SSNP154 – Benchmark NAFEMS of validation of contact 1: *cylinder roller contact*

Summary:

This problem constitutes the first CAS-test of a benchmark NAFEMS of validation of contact-friction. The references of the benchmark are obtained with the codes Abaqus and MARC.
This test models a contact of Hertz with and without friction between a solid mass and a cylinder of different stiffnesses with a grid with different smoothnesses.
An analytical solution exists for the case without friction.

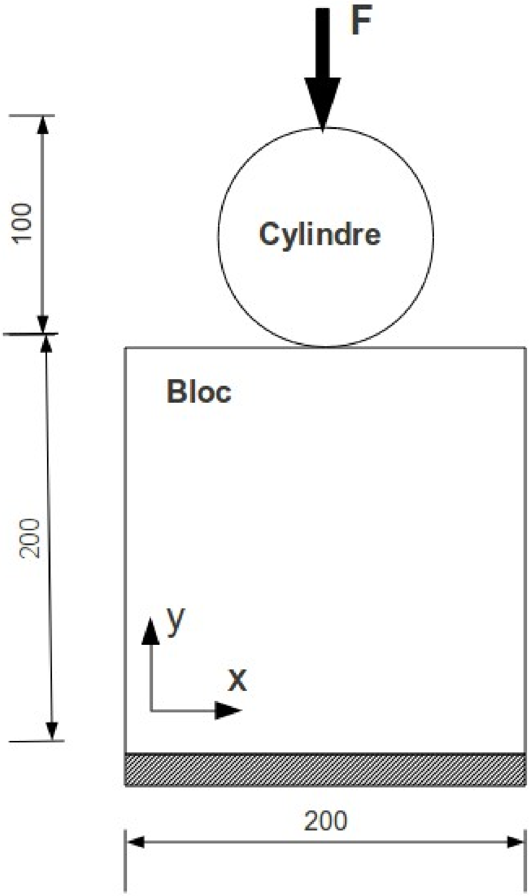
This test comprises 7 modelings making it possible to test:

- linear and quadratic elements,
- formulations of treatment of the contact without and with friction `'DISCRETE'` and `'CONTINUOUS'`.

1 Problem of reference

1.1 Geometry

The structure is modelled in plane deformations.



One notes B the point on the higher side of the block pertaining to the symmetry plane.

1.2 Properties of materials

Block :

Poisson's ratio: $0{,}3$
Young modulus: $70000\,N.mm^{-2}$

Cylinder :

Poisson's ratio: $0{,}3$
Young modulus: $210000\,N.mm^{-2}$

The coefficient of friction between the block and the cylinder is worth $\mu=0{,}1$.

1.3 Boundary conditions and loadings

The structure symmetrical and being subjected to a loading respecting symmetry, only a half is represented. One thus applies $DX=0$ as regards symmetry.

The block is embedded at its base:

- $DX=0$
- $DY=0$

The cylinder is subjected to a specific force on its top:

- $FY=35\,kN$, that is to say $FY=17500\,N$ for the half-structure

2 Reference solution

2.1 Method of calculating

The reference solution comes from results got with the codes Abaqus and MARC in a benchmark NAFEMS of validation of contact-friction [bib1].
For modelings without friction, a comparison with the analytical solution of Hertz is carried out.

2.2 Sizes and results of reference

Vertical displacement of the point B (according to y) (external reference).

Contact pressure at the point B (external reference). The contact pressure raised is that extrapolated starting from the constraints in volume.

2.3 Uncertainties on the solution

Important (average of codes).

2.4 Bibliographical reference

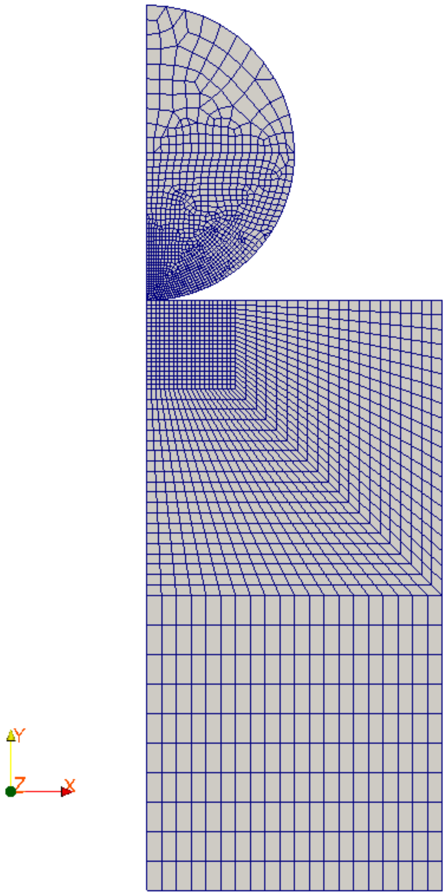
[1] A. KONTER. *"Advanced Finite Element Benchmarks Contact"*. NAFEMS, 2006.

3 Modeling A

3.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is CONTINUOUS, friction is disabled. This CAS-test also validates the order CALC_PRESSION with the formulation continues.

3.2 Characteristics of the grid

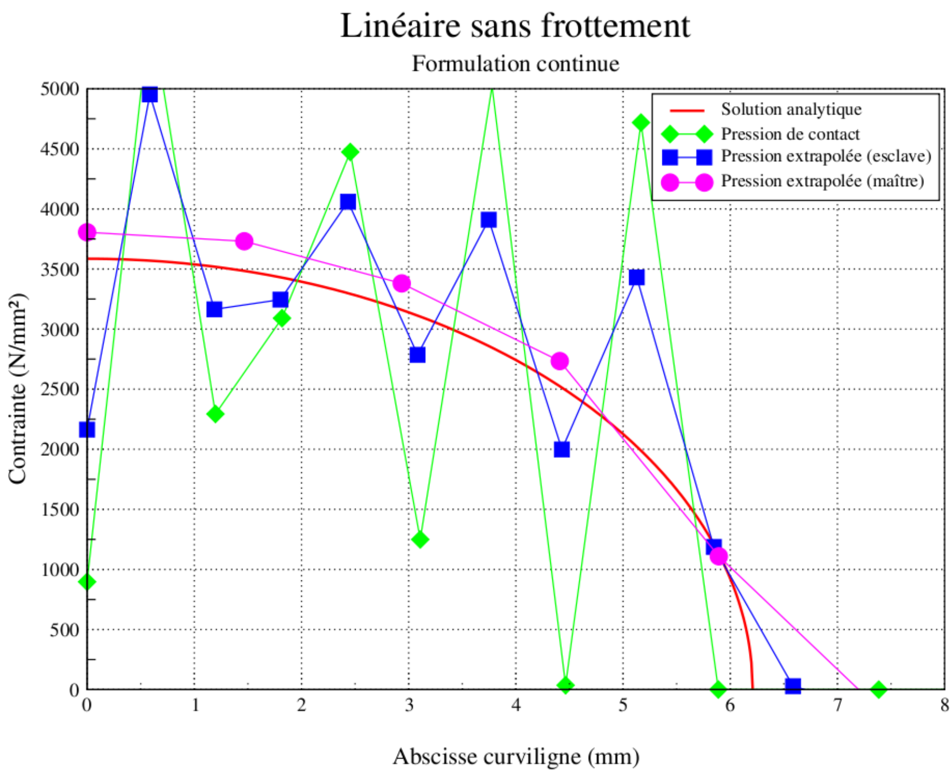


Many nodes: 2625
Many meshs and types: 2467 QUAD4 and 53 TRIA3.

3.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3069040401077	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3800.4949548283	0.1%

3.4 Remarks



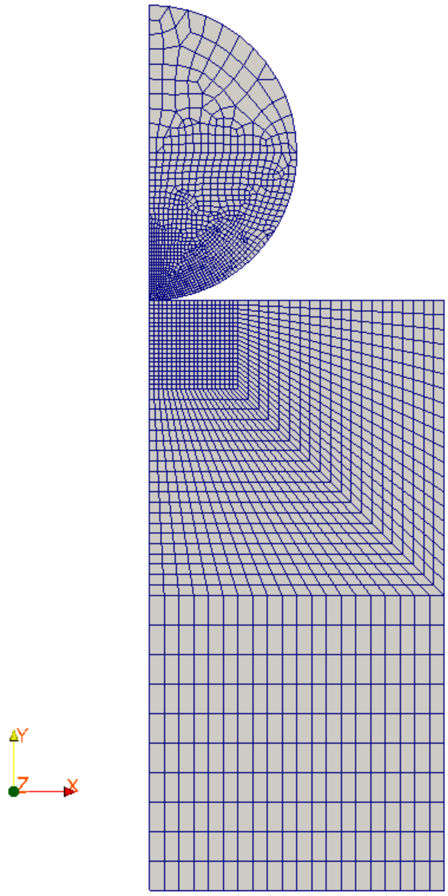
The results got into linear without friction with the formulation continues are in concord with the analytical solution when one records the contact pressure extrapolated on surface Master.
One will however note the strong oscillation of the contact pressure when it is raised starting from the degree of freedom `LAGS_C` specific to the continuous formulation. The amplitude of the oscillations decreases when the grid is refined.

4 Modeling B

4.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is CONTINUOUS, friction is disabled.This CAS-test also validates the order CALC_PRESSION with the formulation continues.

4.2 Characteristics of the grid

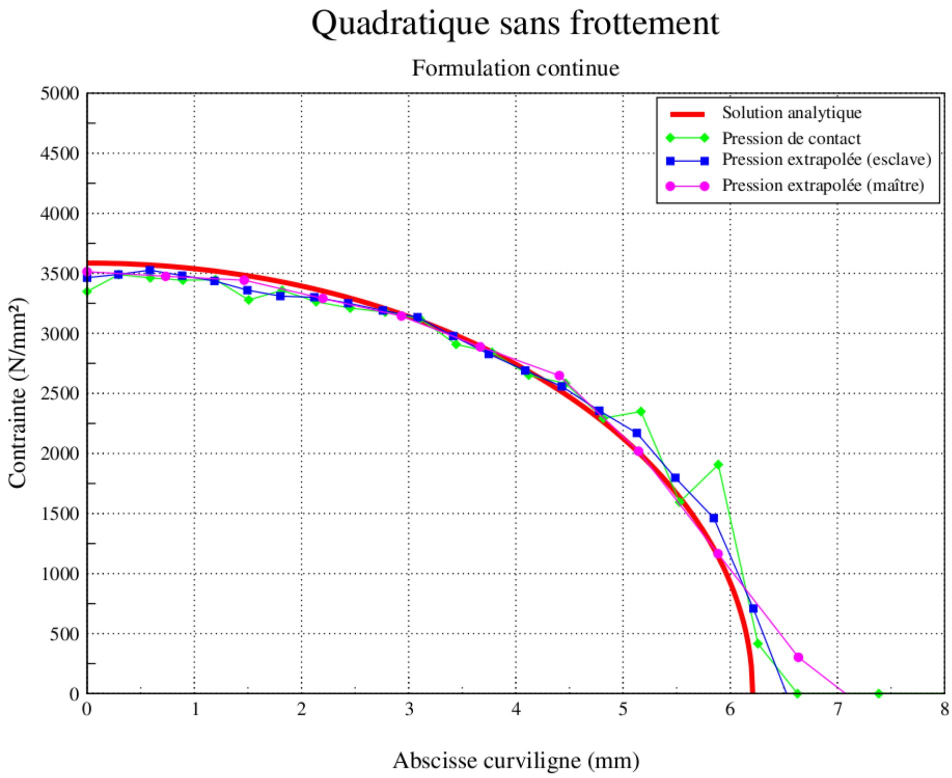


Many nodes: 7768
Many meshs and types: 2467 QUAD8 and 53 TRIA6.

4.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3080192481252	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3513.3741602327	0.1%

4.4 Remarks



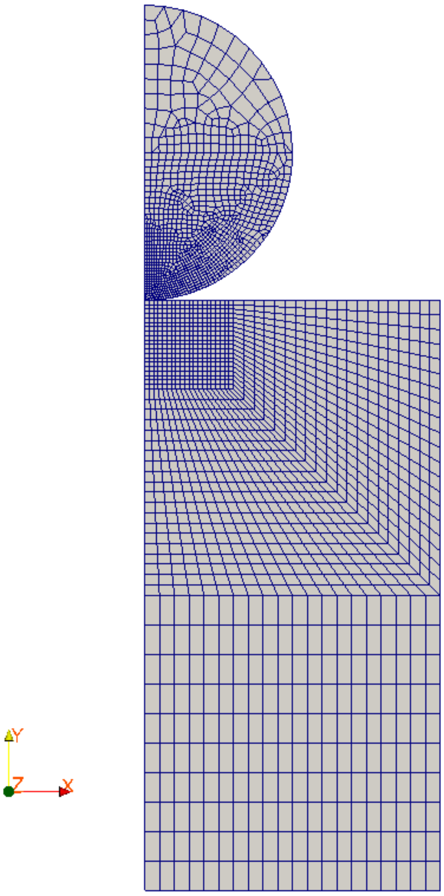
The results got into quadratic without friction with the formulation continues are in very good agreement with the analytical solution whatever the way in which the pressure is recorded.
It will be noted that the oscillations almost disappeared compared to modeling A with linear elements. For that one used a digital integration of the terms of contact of the Gauss type (`INTEGRATION=' GAUSS'`).

5 Modeling C

5.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is CONTINUOUS, friction is taken into account.

5.2 Characteristics of the grid



Many nodes: 2625
Many meshs and types: 2467 QUAD4 and 53 TRIA3.

5.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3010795638714	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3670.2561088662	0.1%

5.4 Remarks

The results got into linear with friction with the formulation continues are in concord with the analytical solution when one records the contact pressure extrapolated on surface Master.
One will however note the strong oscillation of the contact pressure when it is raised starting from the degree of freedom LAGS_C specific to the continuous formulation. The amplitude of the oscillations decreases when the grid is refined.

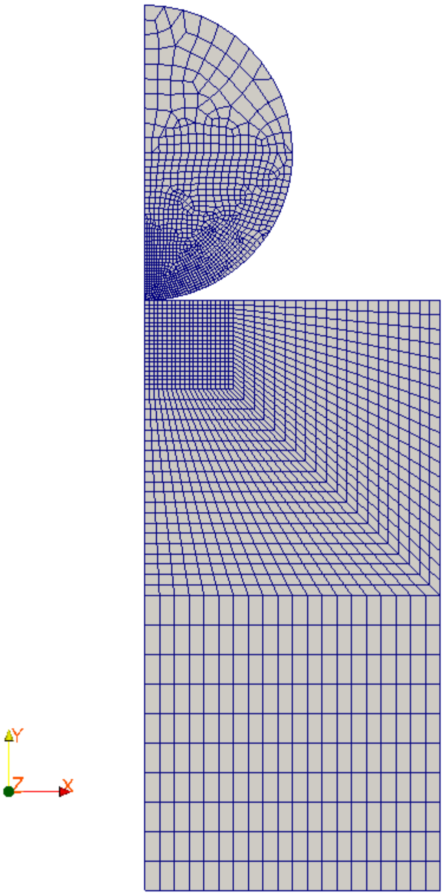
The results got by the commercial codes Abaqus and MARC in the benchmark have also oscillations for the case with friction.

6 Modeling D

6.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is CONTINUOUS, friction is taken into account.

6.2 Characteristics of the grid

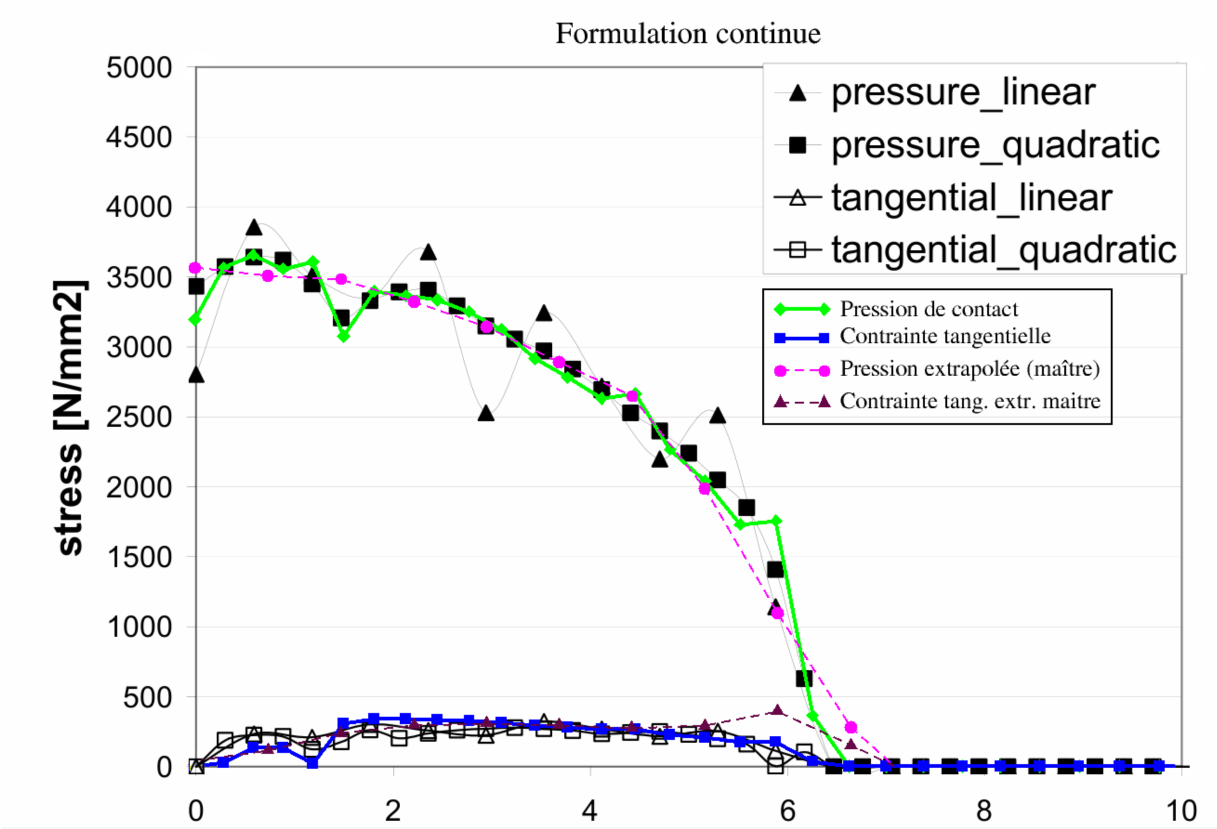


Many nodes: 7768
Many meshs and types: 2467 QUAD8 and 53 TRIA6.

6.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3026356448389	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3542.6878770218	0.1%

6.4 Remarks



The results got into quadratic with friction with the formulation continues are in very good agreement with those obtained in the benchmark (here those of the code MARC).

It will be noted that the contact pressure as well as the tangential constraint noted starting from the degrees of freedom `LAGS_C` and `LAGS_F1` continuous formulation stick perfectly with the sizes calculated by MARC.

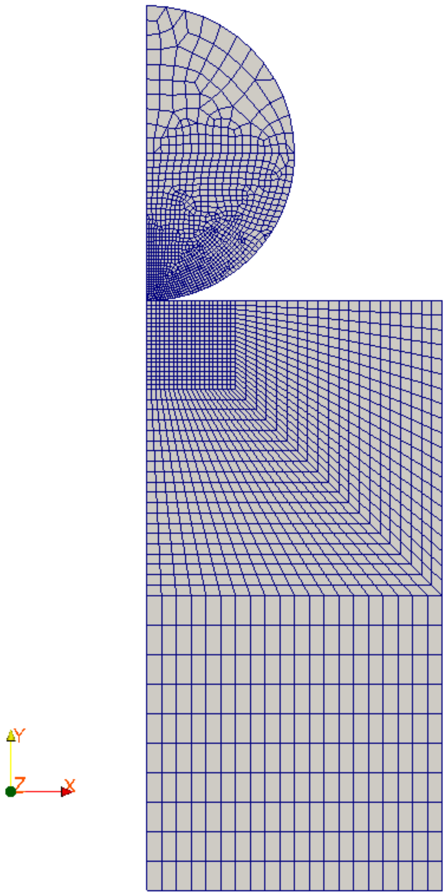
As it was the case without friction, the oscillations is much less important into quadratic, it is besides also the case for MARC.

7 Modeling E

7.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is DISCRETE, friction is disabled. The algorithm of contact used is that by default. This CAS-test also validates the order CALC_PRESSION with the discrete formulation.

7.2 Characteristics of the grid



Many nodes: 2625
Many meshs and types: 2467 QUAD4 and 53 TRIA3.

7.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3067596639633	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3814.1811065942	0.1%

7.4 Remarks

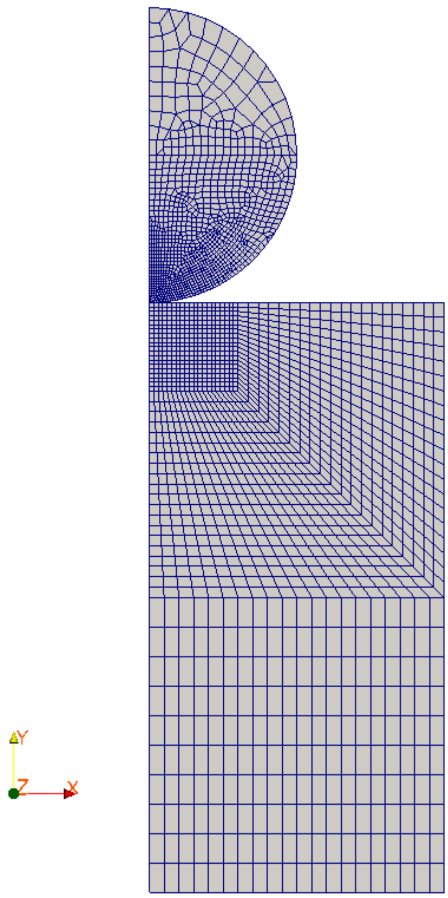
The results got into linear without friction with the discrete formulation are identical to those obtained in formulation continues (modeling A).
In discrete formulation one is obliged to bind the two nodes of the block and the cylinder in opposite initially preventing the rigid movement of body following the axis y.

8 Modeling F

8.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is DISCRETE, friction is disabled.
The algorithm of contact used is that by default.

8.2 Characteristics of the grid



Many nodes: 7768
Many meshs and types: 2467 QUAD8 and 53 TRIA6.

8.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3080923611548	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3502.7937782466	0.1%

8.4 Remarks

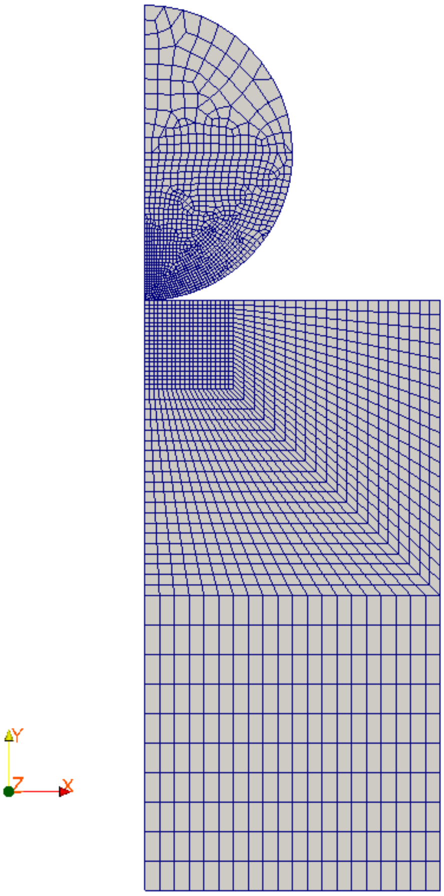
The results got into quadratic without friction with the discrete formulation are identical to those obtained in formulation continues (modeling B).
In discrete formulation one is obliged to bind the two nodes of the block and the cylinder in opposite initially preventing the rigid movement of body following the axis y.

9 Modeling G

9.1 Characteristics of modeling

Modeling is D_PLAN, the formulation of the contact is DISCRETE, friction is taken into account. The algorithm for contact-friction is LAGRANGIAN

9.2 Characteristics of the grid



Many nodes: 2625
Many meshs and types: 2467 QUAD4 and 53 TRIA3.

9.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point B	'SOURCE_EXTERNE'	-1.3010795793844	0.1%
$SIYY$ at the point B	'SOURCE_EXTERNE'	-3670.2559152851	0.1%

9.4 Remarks

The results got into linear with friction with the discrete formulation are identical to those obtained in formulation continues (modeling C).
In discrete formulation one is obliged to bind the two nodes of the block and the cylinder in opposite initially preventing the rigid movement of body following the axis y.

10 Summary of the results

This test makes it possible to validate contact-friction compared to an analytical solution but also compared to references given by commercial computer codes (Abaqus and MARC).
One observes a good agreement between the analytical results and those obtained by *Code_Aster* as well as a good agreement with the results of reference for calculations with friction.

It will be noted that the formulations continues and discrete give identical results with however the following restrictions:

- calculation in continuous formulation is easier to carry out because the blocking of the movement of vertical rigid body is carried out automatically
- calculation with friction on a quadratic grid could not be carried out in discrete formulation

Into quadratic, the contact pressure obtained starting from the degree of freedom `LAGS_C` in continuous formulation has much less oscillations than into linear.