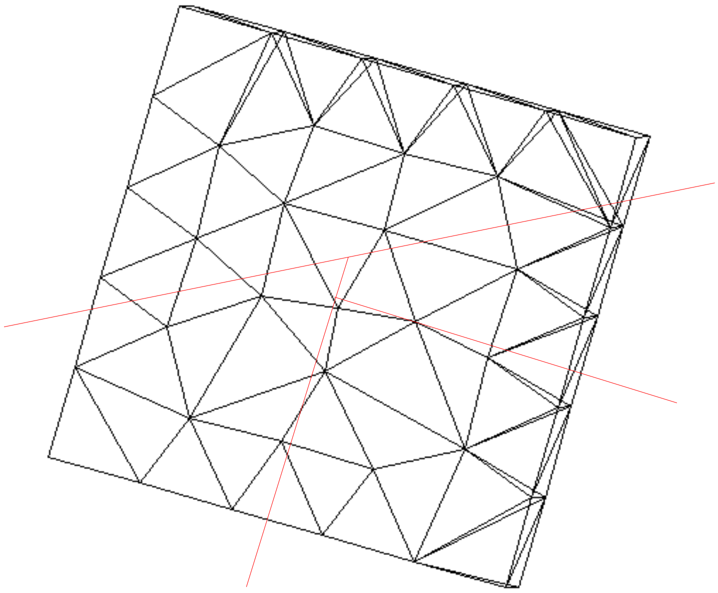


Figure 6.2-a: The mesh of modelization D.

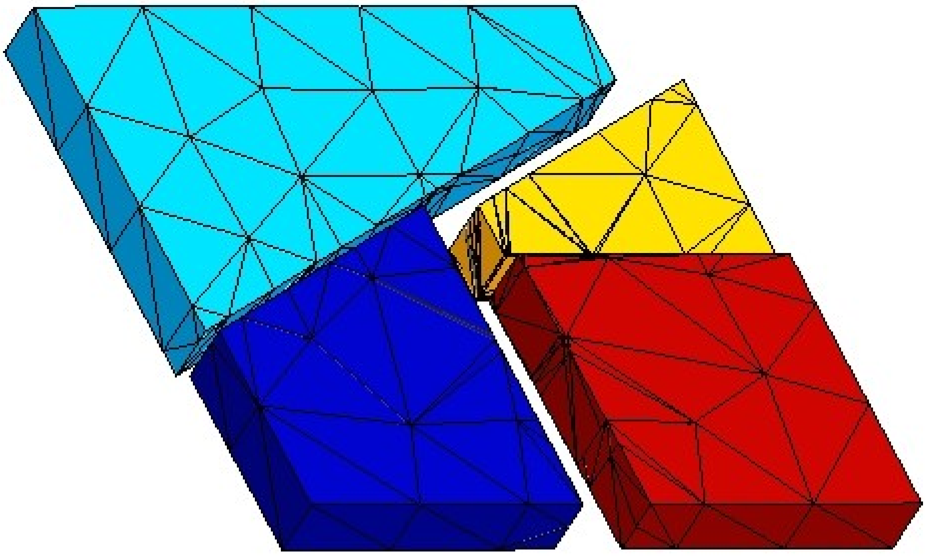
6.3 Grandeurs tested and results

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

Identification			*Reference*	*% 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 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 specified 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 junctions are 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 crossed by 3 cracks 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`.

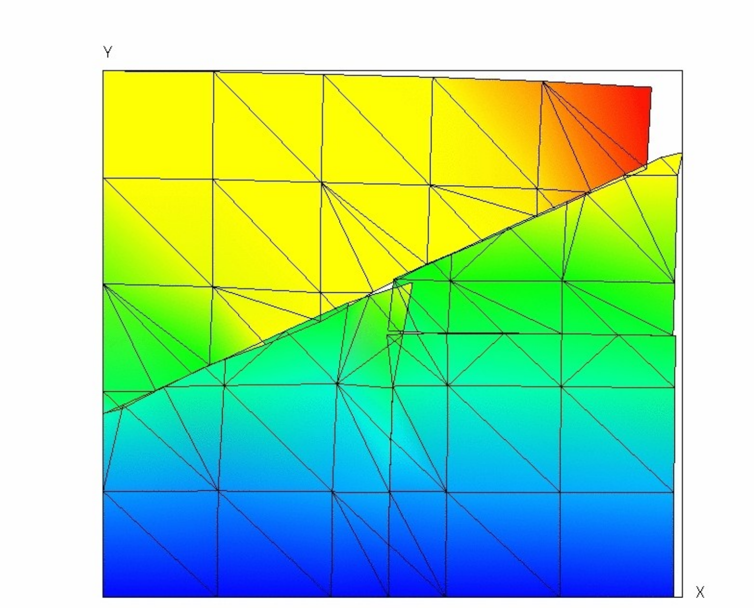
7.4 Quantities tested and results

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 the function $Depl_Y$ of equation 2.1-2. One obtains the deformed shape 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 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 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 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 junctions are 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.

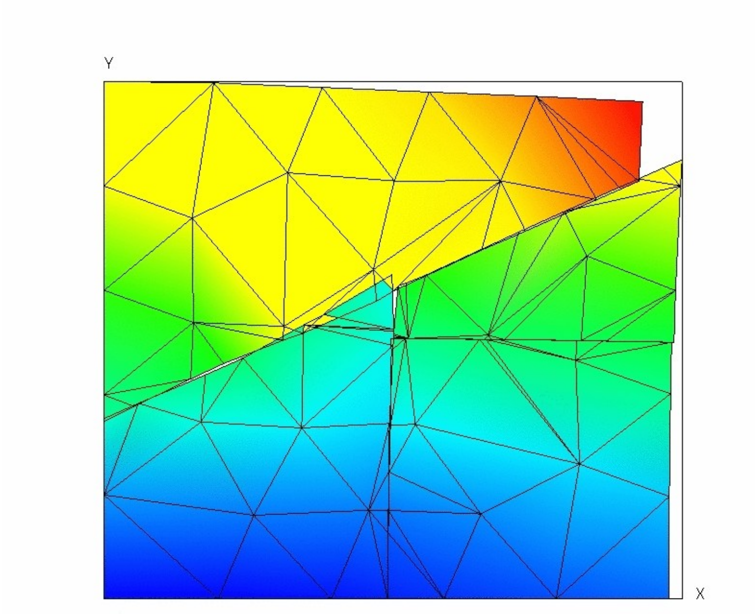
8.3 Quantities tested and results

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

Identification			*Reference*	*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 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 junctions are 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.

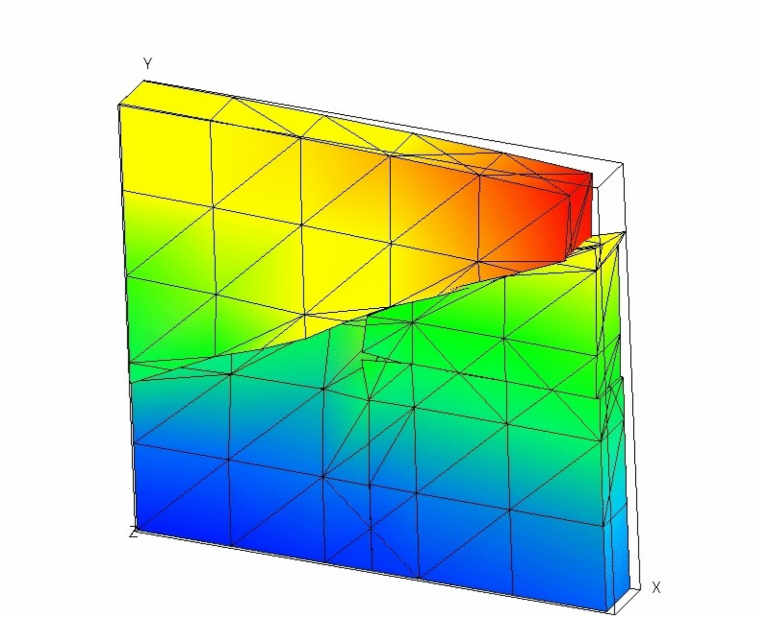
9.3 Quantities tested and results

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

Identification			*Reference*	*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 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.

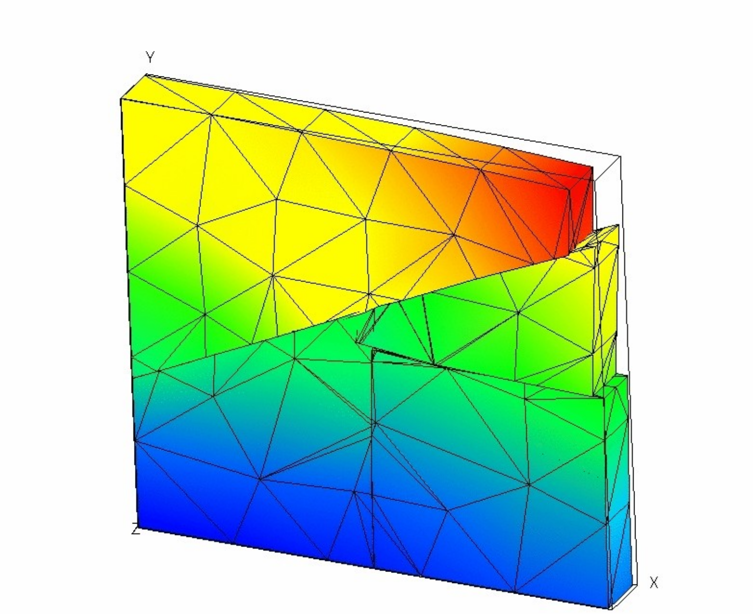
10.3 Quantities tested and results

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

Identification			*Reference*	*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 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

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 mesh in the zone which contains the 2 junctions.
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.