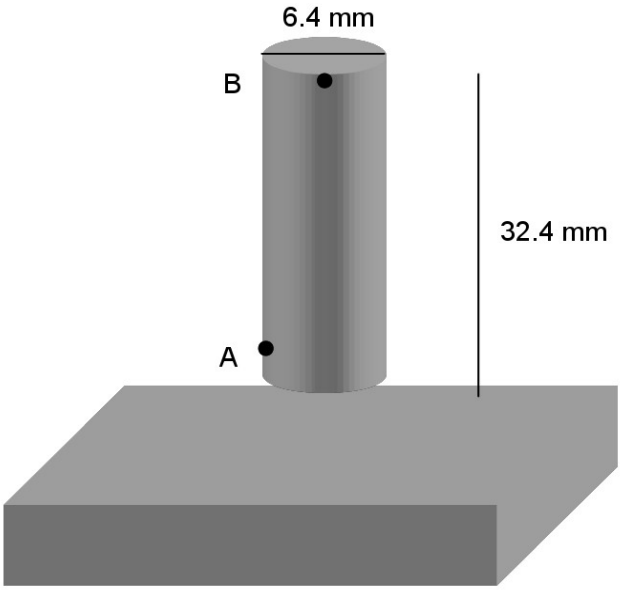
SDNV103 - Impact of an elastoplastic bar of Taylor

Summary:

One studies the impact rubbing of an elastoplastic bar on a rigid solid mass in nonlinear dynamics. Modeling understands: contact, friction, elastoplasticity, great deformations.

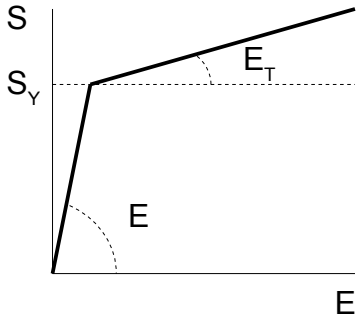
1 Problem of reference

1.1 Geometry



1.2 Properties of material

$E = 117.E3\,MPa$
$\nu = 0.35$
$\rho = 8.93\,E-9\,g/mm^3$
$\sigma_Y = 400.\,MPa$
$E_T = 100.\,MPa$



Coefficient of friction of Coulomb:
$\mu = 0.25$

1.3 Boundary conditions and loadings

The rigid foundation is completely blocked throughout calculation.

The bar is free of any blocking.

There is a relation between unilateral contact and friction of Coulomb between the lower face of the bar and the higher face of the rigid foundation.

1.4 Initial conditions

The bar is subjected at an initial speed of $227.E3\,mm/s$.

2 Reference solution

2.1 Method of calculating

The reference solution comes from [bib1]. They are explicit axisymmetric calculations carried out with various codes. One is unaware of almost all modeling: presence of contact, presence of friction, coefficient of friction. In this measurement, one uses this reference in an indicative way. The other tests will be of not-regression.

2.2 Sizes and results of reference

The sizes tested are:

- Radial displacement of the point A : $\frac{3.93+3.86+3.72+3.88+3.96}{5}=3.87\,mm$
- Vertical displacement of the point B : $\frac{-13.24-13.63-13.62-13.57-13.24}{5}=-13.46\,mm$

2.3 Uncertainties on the solution

Uncertainties on the reference solution are very important (see [§2.1]).

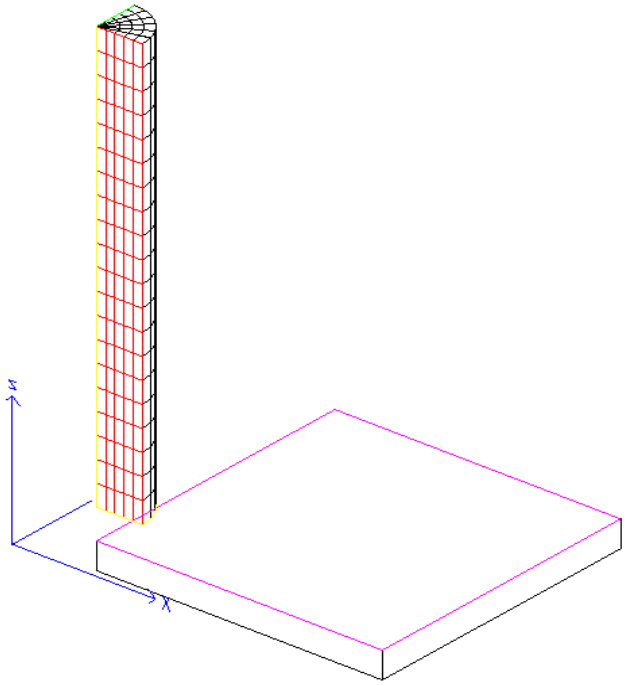
2.4 Bibliographical references

1) L. STAINIER, P.Ph. PONTHOT: "Year improved broad one-point integration method for strain elastoplastic analysis", Comput. Methods Appl. Mech. Engrg. 118 (1994).

3 Modeling A

3.1 Characteristics of modeling

Test of the contact in discrete formulation.



3.2 Characteristics of the grid

Many nodes: 2850
Numbers and types of elements: 480 HEXA20, 200 PENTA15, 224 QUAD8, 6 TRIA6, 280 SEG3, 1 HEXA8, 6 QUAD4, 8 SEG2, 101 POI1

3.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3\,mm/s$ along the axis Oz, one calculates on the transient $[-1.0E5, +2.5E-7]$ (in seconds).

3.4 Sizes tested and results

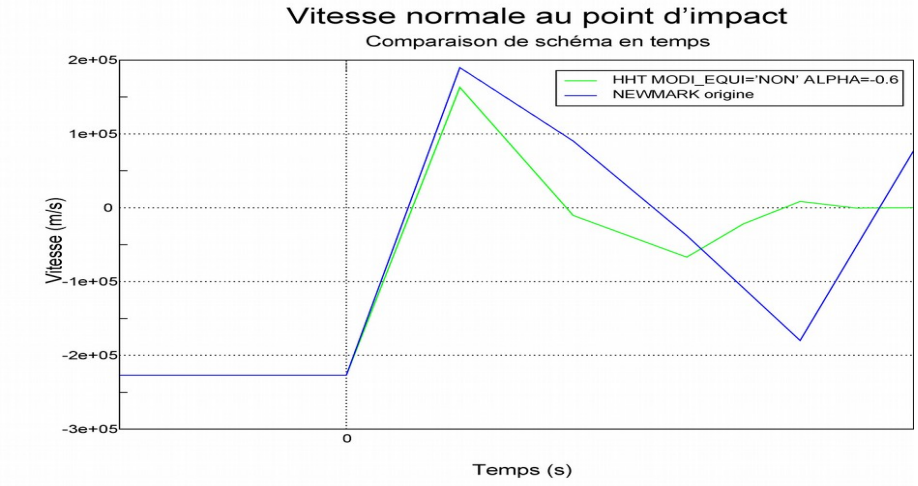
Being given the heaviness of modeling, one takes only some steps of time and one carries out only tests of not-regression.

Identification	Type of reference
DEPL - Not A - DZ	'NON_REGRESSION'
QUICKLY - Not A - DZ	'NON_REGRESSION'
CONT_NOEU - Not A - Game	'NON_REGRESSION'

3.5 Remarks on the quality of the digital solution

In order to be able to evaluate the quality of the solution obtained, one proposes to analyze the evolution speed in the center of the zone of impact. This quantity proves indeed more discriminating than displacement and that will thus make it possible to better judge relevance of the algorithmic choices for the non-linear transitory resolution.

On the following graph one compares the use of two diagrams in time: the nondissipative implicit scheme of NEWMARK (average acceleration) to the dissipative implicit scheme of modified average acceleration (HHT with MOD_EQUI = 'NOT' and ALPHA = -0.6). This second diagram makes it possible to obtain an "optimal" solution within the meaning of the control of the parasitic oscillations on the evolution speed. For that, it is necessary to increase digital dissipation, in particular in high frequency, in the structure.
The mechanical cushioning not being sufficiently taken into account in this CAS-test, one will take of it account through the damping of the diagram, which explains why complete diagram HHT would not be adapted (its damping low frequency is too weak).
As one is interested here only in very short times after the shock, one can allow oneself to strongly increase the parameter of digital damping of diagram HHT.

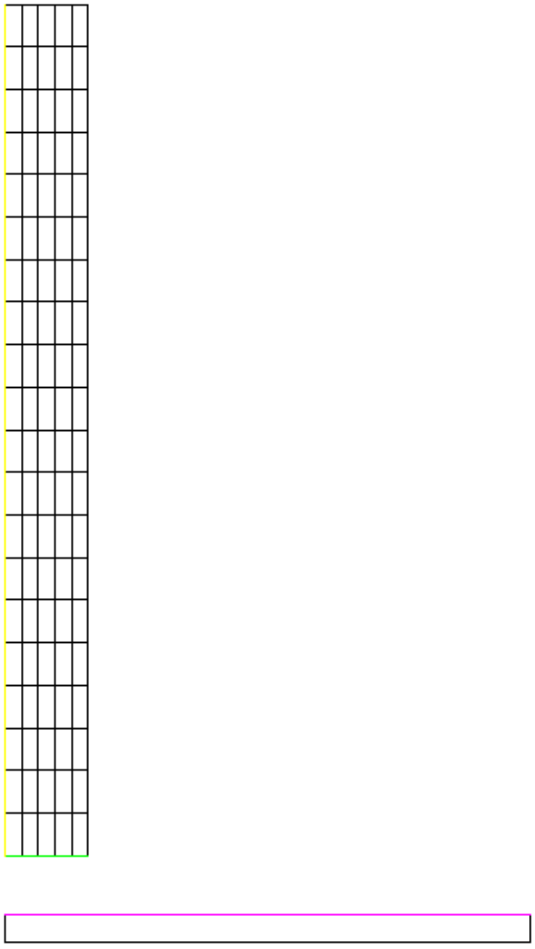


By comparing the calculated solutions, one notes clearly that the diagram of NEWMARK is not very adapted, because the total dissipation of the mechanical system is then too weak. Dissipative diagram HHT tested here makes it possible of good to better control the amplitude of the oscillations of the digital solution. Nevertheless, within the framework of a realistic study, it is paramount as a preliminary to have correctly modelled the physical damping of the system. Damping due to the diagram in time should be used only in the one second time, in complement, if the nondissipative diagram of NEWMARK does not make it possible to obtain a satisfactory solution. For more details one advises the reading of U2.06.13 documentation.

4 Modeling B

4.1 Characteristics of modeling

The point A (respectively B) is in two parts: $A1$ (resp. $B1$) close to the axis and $A2$ (resp. $B2$) outside. Test of the contact in discrete formulation.



4.2 Characteristics of the grid

Many nodes: 359
Numbers and types of elements: 101 QUAD8, 55 SEG3

4.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3\,mm/s$ along the axis Oz , one calculates on the transient $[-1.0\text{E}5\,,+8.0\text{E}-5]$. (in seconds).

4.4 Sizes tested and results

It is an axisymmetric modeling thus DX corresponds to radial displacement and DY with vertical displacement.

Identification	Type of reference	Value of reference	Tolerance
DEPL - Not $B1$ - DX	'SOURCE_EXTERNE'	3.87	29%
DEPL - Not $A2$ - DY	'SOURCE_EXTERNE'	-13.46	6.8%
DEPL - Not $B1$ - DX	'NON_REGRESSION'	-	-
DEPL - Not $A2$ - DY	'NON_REGRESSION'	-	-
QUICKLY – Not $B1$ - DX	'NON_REGRESSION'	-	-
QUICKLY – Not $A2$ - DY	'NON_REGRESSION'	-	-

One also tests the sizes of the contact (game and reaction) at several moments:

Identification	Type of reference	Value of reference	Tolerance
CONT_NOEU - Not A - Game – INST =1E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =2E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =3E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =4E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =5E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =6E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =7E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Game – INST =8E-5	'NON_REGRESSION'	-	-

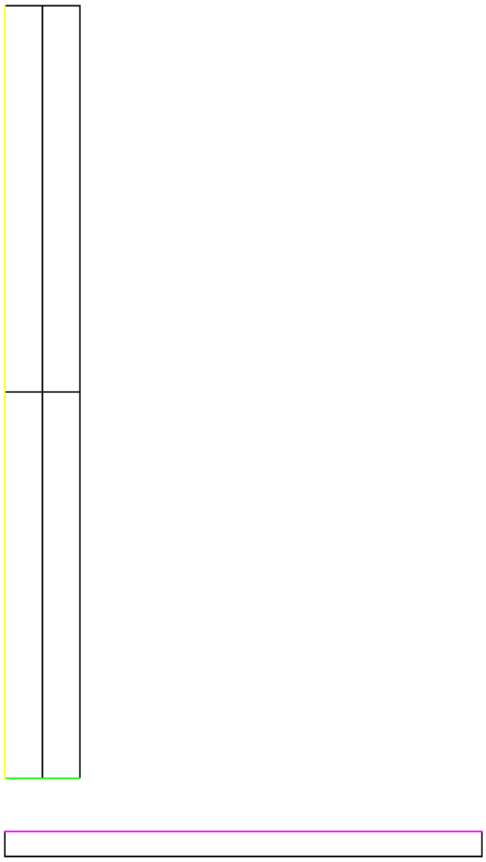
Identification	Type of reference	Value of reference	Tolerance
CONT_NOEU - Not A - Reaction R – INST =1E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Reaction R – INST =2E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Reaction R – INST =3E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Reaction R – INST =4E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Reaction R – INST =5E-	'NON_REGRESSION'	-	-

5			
CONT_NOEU - Not A - Reaction R – INST =6E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Reaction R – INST =7E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not A - Reaction R – INST =8E-5	'NON_REGRESSION'	-	-

5 Modeling D

5.1 Characteristics of modeling

The point A (respectively B) is in two parts: $A1$ (resp. $B1$) close to the axis and $A2$ (resp. $B2$) outside. Test of the contact in discrete formulation.



5.2 Characteristics of the grid

Many nodes: 29
Numbers and types of elements: 5 QUAD8, 12 SEG3

5.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3\,mm/s$ along the axis Oz, one calculates on the transient $[-1.0\text{E}5\,,+2.0\text{E}-5]$. (in seconds).

5.4 Sizes tested and results

It is an axisymmetric modeling thus DX corresponds to radial displacement and DY with vertical displacement.
For this very low-fat modeling which has only one role of algorithmic control, one tests only values of not-regression.

Identification	Type of reference	Value of reference	Tolerance

DEPL - Not $B1$ - DX	'NON_REGRESSION'	-	-
DEPL - Not $A2$ - DY	'NON_REGRESSION'	-	-
QUICKLY – Not $B1$ - DX	'NON_REGRESSION'	-	-
QUICKLY – Not $A2$ - DY	'NON_REGRESSION'	-	-

One also tests the sizes of the contact (game and reaction) at two moments:

Identification	Type of reference	Value of reference	Tolerance
CONT_NOEU - Not $B1$ - Game – INST =1E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not $B1$ - Game – INST =2E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not $B1$ - Reaction – INST =1E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not $B1$ - Reaction – INST =2E-5	'NON_REGRESSION'	-	-

6 Modeling E

6.1 Characteristics of modeling

This modeling highlights a dynamic calculation without loading (it does not have there occurrence of the keyword EXCIT in DYNA_NON_LINE).

The contact is replaced by a unilateral connection on DZ applied to the nodes of the low surface of the bar.

The model is 3D, without conditions of symmetry.

6.2 Characteristics of the grid

Many nodes: 1309
Numbers and types of elements: 1930 TRIA3, 6 QUAD4, 178 SEG2, 1 HEXA8, 5563 TETRA4

6.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3 mm/s$ along the axis Oz, one calculates on the transient $[-1.0E5, +2.5E-7]$. (in seconds).

6.4 Sizes tested and results

For this very low-fat modeling which has only one role of algorithmic control, one tests especially values of not-regression. The test on the vertical displacement of point A validates the unilateral condition.

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $A1$ - DZ	'ANALYTICAL'	-2.27	1.0 E-8%
QUICKLY – Not $A1$ - DZ	'NON_REGRESSION'	-	-

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $B1$ - DZ	'NON_REGRESSION'	-	-
QUICKLY – Not $B1$ - DZ	'ANALYTICAL'	-227000	1.0 E-8%

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $A1$ - DX	'NON_REGRESSION'	-	-
QUICKLY – Not $A1$ - DX	'NON_REGRESSION'	-	-

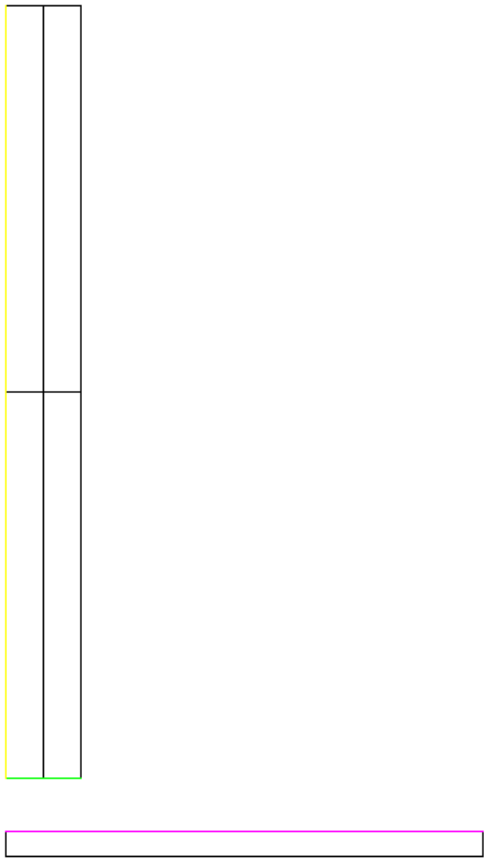
Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $B1$ - DY	'ANALYTICAL'	0	1.0 E-12%
QUICKLY – Not $B1$ -	'ANALYTICAL'	0	1.0 E-8%

DY			

7 Modeling F

7.1 Characteristics of modeling

The point A (respectively B) is in two parts: $A1$ (resp. $B1$) close to the axis and $A2$ (resp. $B2$) outside. Test of the contact in continuous formulation.



7.2 Characteristics of the grid

Many nodes: 29
Numbers and types of elements: 5 QUAD8, 12 SEG3

7.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3\,mm/s$ along axis OZ, one calculates on the transient $[-1.0E5, +2.0E-5]$. (in seconds).

7.4 Sizes tested and results

It is an axisymmetric modeling thus DX corresponds to radial displacement and DY with vertical displacement. This modeling validates the mode of automatic control of collision.

Only values of not-regression are tested. One tests the cutting of the step of time in mode AUTOMATIC.

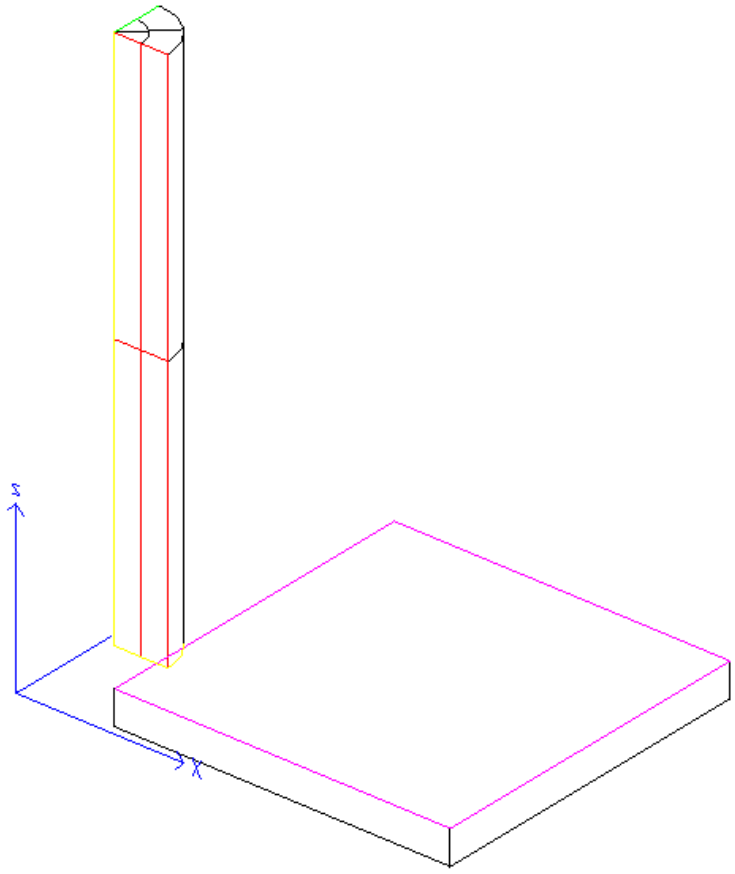
Identification	Type of reference	Value of reference	Tolerance
DEPL - Not $A1$ - DY	'NON_REGRESSION'	-	-
DEPL - Not $A2$ - DY	'NON_REGRESSION'	-	-
QUICKLY – Not $B1$ - DX	'NON_REGRESSION'	-	-
QUICKLY – Not $A2$ - DY	'NON_REGRESSION'	-	-

Identification	Type of reference	Value of reference	Tolerance
CONT_NOEU - Not $B1$ - Game – INST =1E-5	'NON_REGRESSION'	-	-
CONT_NOEU - Not $B1$ - Game – INST =2E-5	'NON_REGRESSION'	-	-

8 Modeling G

8.1 Characteristics of modeling

Test of behavior VMIS_JOHN_COOK in great deformations GDEF_LOG.



8.2 Characteristics of the grid

Many nodes: 2849
Numbers and types of elements: 480 HEXA20, 120 PENTA15, 224 QUAD8, 6 TRIA6, 50 SEG3, 1 HEXA8, 1 QUAD4, 1 SEG2

8.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3 mm/s$ along the axis Oz, one calculates on the transient $[-2.5E-7,+2.5E-7]$. (in seconds).

8.4 Sizes tested and results

For this very low-fat modeling which has only one role of algorithmic control, one tests only values of not-regression.

Identification	Type of reference	Value of reference	Tolerance
DEPL - Not $A2$ - DZ	'NON_REGRESSION'	-	-
QUICKLY - Not $A2$ - DZ	'NON_REGRESSION'	-	-

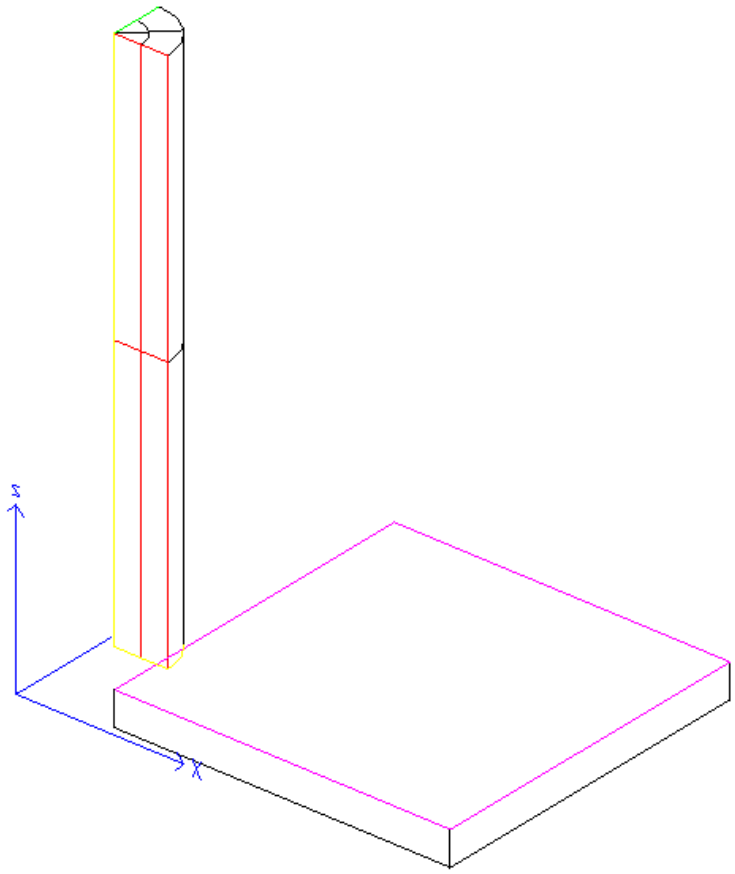
The sizes of the contact (game) are also tested:

Identification	Type of reference	Value of reference	Tolerance
CONT_NOEU - Not $B1$ – Game – INST =2,5E-7	'NON_REGRESSION'	-	-

9 Modeling H

9.1 Characteristics of modeling

Test of the action of cutting of the step of time in the event of collision.



9.2 Characteristics of the grid

Many nodes: 73
Numbers and types of elements: 4 HEXA20, 4 PENTA15, 10 QUAD8, 2 TRIA6, 8 SEG3, 1 HEXA8, 1 QUAD4, 1 SEG2

9.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3\,mm/s$ along the axis Oz, one calculates on the transient $[-1\text{E-}5, +2.0\text{E}-5]$. (in seconds).

9.4 Sizes tested and results

One tests values of not-regression at two moments.
Note: the test is unstable according to the platforms (dynamique+frottement discrete)

Management is tested ***manual*** list of moments:

Identification	Type of reference		
DEPL - Not $B1$ - DX – INST = 1.E-5	'NON_REGRESSION'	Presence of a TOLE_MACHINE	
DEPL - Not $A2$ - DY – INST = 1.E-5	'NON_REGRESSION'		
QUICKLY - Not $B1$ - DX – INST = 1.E-5	'NON_REGRESSION'	Presence of a TOLE_MACHINE	
QUICKLY - Not $A2$ - DY – INST = 1.E-5	'NON_REGRESSION'		

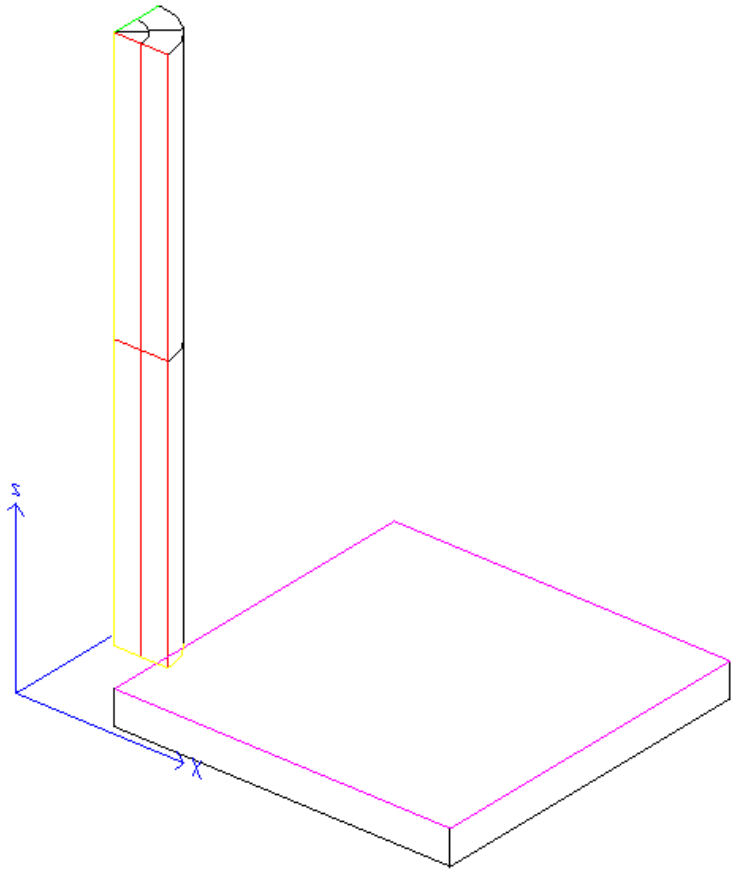
Management is tested ***automatic*** list of moments:

Identification	Type of reference		
DEPL - Not $B1$ - DX – INST = 1.E-5	'NON_REGRESSION'	Presence of a TOLE_MACHINE	
DEPL - Not $A2$ - DY – INST = 1.E-5	'NON_REGRESSION'		
QUICKLY - Not $B1$ - DX – INST = 1.E-5	'NON_REGRESSION'	Presence of a TOLE_MACHINE	
QUICKLY - Not $A2$ - DY – INST = 1.E-5	'NON_REGRESSION'		

10 Modeling I

10.1 Characteristics of modeling

Test of the action of adaptation of the coefficient of penalization by a maximum penetration given by the user (here PENE_MAXI= $1E-5$)



10.2 Characteristics of the grid

Many nodes: 73
Numbers and types of elements: 4 HEXA20, 4 PENTA15, 10 QUAD8, 2 TRIA6, 8 SEG3, 1 HEXA8, 1 QUAD4, 1 SEG2

10.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3 mm/s$ along the axis Oz , one calculates on the transient $[-1E\text{-}5, +2.0E-5]$. (in seconds).

10.4 Sizes tested and results

One tests only values of not-regression at the last moment.

Identification	Type of reference		

DEPL - Not $B1$ - DX	'NON_REGRESSION'		
DEPL - Not $A2$ - DY	'NON_REGRESSION'		
QUICKLY - Not $B1$ - DX	'NON_REGRESSION'		
QUICKLY - Not $A2$ - DY	'NON_REGRESSION'		

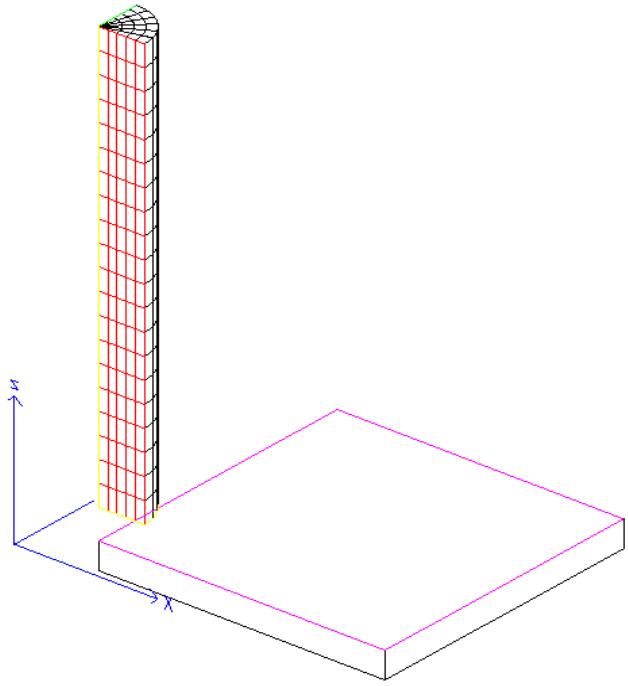
The sizes of the contact are also tested:

Identification	Type of reference	Value of reference	Tolerance
CONT_NOEU – Mini game INST =2,0E-5	'NON_REGRESSION'		

11 Modeling J

11.1 Characteristics of modeling

Test of elements HEXA8 under integrated in dynamics.



11.2 Characteristics of the grid

Many nodes: 2850
Numbers and types of elements: 481 HEXA8, 120 PENTA6, 225 QUAD4, 6 TRIA3, 51 SEG2

11.3 Loading and temporal discretization

After having applied a vertical initial speed of $227.E3 mm/s$ along the axis Oz, one calculates on the transient $[-1.0E5, +2.5E-7]$ (in seconds).

11.4 Sizes tested and results

Being given the heaviness of modeling, one takes only some steps of time and one carries out only tests of not-regression.

Identification	Type of reference	Value of reference	Tolerance
DEPL - Not A - DZ	'NON_REGRESSION'		
QUICKLY - Not A - DZ	'NON_REGRESSION'		
CONT_NOEU - Not A - Game	'NON_REGRESSION'		

12 Modeling K

12.1 Characteristics of modeling

They is the same characteristics of modeling as modeling E, this time the unilateral condition is imposed via the algorithm of penalization.

12.2 Characteristics of the grid

The grid is the same one as that of modeling E.

12.3 Loading and temporal discretization

The loading is the same one as for modeling E.

12.4 Sizes tested and results

The tests are the same ones as for modeling E.

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $A1$ - DZ	'ANALYTICAL'	-2.27	1.0 E-8%
QUICKLY – Not $A1$ - DZ	'NON_REGRESSION'	-	-

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $B1$ - DZ	'NON_REGRESSION'	-	-
QUICKLY – Not $B1$ - DZ	'ANALYTICAL'	-227000	1.0 E-8%

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $A1$ - DX	'NON_REGRESSION'	-	-
QUICKLY – Not $A1$ - DX	'NON_REGRESSION'	-	-

Identification	Type of reference	Value of reference	Tolerance
DEPL – Not $B1$ - DY	'ANALYTICAL'	0	1.0 E-12%
QUICKLY – Not $B1$ - DY	'ANALYTICAL'	0	1.0 E-8%

12.5 Remarks

By imposing a sufficiently large coefficient of penalty (1.0 E+14), one gets exactly same the results as with the algorithm of the active constraints (modeling E).

13 Summary of the results

Present modelings differ from the reference of the literature by the taking into account of additional non-linearities (contact, friction), which explains the differences between their respective results.

It is also noted that calculation 3D presents a overcost of very high time CPU compared to the axisymmetric model, which is explained at the same time by more a large number of degrees of freedom but also by the treatment of the friction which is much more complex in 3D than in 2D.