

SSNP155 – Benchmark NAFEMS of validation of contact 3: *sheet metal forming*

Summary:

This problem constitutes the third 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 stamping of a sheet by a **punch in a matrix**. The problem is three times over **non-linear**: non-linear isotropic **work hardening**, **great displacements** and **contact-friction**.

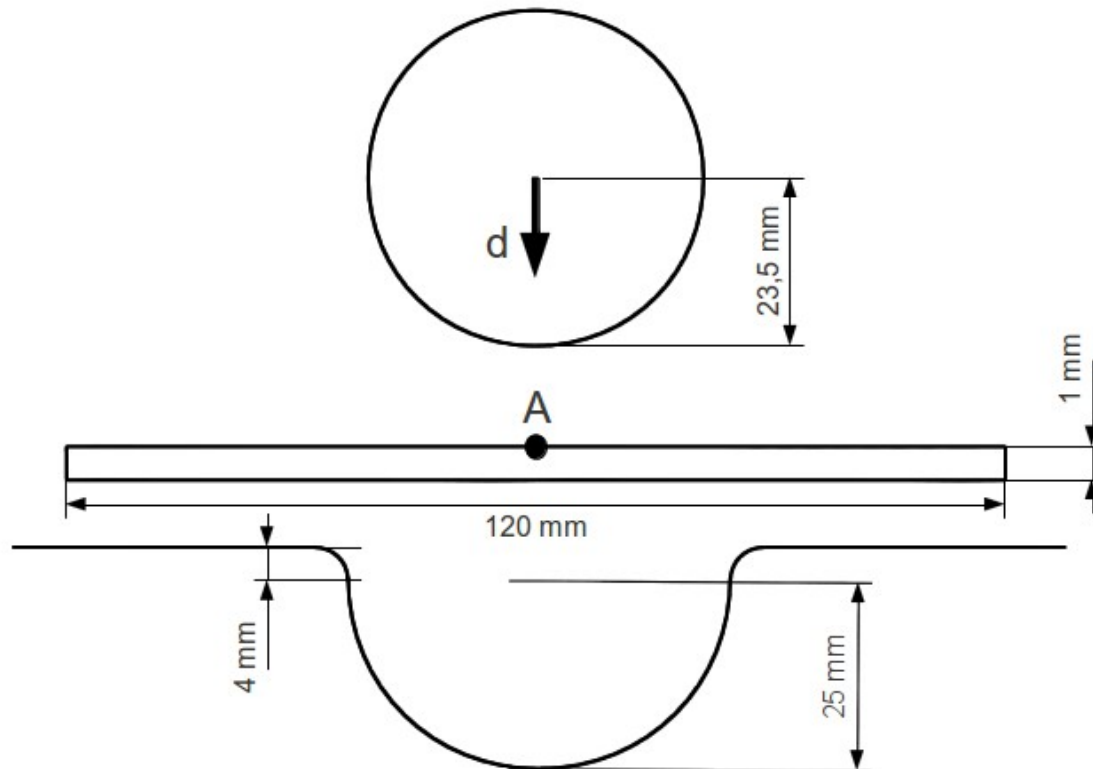
This test comprises only one modeling with:

- under-integrated quadratic elements
- formulation of treatment of the contact without friction 'DISCRETE'.

1 Problem of reference

1.1 Geometry

The structure is modelled in plane deformations. One takes account of **symmetry** to represent only **one half**.



One notes A the point medium of the plate located on the higher edge.

1.2 Properties of materials

Punch and die :

Rigid

Plate :

Poisson's ratio: 0,342

Young modulus: 70500 N.mm^{-2}

Yield stress: $\sigma_0 = 194 \text{ N.mm}^{-2}$

Isotropic **work hardening** of **Hollomon type**: $\sigma = K \epsilon^n$

- $K = 550,4 \text{ N.mm}^{-2}$

- $n = 0,223$

In calculation, this work hardening is represented by a non-linear work hardening with traction diagram:

| ϵ | σ (Mpa) |
|-------------|------------------|
| 2.75177E-03 | 1.94000E+02 |
| 2.32630E-02 | 2.30043E+02 |
| 4.38085E-02 | 2.68496E+02 |
| 6.41689E-02 | 2.93904E+02 |
| 8.44451E-02 | 3.13378E+02 |
| 1.04672E-01 | 3.29365E+02 |
| 2.05453E-01 | 3.84423E+02 |
| 3.05969E-01 | 4.20802E+02 |
| 4.06364E-01 | 4.48681E+02 |
| 5.06689E-01 | 4.71573E+02 |
| 6.06967E-01 | 4.91140E+02 |
| 7.07210E-01 | 5.08317E+02 |
| 8.07428E-01 | 5.23682E+02 |
| 9.07626E-01 | 5.37619E+02 |
| 1.00781E+00 | 5.50399E+02 |
| 1.10797E+00 | 5.62224E+02 |
| 1.20813E+00 | 5.73239E+02 |
| 1.30828E+00 | 5.83564E+02 |
| 1.40842E+00 | 5.93287E+02 |

The coefficient of friction between the rigid plate and tools is worth $\mu=0,1342$.

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 matrix is embedded:

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

The punch is subjected to a vertical displacement:

- $DY=d=-28,5\text{ mm}$

In the second time one withdraws the punch (discharge).

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].
Experimental results are available for the case where friction is taken into account.

2.2 Sizes and results of reference

Vertical displacement of the point A (according to y) after complete descent of the punch then, discharge.

2.3 Uncertainties on the solution

Important (average of codes).

2.4 Bibliographical reference

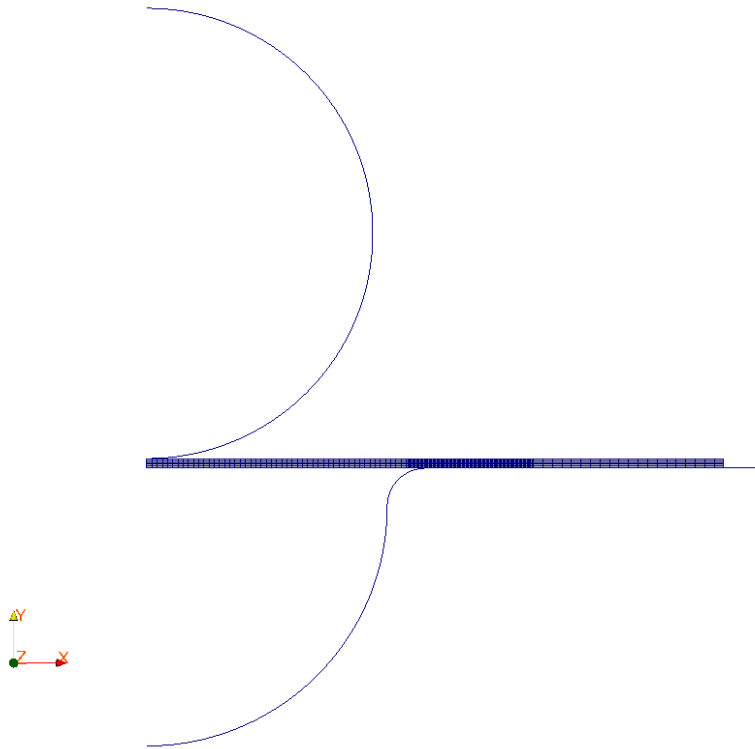
[1] A. KONTER. “Advanced Finite Element Benchmarks Contact”. NAFEMS, 2006.

3 Modeling A

3.1 Characteristics of modeling

Modeling is D_PLAN_SI, the formulation of the contact is DISCRETE, **friction is disabled**.

3.2 Characteristics of the grid



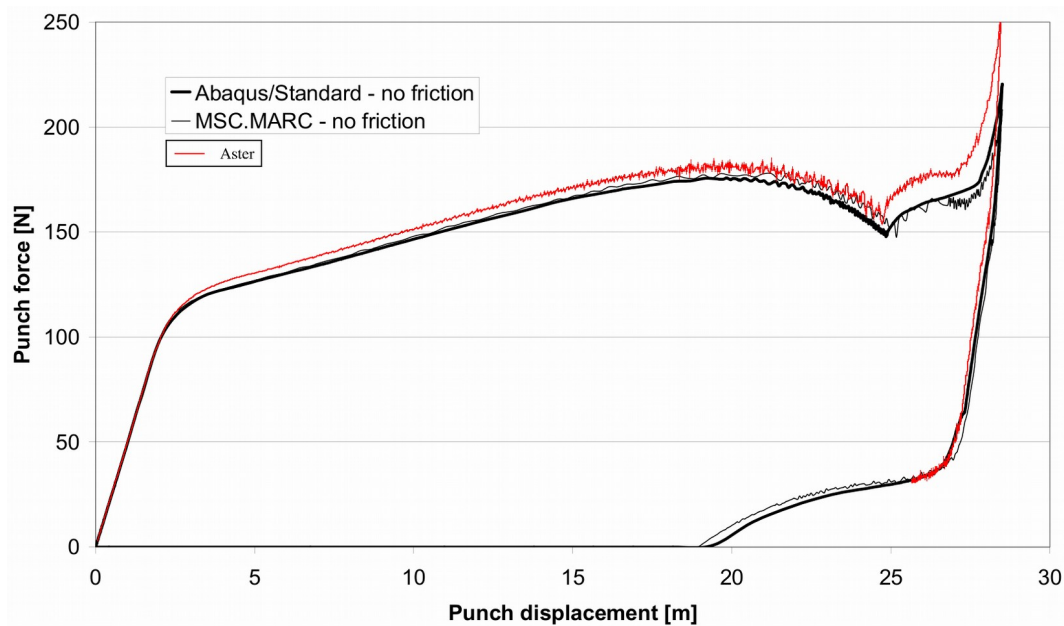
Many nodes: 3436
Many meshes and types: 850 QUAD8 and 533 SEG2.

3.3 Sizes tested and results

Calculation with algorithm of contact 'CONSTRAINT'

| Identification | Type of reference | Value of reference | Tolerance |
|---|-------------------|--------------------|-----------|
| <i>DY</i> at the point <i>A</i> after load | 'SOURCE_EXTERNE' | -28.5 | 0.1% |
| <i>DY</i> at the point <i>A</i> after discharge | 'SOURCE_EXTERNE' | -25.65 | 0.1% |

3.4 Remarks



The results got into quadratic under-integrated without friction with the discrete formulation are in concord with the reference solution.

One will note a light deviation compared to the commercial codes which can be explained by the treatment in slow dynamics of the problem. Indeed the very unstable answer force-displacement obliged to carry out calculation thus in order to profit from the stabilization of a matrix masses.

The discharge was not continued until the end in order to minimize the computing time of the test.

It will be noted that in this test and contrary to the recommendations of the note of use of the contact ([U2.04.04]), a prediction 'TANGENT' was used. It is because the prediction 'RUBBER BAND' cannot pass the final stage of the load, one sees it on the answer force-displacement: the slope at this place is stiffer than the elastic slope.

4 Summary of the results

This test makes it possible to validate the contact coupled to all other non-linearities compared to references given by commercial computer codes (Abaqus and MARC).

One observes a good agreement between the results of reference and those obtained by *Code_Aster*.

One will note that in it *benchmark* particularly difficult:

- calculation in continuous formulation was not possible
- stabilization (by a dynamic calculation in long time) is essential to the unrolled good of the test

Calculation with **friction** was carried out **successfully** in continuous formulation but requires a **too long computing time** to make a modeling of this test of it. For information one gives nevertheless the answer force-displacement of such a calculation.

