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

Summarized:

This problem constitutes the second benchmark 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 with rounded edge (fillet) and a solid mass into axisymmetric. This benchmark validates the contact into axisymmetric and makes it possible to observe the positive effect of a fillet on the singularity of the contact pressure in the vicinity of a sharp angle.

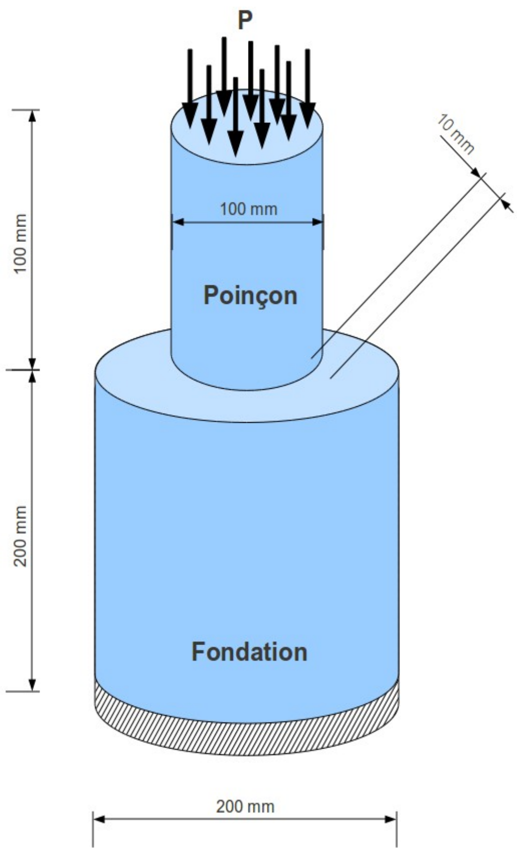
This test comprises 4 modelizations making it possible to test:

- linear and quadratic elements,
- formulations of processing of the contact without and with friction "`DISCRETE`" and "`CONTINUE`".

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 the 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 kinetic 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 $DX=0$ to 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 upper face:

- $P=100\,Mpa$

2 Reference solution

2.1 Method of calculating

the reference solution comes of results obtained with the codes Abaqus and MARC in a benchmark NAFEMS from validation of contact-friction [bib1].

2.2 Quantities 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 stresses in volume.

2.3 Uncertainties on the Important

solution (average of codes).

2.4 Bibliographical reference

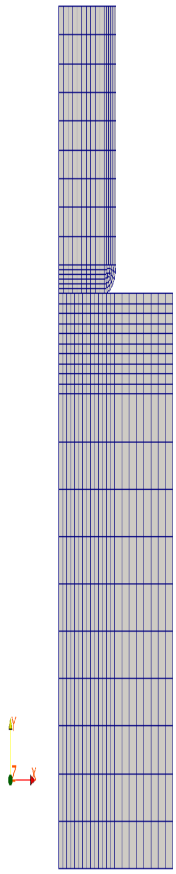
[1] A. KONTER. *“Advanced Finite Element Benchmarks Contact”*. NAFEMS, 2006.

3 Modelization A

3.1 Characteristic of the modelization

The modelization is AXIS, the formulation of the contact is CONTINUE, the cases with and without friction are treated.

3.2 Characteristics of the mesh



Many nodes: 743
Number of meshes and types: 671 QUAD4.

3.3 Quantities tested and results

the First computation (without friction)

Standard	Identification of reference	Value of reference	Tolerance
DY to point M	"SOURCE_EXTERNE"	-0,13073410182805	0,1%
$SIYY$ to point M	"SOURCE_EXTERNE"	-91,100555673515	0,1%

the Second computation (with friction)

Standard	Identification 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

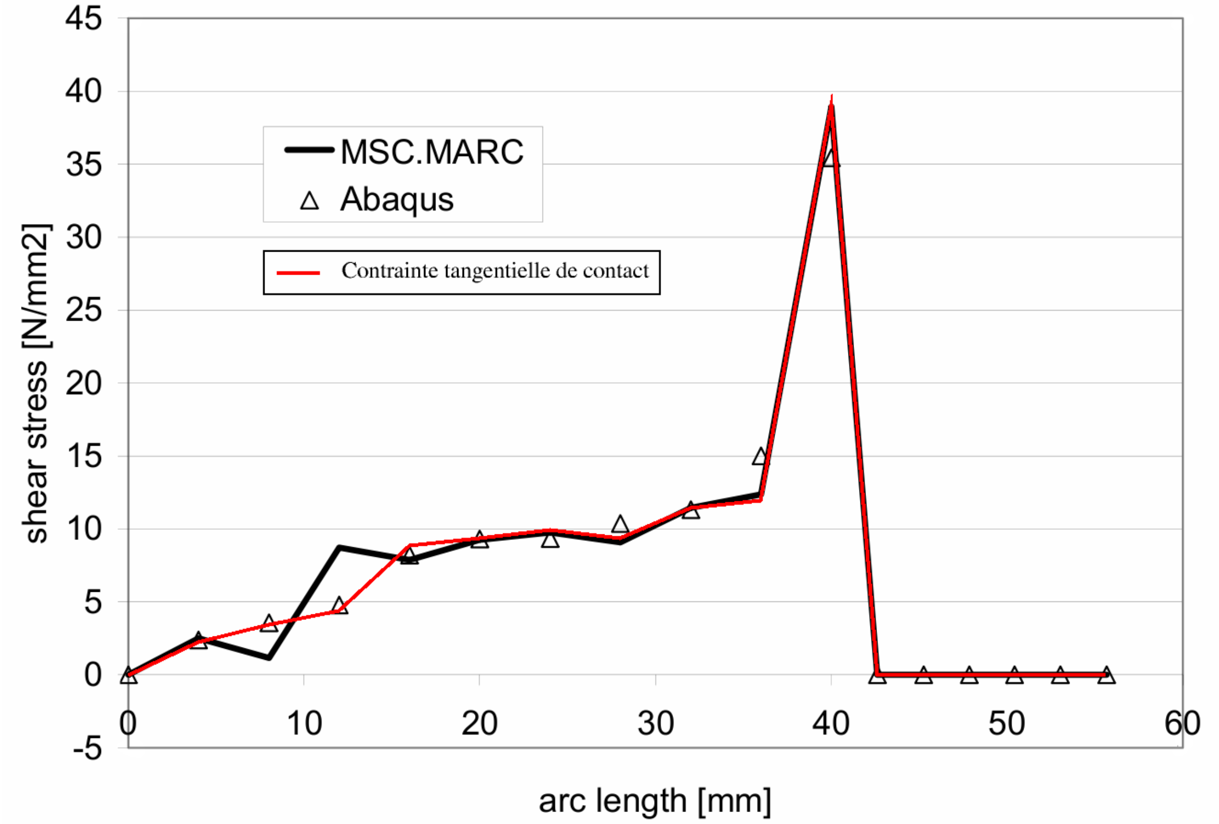


Illustration 1: Comparison of the shear stress between Abaqus, MARC and *Code_Aster*

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 shear stress on edge in contact raised starting from degree of freedom `LAGS_F1` coincides with the solution of MARC.

It will be noted however that the contact pressure given by degree of freedom `LAGS_C` for the point M (located on the axis of revolution) is disturbed in continuous formulation. Indeed the jacobian 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).

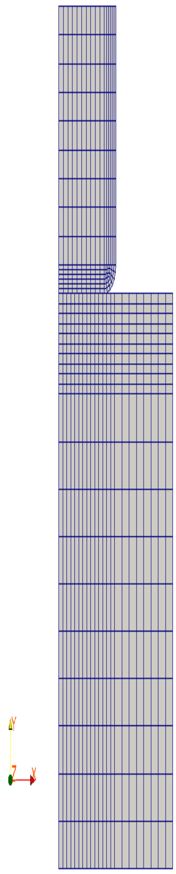
This test illustrates the interest of the features specific to the continuous formulation which make it possible to take into account of the contact initial (to block rigid body motions) and to only exclude from the nodes of friction (to avoid the incompatibilities between boundary conditions and conditions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

4 Modelization B

4.1 Characteristic of the modelization

The modelization is AXIS, the formulation of the contact is CONTINUE, the cases with and without friction are treated.

4.2 Characteristics of the mesh



Many nodes: 2155
Number of meshes and types: 671 QUAD8.

4.3 Quantities tested and results

the First computation (without friction)

Standard	Identification 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 computation (with friction)

Standard	Identification 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

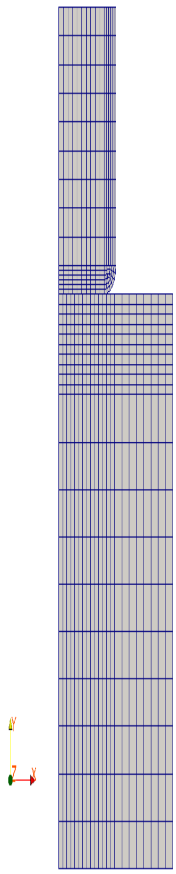
the results on a quadratic mesh change modelization very little compared to the A (linear mesh). They are always also close to the references.

5 Modelization C

5.1 Characteristic of the modelization

The modelization is AXIS, the formulation of the contact is DISCRETE, the cases with and without friction are treated. A discrete element 2D_DIS_T makes it possible to block rigid body motions.
The case without friction is treated with the algorithm of the conjugate gradient project GCP , the case with friction with LAGRANGIAN .

5.2 Characteristics of the mesh



Many nodes: 743
Number of meshes and types: 671 QUAD4.

5.3 Quantities tested and results

the First computation (without friction)

Standard	Identification 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%

the Second computation (with friction)

Standard	Identification of reference	Value of reference	Tolerance
DY at the point M	"SOURCE_EXTERNE"	-0,12857899943778	0,1%
$SIYY$ at the point M	"SOURCE_EXTERNE"	-88,647091038035	0,1%

5.4 Remarks

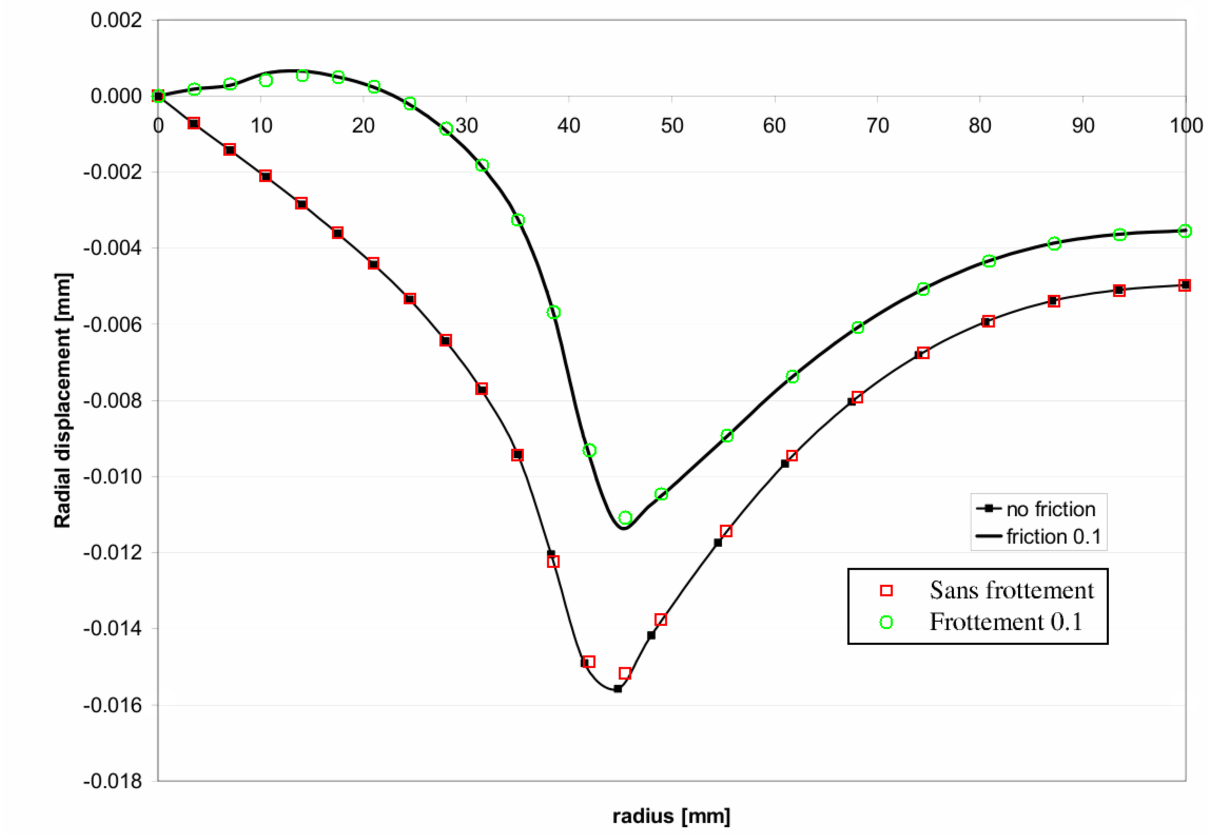


Illustration 2: Radial displacement with and without friction (MARC and *Code_Aster*)

the results got by the discrete formulation 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 radial displacement sticks perfectly to that of the references (here MARC).

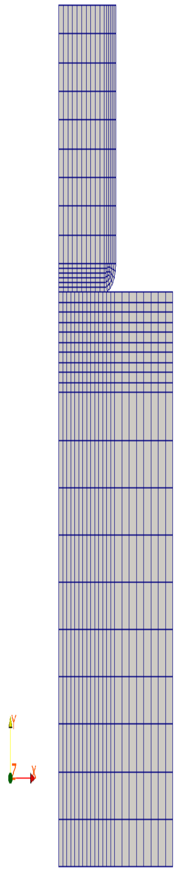
The discrete formulation appreciably gives the same results which the formulation continues (modelization A) but requires a setting in data slightly more complicated. Indeed vertical rigid body motion must be blocked by adding a come out from low stiffness between the 2 bodies while the condition of axisymetry ($DX=0$) on the slave node must be penalized (with a come out from infinite stiffness) in order to avoid an incompatibility in friction.

6 Modelization D

6.1 Characteristic of the modelization

The modelization is AXIS, the formulation of the contact is DISCRETE, the cases with and without friction are treated. A discrete element 2D_DIS_T makes it possible to block rigid body motions.
The case without friction is treated with the algorithm of the conjugate gradient project GCP , the case with friction with LAGRANGIAN .

6.2 Characteristics of the mesh



Many nodes: 2155
Number of meshes and types: 671 QUAD8.

6.3 Quantities tested and results

the First computation (without friction)

Standard	Identification 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%

the Second computation (with friction)

Standard	Identification of reference	Value of reference	Tolerance
DY at the point M	`"SOURCE_EXTERNE"`	-0,13077495250840	0,1%
$SIYY$ at the point M	`"SOURCE_EXTERNE"`	-95,191895551335	0,1%

6.4 Remarks

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

7 Summary of the results

This test makes it possible to validate contact-friction in axisymmetric modelization 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 the results of reference.

It will be noted that the formulations continues and discrete give identical results with however the following restrictions:
−computation in continuous formulation is easier to carry out because the blocking of vertical rigid body motion is carried out automatically
−in discrete formulation with friction, it was necessary to penalize the boundary condition of axisymetry to avoid a singular matrix

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