SSNA122 – Benchmark NAFEMS of validation of contact 2: *punch (rounded edges)*

Summary:

This problem constitutes the second 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 between a punch at rounded edge (leave) and a solid mass into axisymmetric. This CAS-test validates the contact into axisymmetric and makes it possible to observe the positive effect of a leave on the singularity of the contact pressure in the vicinity of a sharp angle.

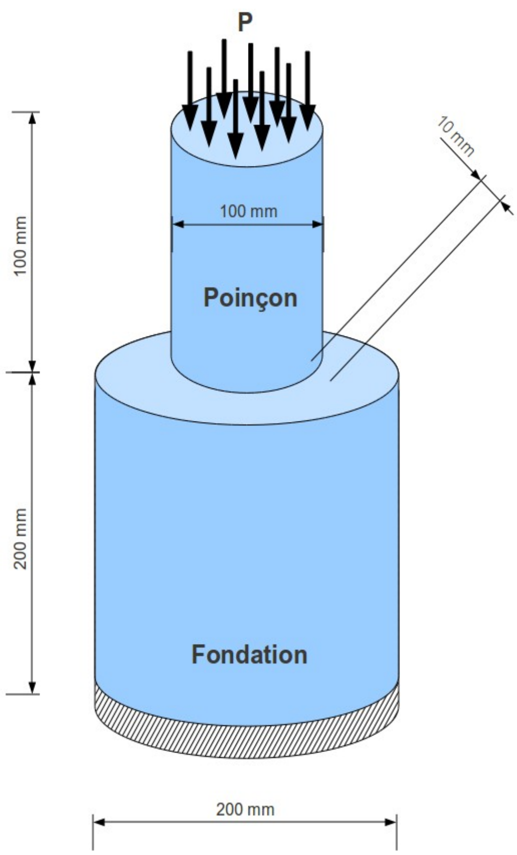
This test comprises 4 modelings making it possible to test:

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

1 Problem of reference

1.1 Geometry

The structure is modelled into axisymmetric.



One notes M the point of the foundation located opposite higher on the axis of revolution.

1.2 Properties of materials

Foundation :

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

Punch :

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 axisymmetric and being subjected to a loading respecting symmetry of revolution, only a slice is represented. One thus applies $DX=0$ on the axis of revolution.

The foundation is embedded at its base:

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

The punch is subjected to a uniform pressure on its higher face:

- $P=100\,Mpa$

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].

2.2 Sizes and results of reference

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

Contact pressure at the point M (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

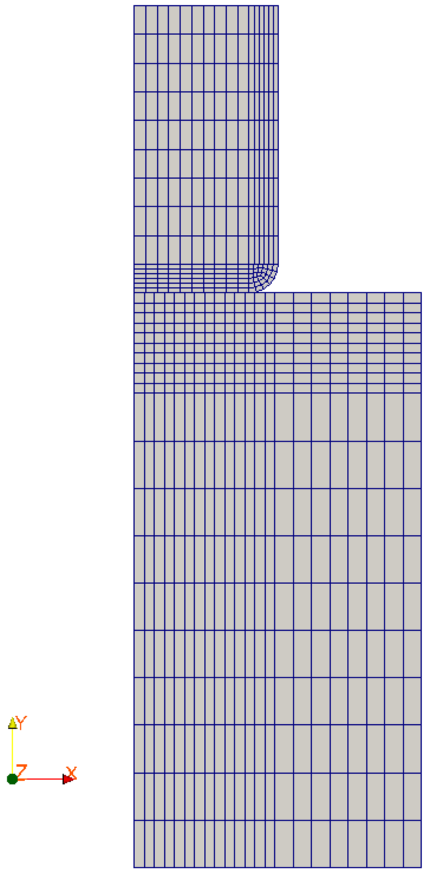
[1] A. KONTER. *“Advanced Finite Element Benchmarks Contact”*. NAFEMS, 2006.

3 Modeling A

3.1 Characteristics of modeling

Modeling is AXIS, the formulation of the contact is CONTINUOUS, the cases with and without friction are treated.

3.2 Characteristics of the grid



Many nodes: 743
Many meshs and types: 671 QUAD4.

3.3 Sizes tested and results

The first calculation (without friction)

Identification	Type of reference	Value of reference	Tolerance
DY at the point M	'SOURCE_EXTERNE'	-0.13073410182805	0.1%
$SIYY$ at the point M	'SOURCE_EXTERNE'	-91.100555673515	0.1%

The second calculation (with friction)

Identification	Type of reference	Value of reference	Tolerance
DY at the point M	'SOURCE_EXTERNE'	-0.12858017574262	0.1%

$SIYY$ at the point M	'SOURCE_EXTERNE'	-88.665240835356	0.1%

3.4 Remarks

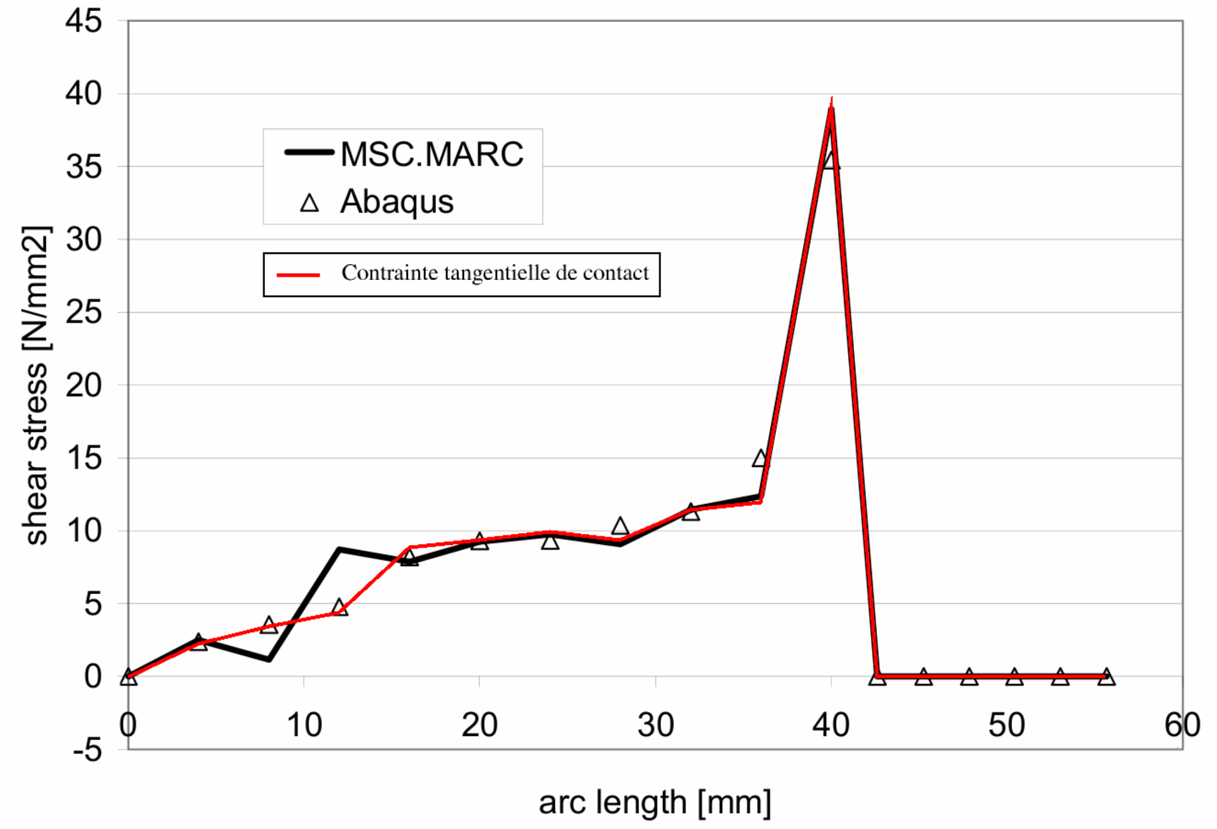


Illustration 1: Comparison of the tangential constraint between Abaqus, MARC and *Code_Aster*

The results got by the formulation continues in *Code_Aster* with as without friction are in very good agreement with those of the codes of reference. The figure above watch for example that the tangential constraint on the edge in contact raised starting from the degree of freedom `LAGS_F1` coincide with the solution of MARC.

It will be noted however that the contact pressure given by the degree of freedom `LAGS_C` for the point M (located on the axis of revolution) is disturbed in continuous formulation. Indeed the jacobien is null for the points of the axis of revolution. However for linear elements, the diagram of integration by default (and advised) is of standard trapezoid (thus with the nodes).

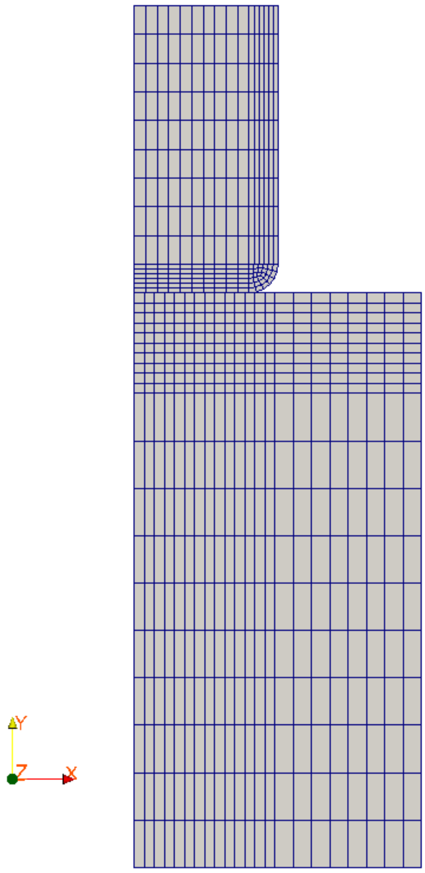
This test illustrates the interest of the features specific to the continuous formulation which make it possible to take into account of the initial contact (to block the movements of rigid body) and to only exclude from the nodes of friction (to avoid the incompatibilities between boundary conditions and conditions of contact-friction).

4 Modeling B

4.1 Characteristics of modeling

Modeling is `AXIS`, the formulation of the contact is `CONTINUOUS`, the cases with and without friction are treated.

4.2 Characteristics of the grid



Many nodes: 2155
Many meshs and types: 671 `QUAD8`.

4.3 Sizes tested and results

The first calculation (without friction)

Identification	Type of reference	Value of reference	Tolerance
DY at the point M	'SOURCE_EXTERNE'	-0.13294119101090	0.1%
$SIYY$ at the point M	'SOURCE_EXTERNE'	-94.122096406847	0.1%

The second calculation (with friction)

Identification	Type of reference	Value of reference	Tolerance
DY at the point M	'SOURCE_EXTERNE'	-0.13079352874552	0.1%

$SIYY$ at the point M	'SOURCE_EXTERNE'	-95.473963617887	0.1%

4.4 Remarks

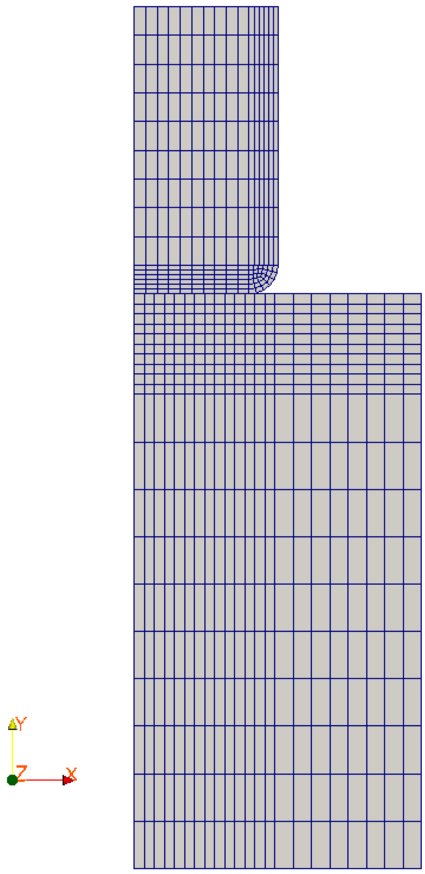
The results on a quadratic grid change very little compared to modeling A (linear grid). They are always also close to the references.

5 Modeling C

5.1 Characteristics of modeling

Modeling is AXIS, the formulation of the contact is DISCRETE, only the case without friction is treaty. A discrete element 2D_DIS_T allows to block the movements of rigid body.
contact is treated with the algorithm of the gradient combined project GCP.

5.2 Characteristics of the grid



Many nodes: 743
Many meshs and types: 671 QUAD4.

5.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point M	'SOURCE_EXTERNE'	-0.13081498724905	0.1%
$SIYY$ at the point M	'SOURCE_EXTERNE'	-91.081142208614	0.1%

5.4 Remarks

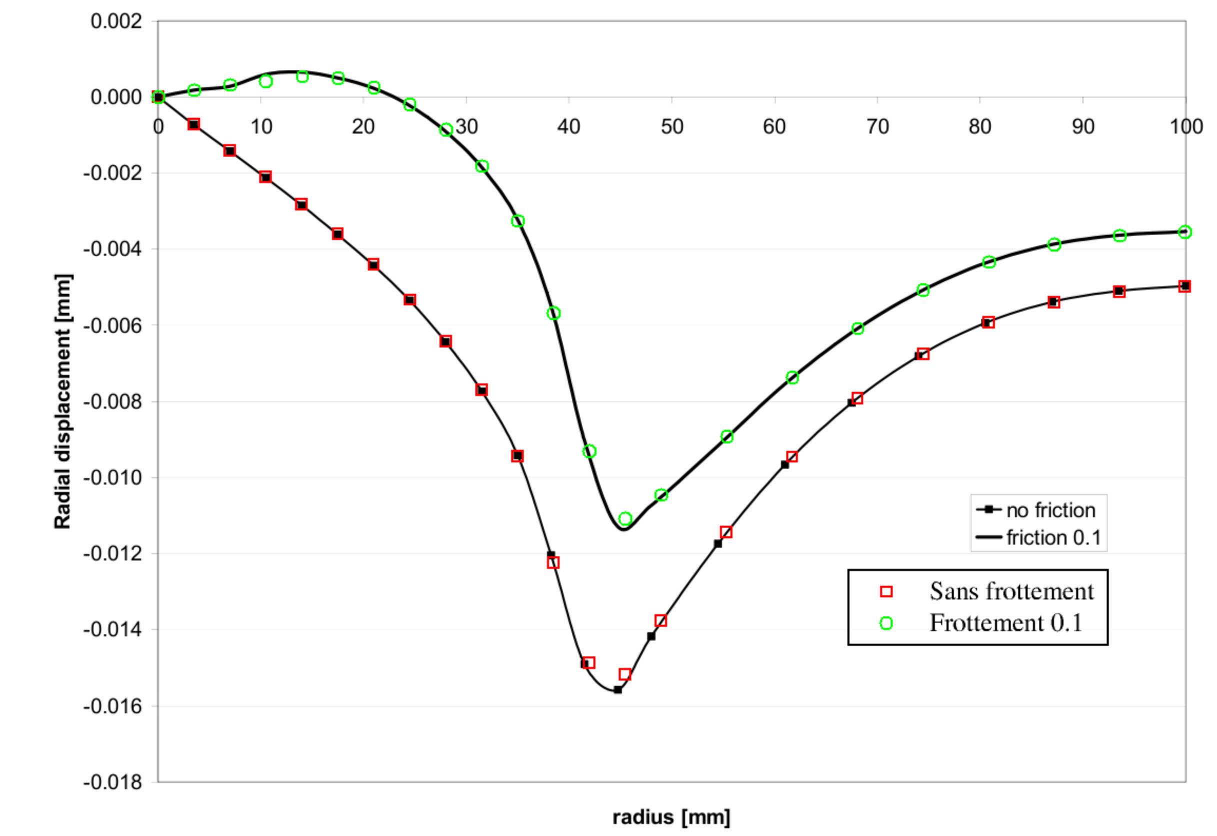


Illustration 2: Radial displacement with and without friction (MARC and *Code_Aster*)

Results got by the discrete formulation in *Code_Aster* are in very good agreement with those of the codes of reference. The figure above watch for example that radial displacement sticks perfectly to that of the references (here MARC).

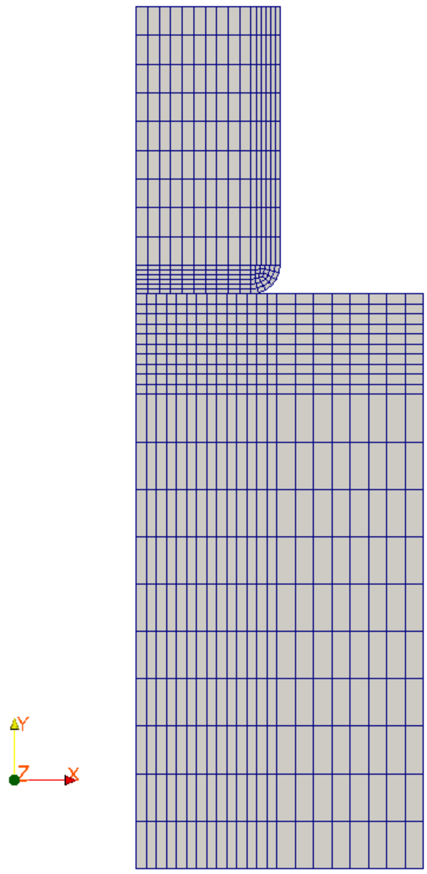
The discrete formulation appreciably gives the same results which the formulation continues (modeling A) but requires a setting in data slightly more complicated. Indeed the movement of vertical rigid body must be blocked by adding a spring of low stiffness between the 2 bodies.

6 Modeling D

6.1 Characteristics of modeling

Modeling is `AXIS`, the formulation of the contact is `DISCRETE`, only the case without friction is treaty.
A discrete element `2D_DIS_T` allows to block the movements of rigid body.
contact is treated with the algorithm of the gradient combined project `GCP` .

6.2 Characteristics of the grid



Many nodes: 2155
Many meshs and types: 671 `QUAD8`.

6.3 Sizes tested and results

Identification	Type of reference	Value of reference	Tolerance
DY at the point M	'SOURCE_EXTERNE'	-0.13289744810653	0.1%
$SIYY$ at the point M	'SOURCE_EXTERNE'	-93.626123536884	0.1%

6.4 Remarks

The results on a quadratic grid change very little compared to modeling C (linear grid). They are always also close to the references.

7 Summary of the results

This test makes it possible to validate contact-friction in axisymmetric modeling compared to references given by commercial computer codes (Abaqus and MARC).
One observes very a good agreement between the results got by *Code_Aster* and results of reference.

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

This test also shows the regularization of the contact pressure by a leave in the vicinity of sharp angles.