difference

SSNV173 – the purpose of Bar fissured with X-FEM

Summarized

This test is validating two aspects of elementary computation in the frame of X-FEM [R7.02.12]:

- the integration of a discontinuous quantity thanks to a under-cutting of the element,
- the enrichment of the shape functions by the Heaviside function.

This test brings into play a parallelepipedic bar fissured on all its section (one will speak then about interface), subjected to an imposed displacement, which has as a consequence the separation of the two parts of structure.

The influence of the mesh and the boundary conditions is also studied.

One also studies in $2D$ the case of a plate.

1 Problem of reference

1.1 Geometry 3D

the structure is a right parallelepiped at square base. Dimensions of the bar (see [Figure 1.1-a]) are: $LX=5m$, $LY=5m$ and $LZ=25m$.

The crack (or rather the interface) is introduced by functions of level (level sets) directly into the file orders using operator DEFI_FISS_XFEM [U4.82.08]. The interface is present in the middle of structure by the means of its representation by a level set LSN (see [Figure 1.1-a]) of equation:

LSN (for the plane of the interface): $Z-\frac{LZ}{2}$

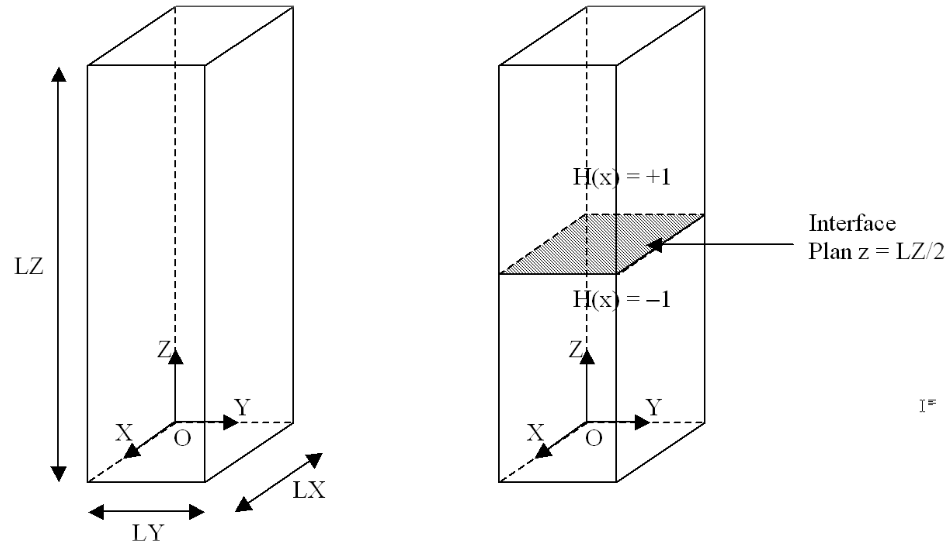


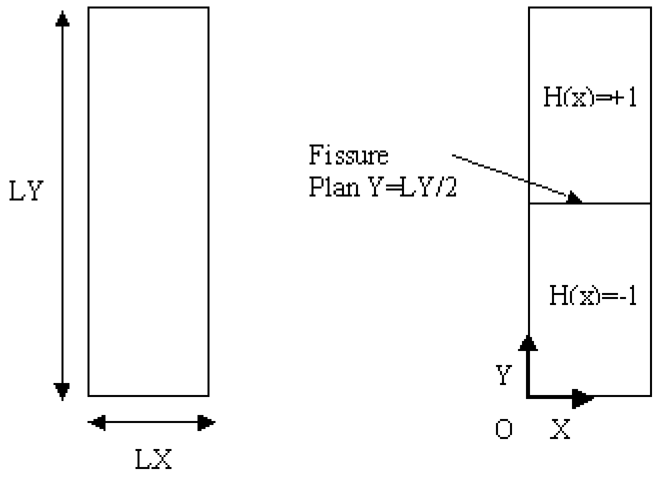
Figure 1.1-a : Geometry of the bar and positioning of the interface

1.2 Geometry 2D

the structure is a rectangle. Dimensions of the bar (see [Appear 1.2-a]) are: $LX=1m$ $LY=5m$.

The interface is introduced by a function of level (level set) directly into the file orders using operator DEFI_FISS_XFEM [U4.82.08]. The interface is present in the middle of structure by the means of its representation by a level set LSN (see [Appear 1.2-a]) of equation:

LSN (for the plane of the interface): $Y-\frac{LY}{2}$



Appear 1.2-a : Geometry of the plate and positioning of the interface

1.3 Properties of the material

Modulus Young: $E=205000\,MPa$

Poisson's ratio: $\nu=0.3$

1.4 Boundary conditions and loadings

the nodes of the lower face of the bar are embedded and a displacement is imposed on those of the upper face. One wishes to show here the possibility X of separating a finite element into two with - FEM.

2 Modelization A

2.1 Characteristic of the mesh

the structure is with a grid by only one mesh of the type HEXA8. The interface is thus present within this element by the means of level sets.

2.2 Boundary conditions

Let us recall that displacement under X-FEM is the sum of a continuous displacement and a discontinuous displacement. In the case of an interface, without crack tip, the approximation of displacement is written in the following way:

$$u^h(x)=\sum_{i\in N_n(x)} a_i \phi_i(x)+\sum_{j\in N_n(x)\cap K} b_j \phi_j(x) H(lsn(x))$$

Where:

a_i and b_i of displacement to the node the shape functions associated i

ϕ_i with the node are the degrees of freedom i

$N_n(x)$ is all the nodes whose support contains the point x

K is all the nodes whose support is entirely cut by the interface

$H(x)$ is the Heaviside function generalized defined by $H(x)=\begin{cases}-1 & \text{si } x<0\\ +1 & \text{si } x\geq 0\end{cases}$

$lsn(x)$ is the normal value of the level-set at the point x

For more details, to refer to documentation of reference X-FEM [R7.02.12].

Considering the nodes close to the interface, i.e. here the 8 nodes of the mesh are enriched by additional degrees of freedom, the boundary conditions are written a little differently. That is relating to the enrichment of the classical shape functions [R7.02.12] by the Heaviside function $H(x)$.

To impose a null displacement on the nodes of the lower face amounts writing a linear relation between the degrees of freedom. For each node, one imposes $a_{ix}-b_{ix}=0$ (idem according to y and z).

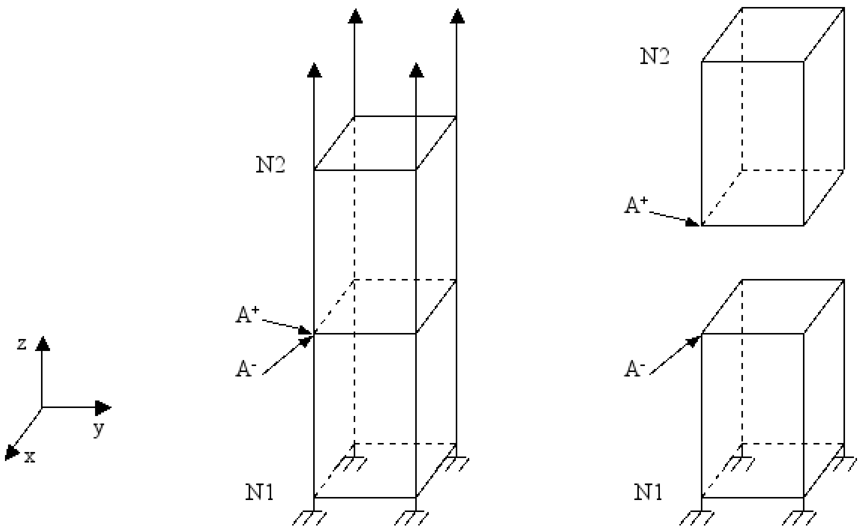
For the nodes of the upper face, one imposes a following displacement z being worth 10^{-6} and no one according to the two other directions, i.e. $a_{ix}+b_{ix}=0$, $a_{iy}+b_{iy}=0$ and $a_{iz}+b_{iz}=10^{-6}$.

These relations are imposed **automatically** when one uses key word DDL_IMPO on a node X-FEM. For example, the imposition of displacement following X no one of the node X-FEM $N1$ is thus done in the classical way:

```
DDL_IMPO=_F (NOEUD=' N1', DX=0)
```

2.3 analytical Resolution

the solution of such a problem is of course obvious. It is seen well that mechanically speaking, the two parts of structure will be detached: the lower part will have a null displacement and the upper part will have an overall motion equal to imposed displacement (see [Appear 2.3-a]).



Appear 2.3-a : States initial and final of structure

the analytical solution is then the following one: all displacements according to x and y are null, all displacements following z below the level set are null and all displacements following z to the top of the level set are equal to the displacement imposed u_z on the top of structure.

2.4 Quantities tested and results

operator `POST_MAIL_XFEM` allows to net cracks represented by the method X-FEM. Operator `POST_CHAM_XFEM`, then allows to export the X-FEM results on this new mesh. These two operators are to be used only in a posterior way with computation at sights of postprocessing. They make it possible to generate nodes right in lower part and with the top of the interface and to display their displacements.

One thus tests the values of displacement right in lower part and with the top of the interface after convergence of the iterations of operator `STAT_NON_LINE`. It is checked that one finds well the values determined with [§2.32.3].

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	0.00	1.0E-16
DZ for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

2.5 Comments

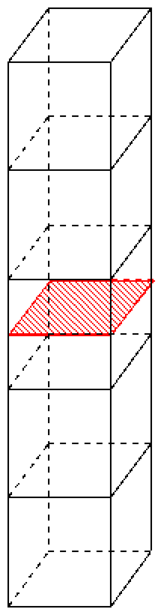
One notices the discontinuity of the field of displacements while crossing the interface which is possible thanks to the enrichment of the elements with the Heaviside degree of freedom.

3 Modelization B

3.1 Characteristic of the mesh

One meshes discretizes structure into 5 of type HEXA8.

The nodes on both sides of the interface are nodes nouveau riches, therefore three the meshes central ones having such nodes are also enriched. Only two the meshes extreme ones are the meshes classical ones having only classical nodes.



Appear 3.1-a : mesh with 5 HEXA8

3.2 Boundary conditions

the boundary conditions applied represent the same physical phenomenon that for modelization A. One embeds the nodes of the lower face and one imposes a displacement of the nodes of the upper face:

Lower face (Nodes $N1 \quad N6 \quad N11$, $N16$): $DX=0$, $DY=0$ and $DZ=0$
Upper face (Nodes $N21 \quad N22 \quad N23$, $N24$): $DX=0$, $DY=0$ and $DZ=uz$
This constitutes the 1st case of loading.

In fact, one takes freedom to move the upper part of structure according to the three directions, one will thus choose like 2nd case of loading:
Lower face (Nodes $N1 \quad N6 \quad N11$, $N16$): $DX=0$, $DY=0$ and $DZ=0$
Upper face: $DX=ux$, $DY=uy$ and $DZ=uz$

$$ux=1.10^{-6}$$
$$uy=2.10^{-6}$$
$$uz=3.10^{-6}$$

3.3 analytical Resolution

the solution of such a problem is of course still obvious. All displacements according to x and y are null, all displacements according to x, y and z below the level set are null and all displacements according to x, y and z with the top of the level set are equal to imposed displacement u_x, u_y and u_z the top of structure.

3.4 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§3.33.3] for the 2 cases of loadings.

One obtains the following table for the 1st case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	0.00	1.0E-16
DZ for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

One obtains the following table for the 2nd case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	1.0E-6	1.0E-9%
DY for all the nodes right with the top of the interface	2.0E-6	1.0E-9%
DZ for all the nodes right with the top of the interface	3.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

3.5 Comments

One notices the discontinuity of the field of displacements while crossing the interface which is possible thanks to the enrichment of the elements with the Heaviside degree of freedom.

4 Modelization C

4.1 Characteristic of the mesh and the interface

One considers a structure of dimensions $LX=5m$, $LY=5m$ and $LZ=25m$. This structure is discretized with 5 meshes HEXA8. One is interested in a plane interface of norm

$$n=\begin{pmatrix}-1\\1\\1\end{pmatrix}$$

passing by the point A of coordinates $(5,5\delta,5)$. [Figure 4.1-a] the watch a zoom of the 2nd element where the trace of the interface is represented in red.

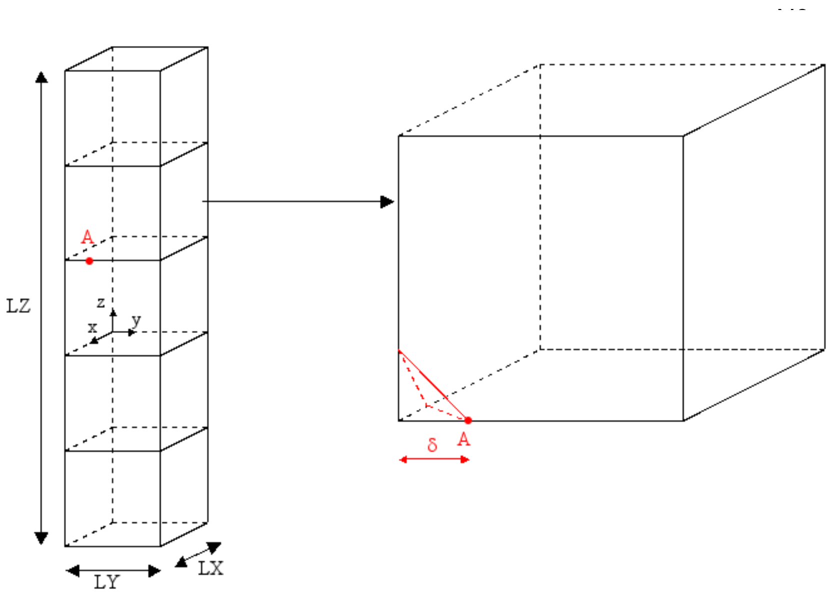


Figure 4.1-a : Mesh C and zoom

the interface is characterized by the level set norm having for Cartesian equation:

$$lsn=-x+y+z-5\delta$$

Note:

> *The parameter δ has a strong influence on the problem. If δ 0 or 1 are worth, then the pointcoïncide A with a node, and the interface passes by this node. If δ is non-zero, but small in front of 1, the interface will separate the element in 2 parts, of very different volumes. In this situation, the enrichment of the node $N9$ (see Figure 4.1-a) by the Heaviside function becomes almost useless, and led to very small pivots during the factorization of the stiffness matrix. That results in a significant loss amongst decimals and with result false. For $\delta=0.1$ (that is to say a point A accounting for 10% of the edge), one loses already 8 decimals (value by default causing a fatal error) and for $\delta=0.05$, one loses 10 decimals. The idea thus consists in not enriching the node $N9$ by the Heaviside function when such cases arise. An algorithm of detection was set up, based on the volumetric ratio for an element cut into two. This problem makes it possible to test the good performance of the algorithm, when the parameter δ becomes small.*
> *In the continuation, one will take $\delta=0.02$. This value leads to the loss of 13 decimals during factorization (before the installation of a special processing).*

The algorithm will be validated if computation proceeds normally, without loss of decimals in factorization. One will check also solution displacement in a selected node.

4.2 Boundary conditions

the boundary conditions are the same ones as those of the modelization B. the nodes of the lower face are embedded and one imposes a displacement of tension on the nodes of the upper face:

Lower face: $DX=0$, $DY=0$ and $DZ=0$
Upper face: $DX=0$, $DY=0$ and $DZ=10^{-6}$

4.3 Quantities tested and results

the good progress of computation makes it possible *a priori* to validate the case. One thus tests the values of displacement right to the top of the interface after convergence of the iterations of operator STAT_NON_LINE.

Identification	Reference	Tolerance
DZ for all the nodes right to the top of the interface	$1.0\mathrm{E}-6$	1.0E-3%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

5 Modelization D

This modelization is based on modelization A.
the type of element chosen for the mesh is the only difference between these two modelizations.

5.1 Characteristics of the mesh

One discretizes structure in 6 finite elements TETRA4
the interface is present within these 6 elements by the means of level sets.

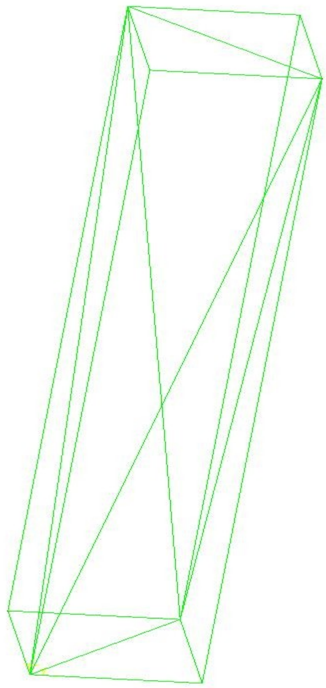


Figure 5.1-a : 5.1-a Mesh

5.2 Boundary conditions

the boundary conditions are those of modelization a: one embeds the nodes of the lower face and one imposes a displacement of the nodes of the upper face.

5.3 Analytical resolution

the analytical solution is that presented in the modelization A [§2.32.3] : all the degrees of freedom according to x and y are null and all the degrees of freedom according to z are worth $uz/2$, where $uz=10^{-6}$

5.4 Quantities tested and results

One tests the values of displacement right in lower part and with the top of the interface after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§2.32.3].

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	0.00	1.0E-16
DZ for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

to test all the only one nodes times, one tests the MINIMUM and the maximum of column.

5.5 Comments

One notices the discontinuity of the field of displacements while crossing the interface which is possible thanks to the enrichment of the elements with the Heaviside degree of freedom.

6 Modelization E

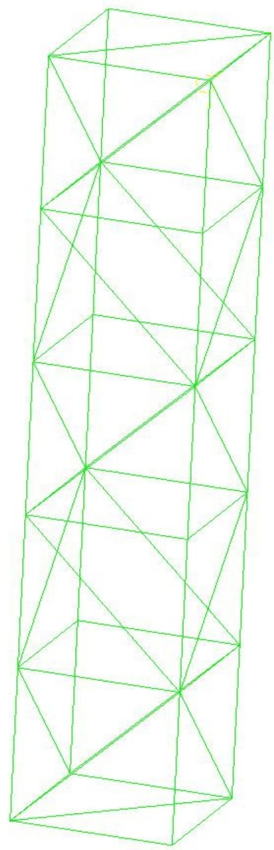
This modelization is based on the modelization B.
the type of element chosen for the mesh is the only difference between these two modelizations.

6.1 Characteristics of the mesh

Each mesh HEXA8 of the modelization B is broken up into 6 TETRA4 for the modelization E.
Thus the structure is discretized in 30 finite elements TETRA4.

The nodes on both sides of the interface are nodes nouveau riches, therefore the tetrahedrons contained in three the meshes central ones of the modelization B having such nodes are also nouveau riches. Only the tetrahedrons contained in the two extreme hexahedrons of the modelization B are the meshes classical ones having only classical nodes.

One will be able to thus impose boundary conditions on the meshes extreme ones in the usual way.



Appear 6.1-a : Mesh

6.2 Boundary conditions

One embeds the nodes of the lower face and one imposes a displacement of the nodes of the upper face:

Lower face: $DX=0$, $DY=0$ and $DZ=0$
Upper face: $DX=0$, $DY=0$ and $DZ=uz$.
This constitutes the 1st case of loading.

In fact, one takes freedom to move the upper part of structure according to the three directions, one will thus choose like 2nd case of loading:
Lower face: $DX=0$, $DY=0$ and $DZ=0$
Upper face: $DX=ux$, $DY=uy$ and $DZ=uz$

$$ux=10^{-6}$$
$$uy=2.10^{-6}$$
$$uz=3.10^{-6}$$

6.3 analytical Resolution

the solution of such a problem is of course still obvious : all displacements according to x and y are null, all displacements following z below the level set are null and all displacements following z to the top of the level set are equal to the displacement imposed u_z on the top of structure.

6.4 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator `STAT_NON_LINE`. It is checked that one finds well the values determined with [§3.33.3] for the 2 cases of loadings.

One obtains the following table for the 1st case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	0.00	1.0E-16
DZ for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

One obtains the following table for the 2nd case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	1.0E-6	1.0E-9%
DY for all the nodes right with the top of the interface	2.0E-6	1.0E-9%
DZ for all the nodes right with the top of the interface	3.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

6.5 Comments

One notices the discontinuity of the field of displacements while crossing the interface which is possible thanks to the enrichment of the elements with the Heaviside degree of freedom.

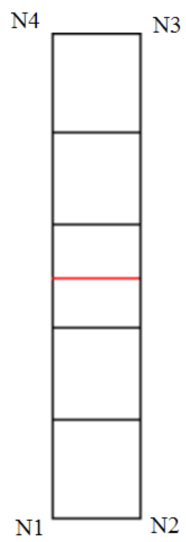
7 Modelization F

7.1 Characteristic of the mesh

One discretizes structure in 5 finite elements QUAD4.

The nodes on both sides of the interface are nodes nouveau riches, therefore three the meshes central ones having such nodes are also enriched. Only two the meshes extreme ones are the meshes classical ones having only classical nodes.

One will be able to thus impose boundary conditions on the meshes extreme ones in the usual way.



Appear 7.1-a : Mesh F

7.2 Boundary conditions

the boundary conditions applied represent the same physical phenomenon that for modelization A. One embeds the nodes of the lower face and one imposes a displacement of the nodes of the upper face:

Lower face (Nodes $N1$ and $N2$): $DX=0$ and $DY=0$
Upper face (Nodes $N3$ and $N4$): $DX=0$ $DY=uy=10^{-5}$.

7.3 Analytical resolution

the solution of such a problem is of course still obvious : all displacements according to x are null, all displacements following y below the level set are null and all displacements following y to the top of the level set are equal to the displacement imposed u_y on the top of structure.

7.4 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§7.37.3].

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16

DY for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

to test all the only one nodes times, one tests the MINIMUM and the maximum of column.

One of the command tests also the values of displacement resulting POST_CHAM_XFEM. One tests in fact the value of the sum of the absolute values of displacements of the nodes of the cracked mesh. It is a test of NON-regression compared to the values obtained with version 8.2.13 for DX and 9.0.21 for DY.

Identification	Reference	Difference
SOMM_ABS (DX)	0.000	1.E-12
SOMM_ABS (DY)	1.3E-05	1.0E-04%

7.5 Comments

One notices the discontinuity of the field of displacements while crossing the interface which is possible thanks to the enrichment of the elements with the Heaviside degree of freedom.

8 Modelization G

8.1 Characteristic of the mesh

the structure is modelled by only one finite element of type `QUAD4`. The interface is thus present within this element by the means of level sets.

8.2 Boundary conditions

the same reasoning is taken again as for modelization A.

On the lower face one imposes a null displacement:
$a_{ix}-b_{ix}=0$ and $a_{iy}-b_{iy}=0$.
On the upper face one imposes a displacement according to the axis Y :
$a_{ix}+b_{ix}=0$ and $a_{iy}+b_{iy}=10^{-6}$.

These relations are imposed **automatically** when one uses key word `DDL_IMPO` on a node X-FEM.

8.3 Analytical resolution

the solution of such a problem is of course still obvious : all displacements according to x are null, all displacements following y below the level set are null and all displacements following y to the top of the level set are equal to the displacement imposed u_y on the top of structure.

8.4 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator `STAT_NON_LINE`. It is checked that one finds well the values determined with [§8.38.3].

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

8.5 Comments

One notices the discontinuity of the field of displacements while crossing the interface which is possible thanks to the enrichment of the elements with the Heaviside degree of freedom.

9 Modelization H

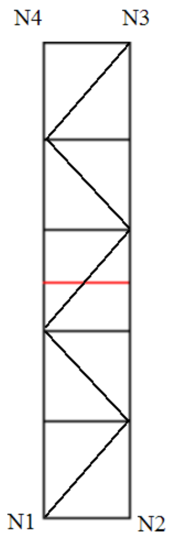
This modelization is based on the modelization F.
the type of element chosen for the mesh is the only difference between these two modelizations.

9.1 Characteristics of the mesh

Each mesh QUAD4 of the modelization F is broken up into 2 TRIA3 for the modelization H.
Ainsi the structure is discretized in 10 finite elements TRIA3.

The nodes on both sides of the interface are nodes nouveau riches, therefore the triangles contained in three the meshes central ones of the modelization F having such nodes are also nouveau riches. Only the triangles contained in the two extreme quadrilaterals of the modelization F are the meshes classical ones having only classical nodes.

One will be able to thus impose boundary conditions on the meshes extreme ones in the usual way.



Appear 9.1-a : Mesh H

9.2 Boundary conditions

One embeds the nodes of the lower face and one imposes a displacement of the nodes of the upper face:

Lower face (Nodes $N1$, $N2$): $DX=0$, and $DY=0$
Upper face (Nodes $N3$, $N4$): $DX=0$ and $DY=uy$

9.3 analytical Resolution

the solution of such a problem is of course still obvious : all displacements according to x are null, all displacements following y below the level set are null and all displacements following y to the top of the level set are equal to the displacement imposed u_y on the top of structure.

9.4 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§9.3].

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

9.5 Comments

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

10 Modelization I

This modelization is exactly the same one as modelization A. the only difference is that the finite element used is a quadratic element instead of a linear element.

10.1 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§2.32.3].

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	0.00	1.0E-16
DZ for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

11 Modelization J

This modelization is exactly the same one as the modelization B. the only difference is that the finite elements used are quadratic elements instead of linear elements.

11.1 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§3.33.3] for the 2 cases of loadings.
One obtains the following table for the 1st case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	0.00	1.0E-16
DY for all the nodes right with the top of the interface	0.00	1.0E-16
DZ for all the nodes right with the top of the interface	1.0E-6	1.0E-9%

One obtains the following table for the 2nd case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-16
DY for all the nodes right below the interface	0.00	1.0E-16
DZ for all the nodes right below the interface	0.00	1.0E-16
DX for all the nodes right to the top of the interface	1.0E-6	1.0E-9%
DY for all the nodes right with the top of the interface	2.0E-6	1.0E-9%
DZ for all the nodes right with the top of the interface	3.0E-6	1.0E-9%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

One of the command tests also the values of displacement resulting POST_CHAM_XFEM . One tests in fact the value of the sum of the absolute values of displacements of the nodes of the cracked mesh. It is a test of NON-regression compared to the values obtained with version 8.2.13 for DX and 9.0.21 for DY

Identification	Reference	Tolerance
SOMM_ABS (DX)	0.000	1.0E-12
SOMM_ABS (DY)	1.3E-05	1.0E-04%

12 Modelization K

This modelization is exactly the same one as the modelization B. the only difference is that as a preliminary with mechanical computation, one calls Homard to refine some meshes HEXA8. This process generates meshes PYRA5.

12.1 Quantities tested and results

One tests the values of displacement after convergence of the iterations of operator STAT_NON_LINE. It is checked that one finds well the values determined with [§3.33.3] for the 2nd case of loading.

Identification	Reference	Tolerance
DX for all the nodes right below the interface	0.00	1.0E-9
DY for all the nodes right below the interface	0.00	1.0E-9
DZ for all the nodes right below the interface	0.00	1.0E-9
DX for all the nodes right to the top of the interface	1.0E-6	1.0E-7%
DY for all the nodes right with the top of the interface	2.0E-6	1.0E-7%
DZ for all the nodes right with the top of the interface	3.0E-6	1.0E-7%

to test all the nodes in only once, one tests the MINIMUM and the maximum of column.

13 Summaries of the results

the purposes of this test are reached:

- It is a question of validating the taking into account of enrichment by the Heaviside function of the classical shape functions.
- Moreover, the modelization B made it possible to validate the suppression of the degrees of freedom nouveau riches in excess, which is made at the assembly time terms of the matrix and the second member.
- The quality of the results (displacements) was not disturbed by the change of the type of mesh (HEXA towards TETRA).