SDNV103 - Impact of an elastoplastic bar of Summarized

Taylor:

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

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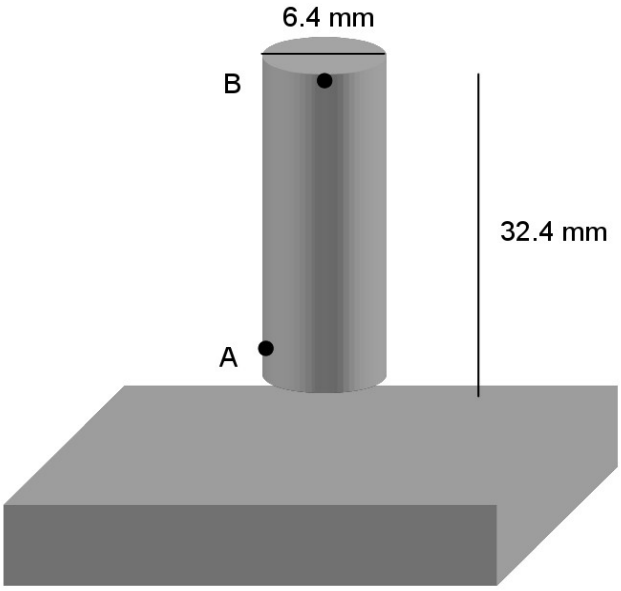
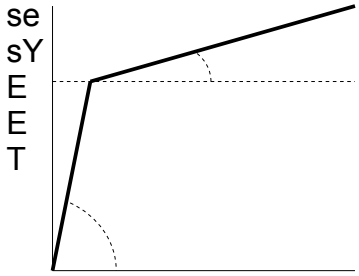
1 Problem of reference

1.1 Geometry



1.2 Properties of the material

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



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

1.3 Boundary conditions and loadings

the rigid foundation is completely blocked throughout computation.

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 upper face of the rigid foundation.

1.4 Initial conditions

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

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2 Reference solution

2.1 Method of calculating

the reference solution comes from [bib1]. They are explicit axisymmetric computations carried out with various codes. One is unaware of almost all the modelization: presence of contact, presence of friction, coefficient of kinetic friction. In this measurement, one uses this reference in an indicative way. The other tests will be of NON-regression.

2.2 Quantities and results of reference

the quantities tested are:

Radial displacement of point: A $\frac{3.93+3.86+3.72+3.88+3.96}{5}=3.87\,mm$

Vertical displacement of 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: "Broad Year improved one-point integration method for strain elastoplastic analysis", Comput. Methods Appl. Mech. Engrg. 118 (1994).

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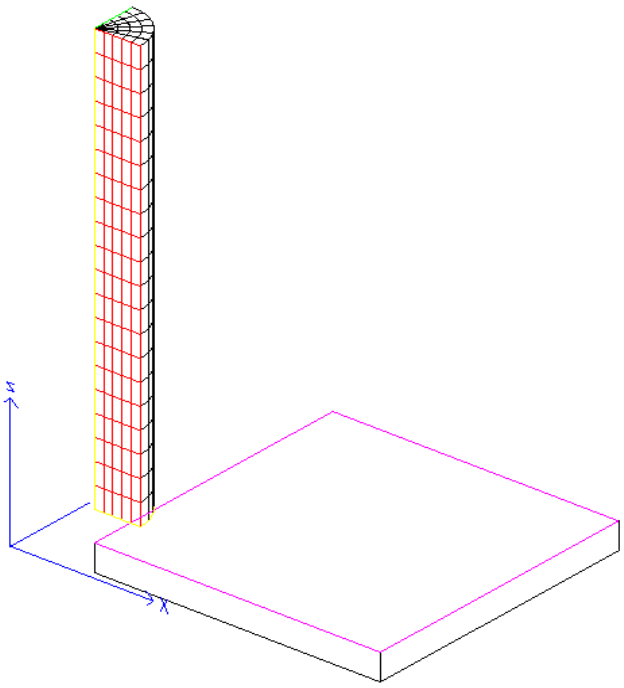
3 Modelization A

3.1 Characteristic of the modelization

Test of the contact in discrete formulation.



3.2 Characteristics of the mesh

Many nodes: 2850
Numbers and element types: 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 velocity of $227.E3\,mm/s$ following the axis Oz, one calculates on the transient $[-1.0E5, +2.5E-7]$ (in seconds).

3.4 Quantities tested and results

being given the heaviness of the modelization, one only makes some time step and one carries out only tests of NON-regression.

Standard	identification of reference	Value of reference	Tolerance
DEPL - Not A - DZ	"NON_REGRESSION"	-2,32675	7.0E-4%
VITE - Not A - DZ	"NON_REGRESSION"	-2.27000000172E+05	3.7E-4%
VALE_CONT - Not A - Clearance	"NON_REGRESSION"		0.1.0E-6%

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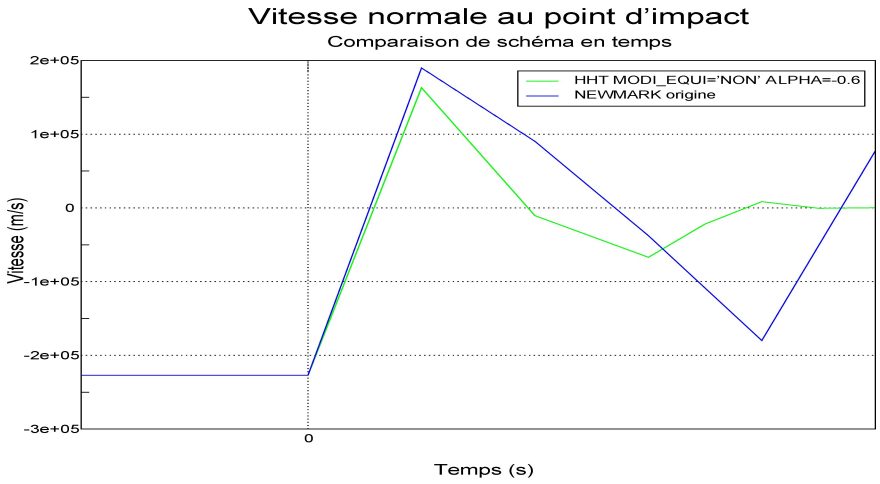
3.5 Remarks on the quality of the numerical solution

In order to be able to evaluate the quality of the solution obtained, one proposes to analyze the evolution the velocity 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 nonlinear transitory resolution.

On the following graph one compares the use of two time schemes: the nondissipative implicit scheme of NEWMARK (average acceleration) to the dissipative implicit scheme of the modified average acceleration (HHT with MOD_EQUI = "NON" 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 velocity. For that, it is necessary to increase numerical dissipation, in particular in high frequency, in structure.
The damping mechanical not being sufficiently taken into account in this case, 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 numerical 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 numerical solution. Nevertheless, in the frame of a realistic study, it is paramount as a preliminary to have correctly modelled the physical damping of the system. The damping due to the time scheme must 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.

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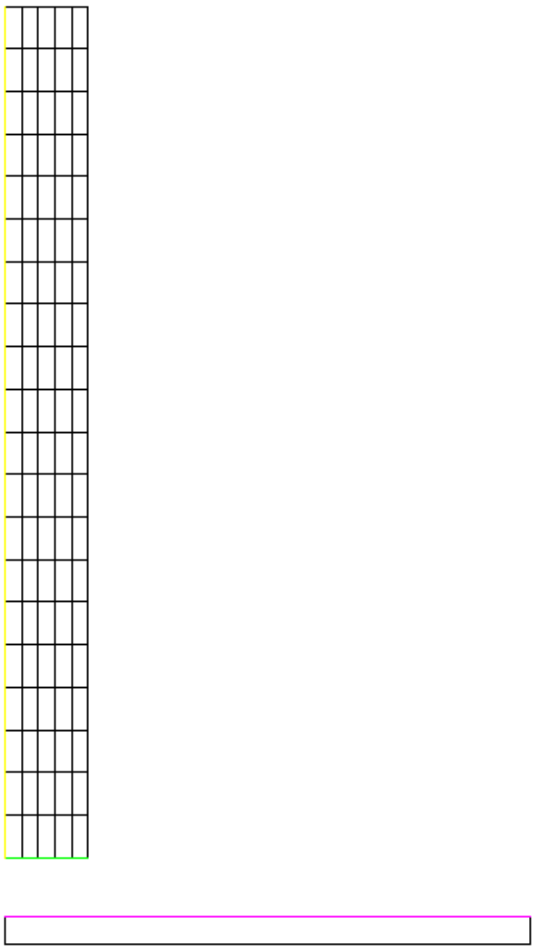
4 Modelization B

4.1 Characteristic of the modelization

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 mesh

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

4.3 Loading and temporal discretization

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

4.4 Quantities tested and results

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

Standard	identification of	Value of reference	Tolerance

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	reference		
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"	2.9111775334429	1,0 E-4%
DEPL - Not $A2$ - DY	"NON_REGRESSION"	-12.691675675045	3,0 E-4%
VITE – Not $B1$ - DX	"NON_REGRESSION"	-849.73270947624	1,0 E-4%
VITE – Not $A2$ - DY	"NON_REGRESSION"	15804.983850896	3,0 E-4%

One also tests the quantities of the contact (clearance and reaction) at several times:

Standard	identification of reference	Value of reference	Tolerance
VALE_CONT - Not A - Clearance – INST =1E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =2E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =3E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =4E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =5E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =6E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =7E-5	"NON_REGRESSION"	0.1,0	E-15%
VALE_CONT - Not A - Clearance – INST =8E-5	"NON_REGRESSION"	0.1,0	E-15%

Standard	Identification of reference	Value of reference	Tolerance
VALE_CONT - Not A - Reaction R – INST =1E-5	"NON_REGRESSION"	95.900213845233	1,0 E-3%
VALE_CONT - Not A - Reaction R – INST =2E-5	"NON_REGRESSION"	146.12608403838	1,0 E-3%
VALE_CONT - Not A - Reaction R – INST =3E-5	"NON_REGRESSION"	241.79870957283	1,0 E-3%
VALE_CONT - Not A - Reaction R – INST =4E-5	"NON_REGRESSION"	333.20191974472	1,0 E-3%
VALE_CONT - Not A - Reaction R – INST	"NON_REGRESSION"	156.09427387822	1,0 E-3%

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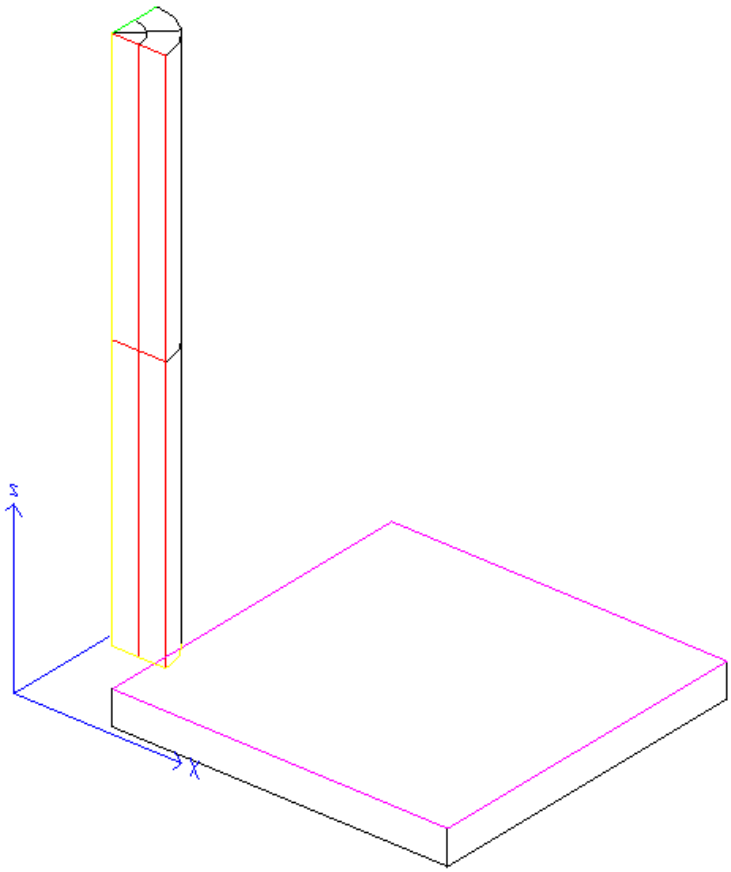
=5E-5			
VALE_CONT - Not A - Reaction R – INST =6E-5	"NON_REGRESSION"	151.64633838026	1,0 E-3%
VALE_CONT - Not A - Reaction R – INST =7E-5	"NON_REGRESSION"	150.68007803106	1,0 E-3%
VALE_CONT - Not A - Reaction R – INST =8E-5	"NON_REGRESSION"	150.4652430174	1,0 E-3%

5 Modelization C

5.1 Characteristic of the modelization

Test of the contact in discrete formulation.



5.2 Characteristics of the mesh

Many nodes: 74
Numbers and element types: 4 HEXA20, 4 PENTA15, 10 QUAD8, 2 TRIA6, 14 SEG3, 1 HEXA8, 6 QUAD4, 8 SEG2, 17 POI1

5.3 Loading and temporal discretization

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After having applied a vertical initial velocity of $227.E3mm/s$ following the axis Oz, one calculates on the transient $[-1.0E5,+2.0E-5]$. (in seconds).

5.4 Quantities tested and results

For this very low-fat modelization which has only one role of algorithmic control, only values of NON-regression are tested.

Standard	identification of reference	Value of reference	Tolerance
DEPL - Not $B1$ - DX	"NON_REGRESSION"	1.51757030882	0.010%
DEPL - Not $A2$ - DZ	"NON_REGRESSION"	-6.80092816679	0.010%

One also tests the quantities of the contact (clearance) at two times:

Standard	identification of reference	Value of reference	Tolerance
VALE_CONT - Not A - Clearance – INST =8E-6	"NON_REGRESSION"	0.20876014472300	1,0 E-6%
VALE_CONT - Not A - Clearance – INST =1,8E-5	"NON_REGRESSION"		0.1,0E-12

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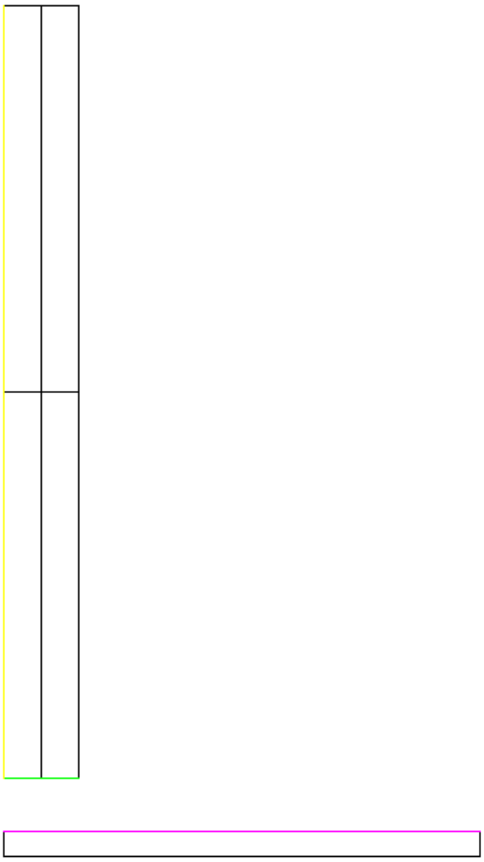
6 Modelization D

6.1 Characteristic of the modelization

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.



6.2 Characteristics of the mesh

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

6.3 Loading and temporal discretization

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

6.4 Quantities tested and results

It is an axisymmetric modelization thus DX corresponds to radial displacement and DY vertical displacement.
For this very low-fat modelization which has only one role of algorithmic control, one tests only values of NON-regression.

Standard	identification of	Value of reference	Tolerance

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	reference		
DEPL - Not $B1$ - DX	"NON_REGRESSION"	1.7282363393497	2,0 E-4%
DEPL - Not $A2$ - DY	"NON_REGRESSION"	-6.7628604429711	7,0 E-4%
VITE – Not $B1$ - DX	"NON_REGRESSION"	79803.474679114	5,0 E-4%
VITE – Not $A2$ - DY	"NON_REGRESSION"	-2.157139536645E+05	7,0 E-4%

One also tests the quantities of the contact (clearance and reaction) at two times:

Standard	identification of reference	Value of reference	Tolerance
VALE_CONT - Not $B1$ - Clearance – INST =1E-5	"NON_REGRESSION"	0.026799840884025	1,1 E-3%
VALE_CONT - Not $B1$ - Clearance – INST =2E-5	"NON_REGRESSION"	0.077298468952968	1,0 E-3%
VALE_CONT - Not $B1$ - Reaction – INST =1E-5	"NON_REGRESSION"	0	0
VALE_CONT - Not $B1$ - Reaction – INST =2E-5	"NON_REGRESSION"	0	0

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7 Modelization E

7.1 Characteristic of the modelization

This modelization highlights a dynamic computation without loading (there is no occurrence of 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.

7.2 Characteristics of the mesh

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

7.3 Loading and temporal discretization

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

7.4 Quantities tested and results

For this very low-fat modelization which has only one role of algorithmic control, one tests especially values of NON-regression. The test on the vertical displacement of the point A validates the unilateral condition.

Standard	identification of reference	Value of reference	Tolerance
DEPL – Not $A1$ - DZ	"ANALYTIQUE"	-2,27	1,0 E-8%
VITE – Not $A1$ - DZ	"NON_REGRESSION"	-194530	1,0 E-8%

Standard	Identification of reference	Value of reference	Tolerance
DEPL – Not $B1$ - DZ	"NON_REGRESSION"	-2,32675	1,0 E-8%
VITE – Not $B1$ - DZ	"ANALYTIQUE"	-227000	1,0 E-8%

Standard	Identification of reference	Value of reference	Tolerance
DEPL – Not $A1$ - DX	"NON_REGRESSION"	1.561365E-003	1,0 E-8%
VITE – Not $A1$ - DX	"NON_REGRESSION"	-16297.46	1,0 E-8%

Standard	Identification of reference	Value of reference	Tolerance
DEPL – Not $B1$ - DY	"ANALYTIQUE	0	E-12%

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VITE – Not $B1 - DY$	"ANALYTIQUE"	0	E-8%

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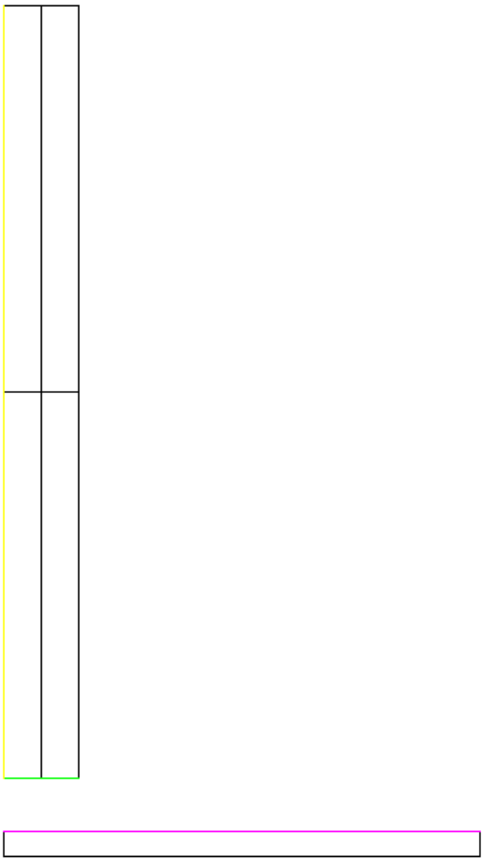
8 Modelization F

8.1 Characteristic of the modelization

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.



8.2 Characteristics of the mesh

Many nodes: 29
Numbers and standard D" elements: 5 QUAD8, 12 SEG3

8.3 Loading and temporal discretization

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

8.4 Quantities tested and results

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

Only values of NON-regression are tested. One tests the cutting of time step in mode MANUEL and mode AUTOMATIQUE.

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In mode MANUEL :

Standard	identification of reference	Value of reference	Tolerance
DEPL - Not $A1$ - DY	"NON_REGRESSION"	1.7496298183762	3,0%
DEPL - Not $A2$ - DY	"NON_REGRESSION"	-6.708400431849	0,7%
VITE – Not $B1$ - DX	"NON_REGRESSION"	78981.886179879	3,0%
VITE – Not $A2$ - DY	"NON_REGRESSION"	-2.0385434072951E+05	4,0%

Standard	Identification of reference	Value of reference	Tolerance
VALE_CONT - Not $B1$ - Clearance – INST =1E-5	"NON_REGRESSION"	0.089534326856020	1.E-8%
VALE_CONT - Not $B1$ - Clearance – INST =2E-5	"NON_REGRESSION"	0	1.E-15

In mode AUTOMATIQUE :

Standard	identification of reference	Value of reference	Tolerance
DEPL - Not $A1$ - DY	"NON_REGRESSION"	1.767749149604	3,0%
DEPL - Not $A2$ - DY	"NON_REGRESSION"	-6.708400431849	0,7%
VITE – Not $B1$ - DX	"NON_REGRESSION"	79430.997053331	3,0%
VITE – Not $A2$ - DY	"NON_REGRESSION"	-2.0385434072951E+05	4,0%

Standard	Identification of reference	Value of reference	Tolerance
VALE_CONT - Not $B1$ - Clearance – INST =1E-5	"NON_REGRESSION"	0.084020393828398	1.E-8%
VALE_CONT - Not $B1$ - Clearance – INST =2E-5	"NON_REGRESSION"	0	1.E-15

the differences come owing to the fact that automatic cutting does not produce necessarily the same temporal discretization as manual cutting.

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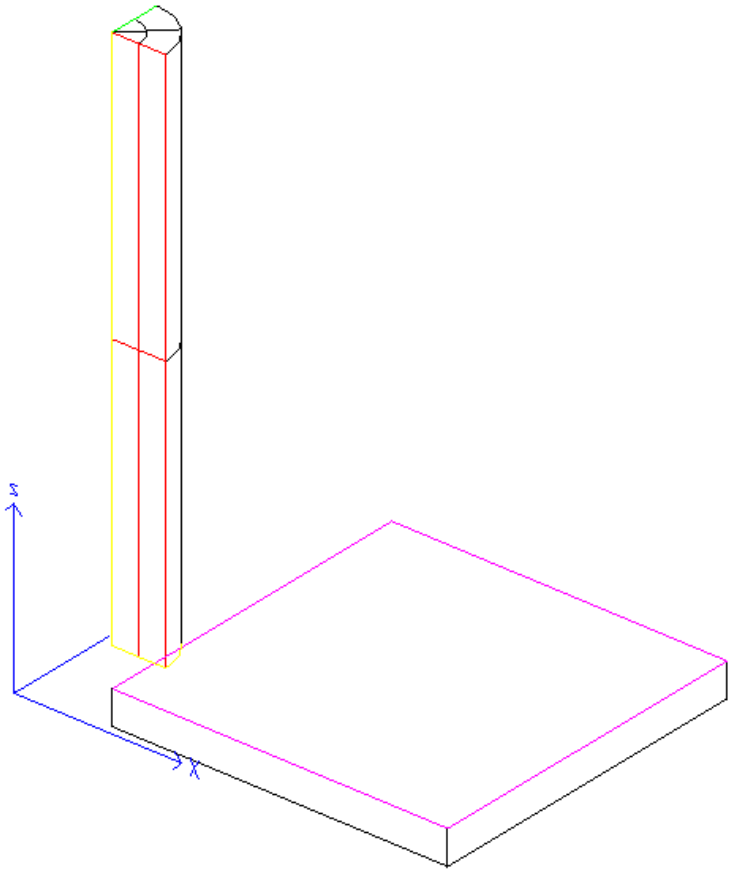
9 Modelization G

9.1 Characteristic of the modelization

Test of behavior VMIS_JOHN_COOK in large deformations GDEF_LOG.



9.2 Characteristics of the mesh

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

9.3 Loading and temporal discretization

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

9.4 Quantities tested and results

For this very low-fat modelization which has only one role of algorithmic control, only values of NON-regression are tested.

Standard	identification of reference	Value of reference	Tolerance

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DEPL - Not $A2$ - DZ	"NON_REGRESSION"	-2.32675	7,00E-4%
VITE - Not $A2$ - DZ	"NON_REGRESSION"	-227000	3,65E-4%

One also tests the quantities of the contact (clearance):

Standard	identification of reference	Value of reference	Tolerance
VALE_CONT - Not $B1$ – Clearance – INST =2,5E-7	"NON_REGRESSION"	0	1.00E-006

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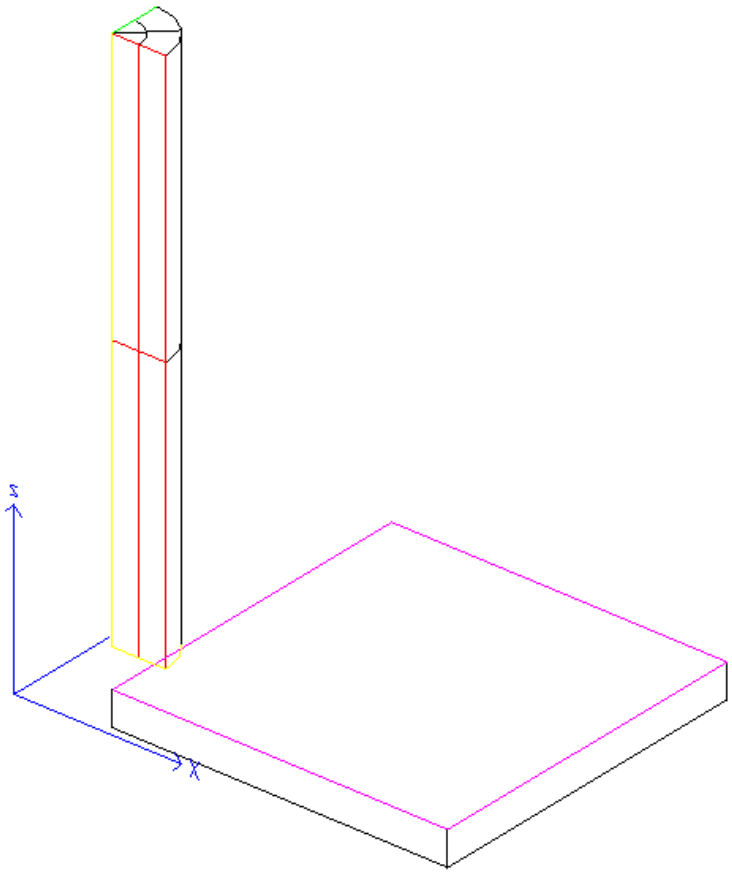
10 Modelization H

10.1 Characteristic of the modelization

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



10.2 Characteristics of the mesh

Many nodes: 73
Numbers and element types: 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 velocity of $227.E3\,mm/s$ following the axis Oz, one calculates on the transient $[-1\text{E-}5,+2.0\text{E}-5]$. (in seconds).

10.4 Quantities tested and results

One tests values of NON-regression at two times.

Standard	identification of reference	Value of reference	Tolerance
DEPL - Not $B1$ - DX – INST =	"NON_REGRESSION"	0.75715311454588	1,50E-3%

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8.901098901099e-06			
DEPL - Not $A2$ - DY – INST = 8.901098901099e-06	"NON_REGRESSION"	0.000000E+000	1, 00E- 10
VITE - Not $B1$ - DX – INST = 8.901098901099e-06	"NON_REGRESSION"	78447.637401481	1,00E-3%
VITE - Not $A2$ - DY – INST = 8.901098901099e-06	"NON_REGRESSION"	0.000000E+000	1,0 E -10

Standard	Identification of reference	Value of reference	Tolerance
VALE_CONT - Not $B1$ – Clearance – INST = 8.901098901099e-06	"NON_REGRESSION"	0	E-15
VALE_CONT - Not $B1$ – Reaction – INST = 8.901098901099e-06	"NON_REGRESSION"	289.96538798755	2,0 E-3%

Standard	Identification of reference	Value of reference	Tolerance
DEPL - Not $B1$ - DX – INST = 1.E-5	"NON_REGRESSION"	0.75961887541710	3,00E-3%
DEPL - Not $A2$ - DY – INST = 1.E-5	"NON_REGRESSION"	0.000000E+000	1, 00E- 10
VITE - Not $B1$ - DX – INST = 1.E-5	"NON_REGRESSION"	86687.032089558	1,20E-3%
VITE - Not $A2$ - DY – INST = 1.E-5	"NON_REGRESSION"	0.000000E+000	1,0 E -10

Standard	Identification of reference	Value of reference	Tolerance
VALE_CONT - Not $B1$ – Clearance – INST= 1.E-5	"NON_REGRESSION"	0	E-15
VALE_CONT - Not $B1$ – Reaction – INST = 1.E-5	"NON_REGRESSION"	277.99589251312	7,0 E-3%

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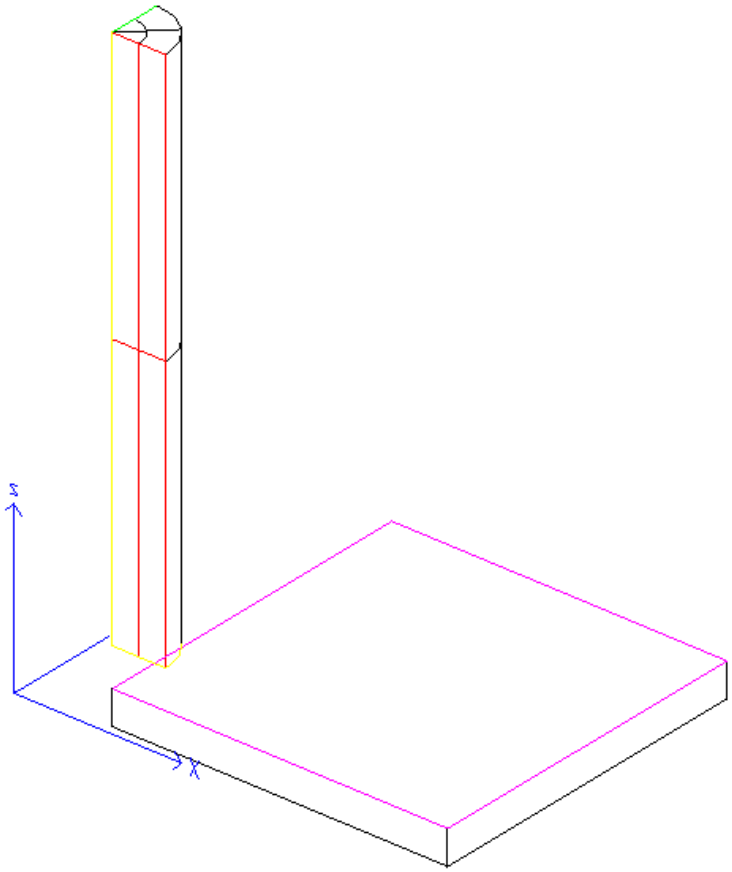
11 Modelization I

11.1 Characteristic of the modelization

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



11.2 Characteristic mesh

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

11.3 Loading and temporal discretization

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

11.4 Quantities tested and results

One tests only values of NON-regression at the last moment.

Standard	identification of reference	Value of reference	Tolerance

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DEPL - Not *B1* - *DX*	"NON_REGRESSION"	1.4464242806669	1,00E-8%
DEPL - Not *A2* - *DY*	"NON_REGRESSION"	0.000000E+000	1, 00E- 10
VITE - Not *B1* - *DX*	"NON_REGRESSION"	83900.271694816	2,50E-8%
VITE - Not *A2* - *DY*	"NON_REGRESSION"	0.000000E+000	1,0 E -10

One also tests the quantities of the contact:

Standard	identification of reference	Value of reference	Tolerance
VALE_CONT – Clearance mini INST =2,0E-5	"NON_REGRESSION"	0	E-15

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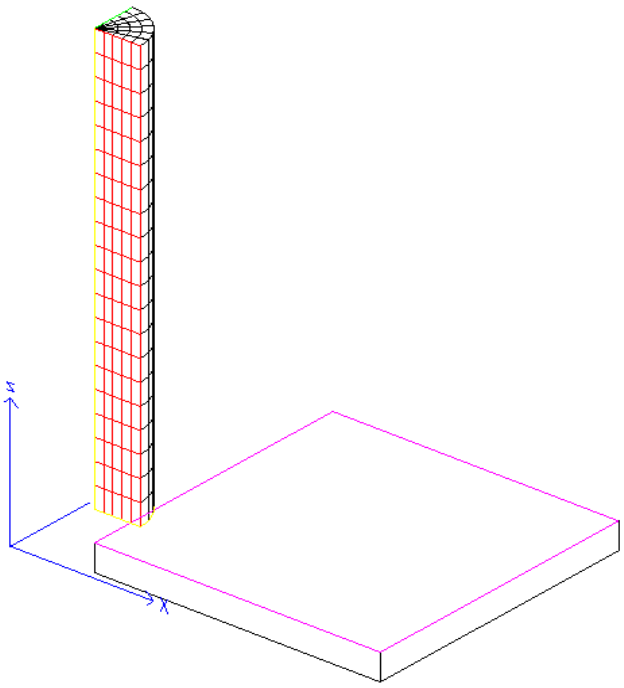
12 Modelization J

12.1 Characteristic of the modelization

Test of elements HEXA8 under integrated in dynamics.



12.2 Characteristics of the mesh

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

12.3 Loading and temporal discretization

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

12.4 Quantities tested and results

being given the heaviness of the modelization, one only makes some time step and one carries out only tests of NON-regression.

Standard	identification of reference	Value of reference	Tolerance
DEPL - Not A - DZ	"NON_REGRESSION"	-2,32675	7.0E-4%
VITE - Not A - DZ	"NON_REGRESSION"	-2.27000000172E+05	3.7E-4%
VALE_CONT - Not A - Clearance	"NON_REGRESSION"	1.0529710651E-02	1.0E-6%

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13 Summary of the results

the present modelizations 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 computation 3D presents a overcost of very high TEMPS 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 processing of the friction which is much more complex in 3D than in 2D.

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