PERF017 – Interface in contact rubbing with X-FEM

Summary:

This problem corresponds to a quasi-static analysis of a problem of mechanics with contact and friction. A cylinder is subjected to compressive forces on its faces higher and side. It moreover is compressed on a frame which imposes to him forces of contact and friction.

It is about a case complementary to the CAS-test ssnv209 [V6.04.209].

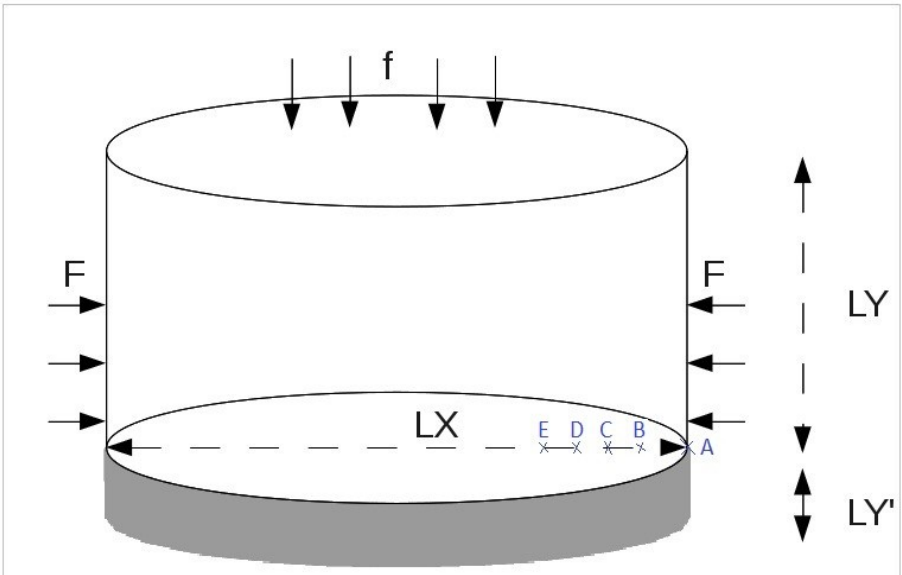
This test brings into play various grids, in $3D$, within the framework of calculations X-FEM [R7.02.12].

It comprises 3 modelings and allows testsR:

- modelings $3D$ (TETRA4),
- a position of crack in the middle of the elements,
- the operand XFEM keyword CONTACT,
- the various diagram of integration by defect for the terms of contact (NODE),
- parameters of the generalized formulation (coefficients of regularization and stabilization for the contact and friction),
- the simultaneous calculation of the separated zones, in slipping contact, and adherent contact,
- postprocessing, in particular the calculation of the normal reaction RN ,
- the algorithm of satisfaction of the condition LBB with the transitions taken off/contact and slipping/adherent,
- method of Lagrangian increased and method penalized for the treatment of contact-friction.

1 Problem of reference

1.1 Geometry



The structure is a cylinder made up of two of the same cylinders material, separated by an interface.

The cylinder to which the pressures are applied has a diameter $LX = 80\ \text{mm}$ and a height $LY = 40\ \text{mm}$.

The second cylinder, comparable to a frame, has a diameter $LX = 80\ \text{mm}$ and a height $LY' = 10\ \text{mm}$.

Taking into account the adopted grid, the positions of the points of reference are (in mm):

	x	y	z
A	40.0	0	0
B	35.0	0	0
C	30.0	0	0
D	25.0	0	0
E	20.0	0	0

1.2 Material properties

Plate and built:

Poisson's ratio: 0.2

Young modulus: $1.3\,10^{11}\,N/m^2$

The coefficient of friction under the plan is $\mu = 1.0$.

1.3 Boundary conditions and loadings

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, bottomless of crack in the following way, the approximation of displacement is written:

$$u^h(x)=\sum_{i\in N_n(x)} a_i\Phi_i(x)-\sum_{i\in\Omega^+(x)\cap K} b_i\Phi_i(x)2\chi_-(x)+\sum_{i\in\Omega^-(x)\cap K} b_i\Phi_i(x)2\chi_+(x)$$

Where:

a_i and b_i are the degrees of freedom of displacement to the node i,
Φ_i functions of form associated with the node i,
$\chi_\pm(x)$ functions characteristic on the sides + and – crack,
$\Omega^\pm(x)$ half spaces + and – determined by the crack,
$N_n(x)$ is the whole of the nodes whose support contains the point x,
K is the whole of the nodes whose support is entirely cut by the crack.

For more details, to refer to the reference material X-FEM [R7.02.12].

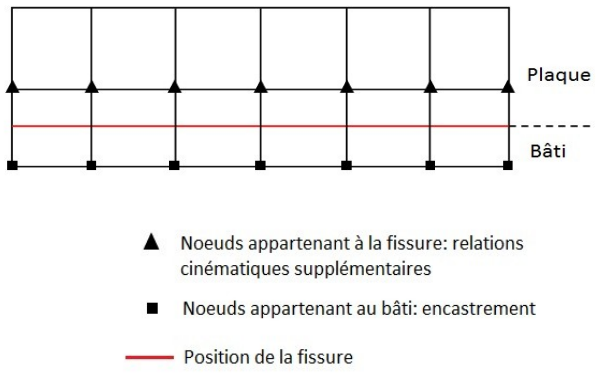
The rigid frame, of the same width than the cylinder, is blocked entirely by an embedding. DDL of displacement of nodes frame according to X, Y and Z are put at 0:

$$DX_{NBATI}=0,\ DY_{NBATI}=0 \text{ and } DZ_{NBATI}=0$$

Additional equations are written on the DDL of the nodes of the elements cut by the crack, so that displacement is null everywhere on the lower part of these elements corresponding to the frame. Very concretely the relations kinematics which impose that in any point built under the interface displacement is quite null are the following ones:

$$DX_{NPLAQUE}-2HX_{NPLAQUE}=0,\quad DY_{NPLAQUE}-2HY_{NPLAQUE}=0 \text{ and } DZ_{NPLAQUE}-2HZ_{NPLAQUE}=0$$

The following figure shows the nodes which carry these relations kinematics, in the case of a grid nonin conformity with the crack.



The plate is subjected to two pressures distributed:

- a vertical pressure acting on the face of the top: $f=-5\ daN/mm^2$,

- a horizontal pressure acting on the side faces, for $y>0$, $F=\pm 15\,daN/mm^2$ (according to the principle of compression)

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution comes from the results got by modeling A, namely a modeling 3D under the keyword FORMULATION= ' CONTINUE' of the operator DEFI_CONTACT.

2.2 Results of reference

Tangential displacements (according to X) at the points $A, B, C, D,$ et E surface of contact.

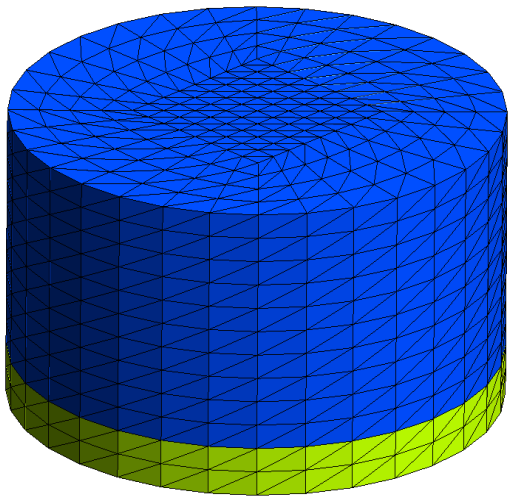
3 Modeling A

3.1 Characteristics of modeling

Modeling: 3D to test the operand 'CONTINUES' keyword FORMULATION da NS the operator DEFI_CONTACT for elements TETRA4 .

3.2 Characteristics of the grid

Many nodes: 2926
Many meshs and types: 13824 TETRA4 for the plate and the frame.
1792 TRIA3 for the elements of edge.



3.3 Sizes tested and results

Identification	Type of reference	Value of reference	Precision
DX at the point A	'AUTRE_ASTER'	-2,37E-005	0,1%
DX at the point B	'AUTRE_ASTER'	-1,84E-005	0,1%
DX at the point C	'AUTRE_ASTER'	-1,30E-005	0,1%
DX at the point D	'AUTRE_ASTER'	-8,09569E-06	0,1%
DX at the point E	'AUTRE_ASTER'	-3,90803E-06	0,1%

3.4 Notice

These results are used as references for modelings B and C.

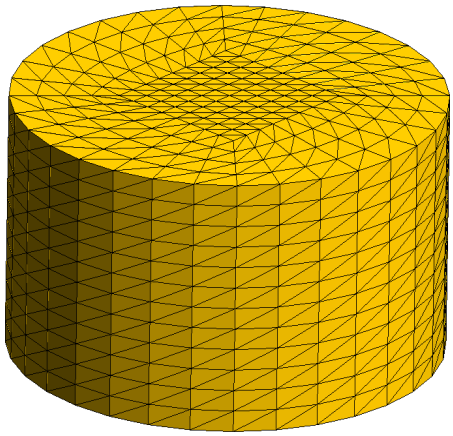
4 Modeling B

4.1 Characteristics of modeling

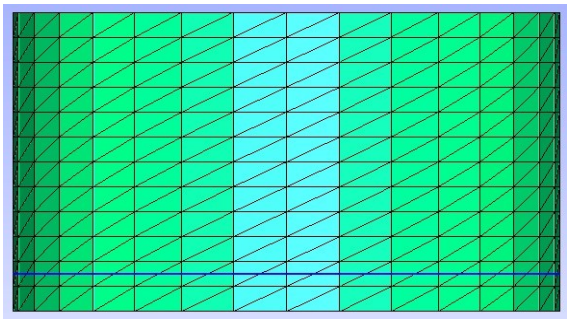
Modeling: 3D cylinder to test the operand 'XFEM' keyword FORMULATION in the operator DEFI_CONTACT for elements TETRA4 .

4.2 Characteristics of the grid

Many nodes: 2717
Many meshs and types: 13824 TETRA4 for the plate and the frame.
1536 TRIA3 for the elements of edge.



The crack (milked blue) coincides with the Z=0 plan and is located at 40 mm below the face superiorE.



4.3 Sizes tested and results

Identification	Type of reference	Value of reference	Precision
DX at the point A	'AUTRE_ASTER'	-2,37083E-05	0,1%
DX at the point B	'AUTRE_ASTER'	-1,83709E-05	0,1%
DX at the point C	'AUTRE_ASTER'	-1,29919E-05	0,1%
DX at the point D	'AUTRE_ASTER'	-8,09569E-06	0,1%
DX at the point E	'AUTRE_ASTER'	-3,90803E-06	0,1%

5 Modeling C

5.1 Characteristics of modeling

It acts of the same modeling as modeling B, but with a penalized formulation this time.

5.2 Characteristics of the grid

It is the same grid as that of modeling B.

5.3 Sizes tested and results

The values of reference and the tolerances are identical to modeling B.

Identification	Type of reference	Value of reference	Precision
DX at the point A	'AUTRE_ASTER'	-2,37083E-05	0,1%
DX at the point B	'AUTRE_ASTER'	-1,83709E-05	0,1%
DX at the point C	'AUTRE_ASTER'	-1,29919E-05	0,1%
DX at the point D	'AUTRE_ASTER'	-8,09569E-06	0,1%
DX at the point E	'AUTRE_ASTER'	-3,90803E-06	0,1%

6 Summary of the results

The cas-test PERF017 makes it possible to observe the three states of the conditions of contact, namely separation, the slipping contact and the adhering contact.

This case test makes it possible to highlight satisfactory results for modelings 3D, in particular the satisfaction of the condition LBB for the modeling of contact-rubbing with X-FEM.

The goals of this test are achieved:

1) with a relative error compared to the reference solution of less 1% for displacements,
2) by using the methods of Lagrangian increased and penalization for the treatment of contact-friction.