PERF005 - Contact of Hertz between two half-spheres

Summary:

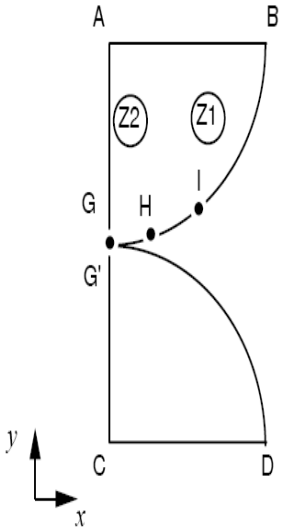
The objective of this CAS-test is to measure the performances of an elastic design with contact 3D.

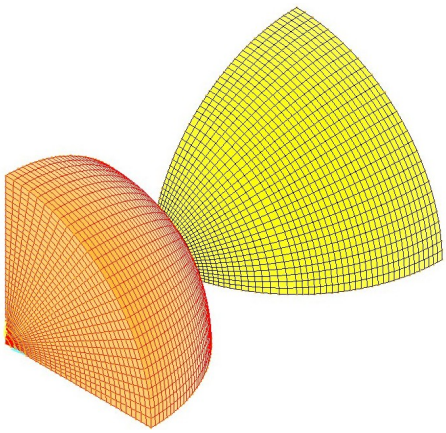
Modelings carried out are the following ones:

- Modeling a: grid PENTA6, 1 400 degrees of freedom, 64 nodes of contact, STAT_NON_LINE ('MULT_FRONT', 'CONSTRAINT')
- Modeling b: grid PENTA6, 96 000 degrees of freedom, 222 nodes of contact, STAT_NON_LINE ('MULT_FRONT', 'CONSTRAINT')
- Modeling C: grid PENTA6, $4.9\,E5$ degrees of freedom, 697 nodes of contact, STAT_NON_LINE ('MULT_FRONT', 'CONSTRAINT')
- Modeling D: grid PENTA6, 1 400 degrees of freedom, 64 nodes of contact, STAT_NON_LINE ('GCPC', 'CONTINUES')
- Modeling E: grid PENTA6, 96 000 degrees of freedom, 222 nodes of contact, STAT_NON_LINE ('GCPC', 'CONTINUES')
- Modeling F: grid PENTA6, $4.9\,E5$ degrees of freedom, 697 nodes of contact, STAT_NON_LINE ('GCPC', 'CONTINUES')
- Modeling G : grid TETRA4, STAT_NON_LINE ('MUMPS', 'CONTINUES', 'MORTAR'),
- Modeling H : grid TETRA10, STAT_NON_LINE ('MUMPS', 'CONTINUES', 'MORTAR'),
- Modeling I : grid HEXA8, STAT_NON_LINE ('MUMPS', 'CONTINUES', 'MORTAR'),
- Modeling J : grid HEXA20, STAT_NON_LINE ('MUMPS', 'CONTINUES', 'MORTAR'),
- Modeling K: grid HEXA27 , STAT_NON_LINE (' MUMPS ', 'CONTINUES', 'MORTAR') ,

1 Problem of reference

1.1 Geometry





- Ray: $R=50\,mm$

1.2 Properties of material

- $E=20\,000\,.MPa$
- $\nu=0.3$

1.3 Boundary conditions and loadings

- Imposed displacements:
  - AC : $DX=0.$
  - AB : $DY=-2.\text{mm}$
  - CD : $DY=2.\text{mm}$

2 Reference solution

2.1 Method of calculating

The constraint σ_{yy} at the point G (and G') is the analytical solution of a problem of hertz $[1]$:

$$\sigma_{yy}=\frac{-E}{\pi}\frac{1}{1-\nu^2}\sqrt{\frac{2h}{R}}$$

where h is imposed crushing $(h=2-(-2)=4\,mm)$.

2.2 Results of reference

σ_{yy} at the point G (analytical solution)
$\sigma_{yy}=-2798.3\ MPa$

2.3 Uncertainties

Analytical solution

2.4 Bibliographical reference

[1] G. DUMONT: “Method of the active constraints applied to the unilateral contact” Note HI-75/93/016.

3 Modeling A

3.1 Characteristics of modeling A

Modeling 3D:

MANY NODES	4004	
MANY MESHS	9484	
	SEG2	208
	TRIA3	1756
	QUAD4	688
	TETRA4	192
	PENTA6	6400
	PYRAM5	240

3.2 Results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1 and G1_2	$SIYY$	$-2.7983\text{E}3$	6

Imposed displacement is applied in only one step of time and required two iterations to converge.

4 Modeling B

4.1 Characteristics of modeling B

Modeling 3D:

MANY NODES	29188	
MANY MESHS	64020	
	SEG2	424
	TRIA3	6828
	QUAD4	2912
	TETRA4	768
	PENTA6	52128
	PYRAM5	960

4.2 Results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1 and G1_2	$SIYY$	$-2.7983\text{E}3$	6

Imposed displacement is applied in only one step of time and required two iterations to converge.

5 Modeling C

5.1 Characteristics of modeling C

Modeling 3D:

MANY NODES	153688	
MANY MESHS	324470	
	SEG2	758
	TRIA3	20430
	QUAD4	9570
	TETRA4	2494
	PENTA6	288144
	PYRAM5	3074

5.2 Results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1 and G1_2	$SIYY$	$-2.7983\text{E}3$	6

Imposed displacement is applied in only one step of time and required two iterations to converge.

6 Modeling D

6.1 Characteristics of modeling D

Modeling 3D: identical to modeling A.

6.2 Results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1 and G1_2	$SIYY$	$-2.7983\text{E}3$	6

This modeling is during modeling A by using a different method of contact here 'CONTINUES' as well as a different linear solvor here 'GCPC'.

In order to be able to compare the performances of the 2 methods of contact, one forces the geometrical convergence criteria with 5% (RESI_GEOM=0.05) in order to make the same iteration count of geometry in the two methods (here 2).

The results are identical to those of modeling A.

7 Modeling E

7.1 Characteristics of modeling E

Modeling 3D: identical to modeling B.

7.2 Results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1 and G1_2	$SIYY$	$-2.7983\text{E}3$	6

This modeling is during modeling B by using a different method of contact here 'CONTINUES' as well as a different linear solvor here 'GCPC'.

In order to be able to compare the performances of the 2 methods of contact, one forces the geometrical convergence criteria with 5% (RESI_GEOM=0.05) in order to make the same iteration count of geometry in the two methods (here 3).

The results are identical to those of modeling B.

8 Modeling F

8.1 Characteristics of modeling F

Modeling 3D: identical to modeling C.

8.2 Results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1 and G1_2	$SIYY$	$-2.7983\mathrm{E}3$	6

This modeling is during modeling C by using a different method of contact here 'CONTINUES' as well as a different linear solvor here 'GCPC'.

In order to be able to compare the performances of the 2 methods of contact, one forces the same iteration count of geometry (here NB_ITER_GEOM = 3).

The results are identical to those of modeling C.

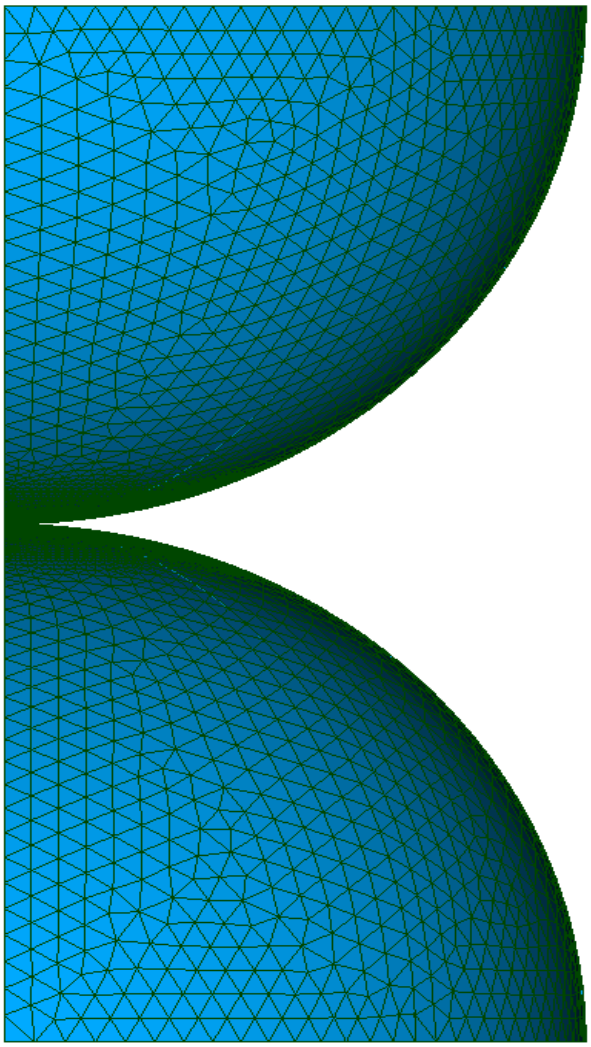
9 Modeling G

9.1 Characteristics of modeling

A modeling is used 3D. The contact is treated with Mortar pairing, ALGO_CONT=LAC and cutting LAKE.

9.2 Characteristics of the grid

The grid contains 66519 elements of the type TETRA4.



9.3 Sizes tested and results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1	$SIYY$	$-2.7983E3$	6
G1_2	$SIYY$	$-2.7983E3$	6

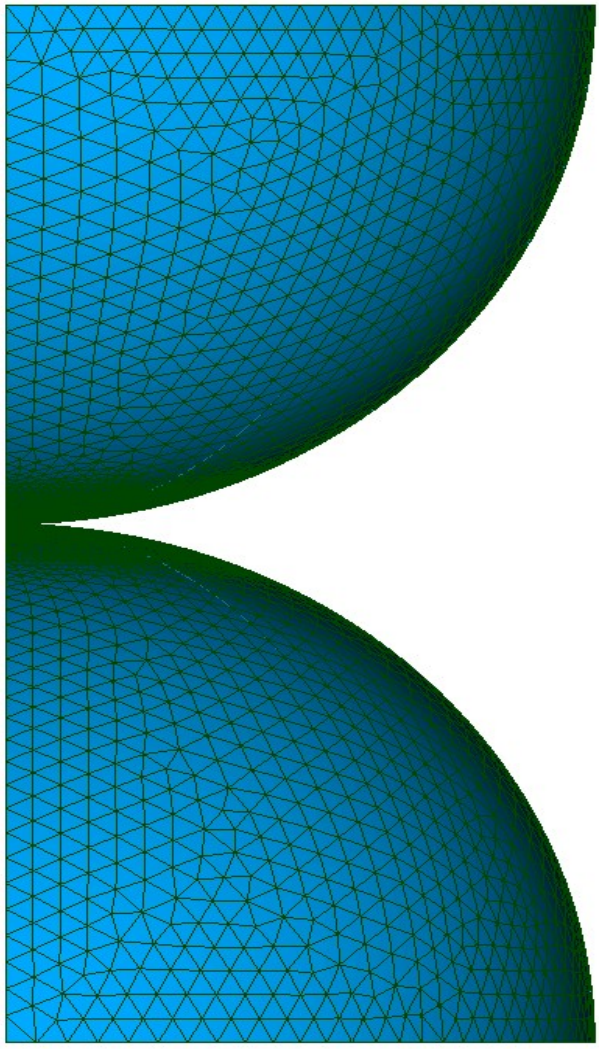
10 Modeling H

10.1 Characteristics of modeling

A modeling is used 3D. The contact is treated with Mortar pairing, ALGO_CONT=LAC and cutting LAKE.

10.2 Characteristics of the grid

The grid contains 66519 elements of the type TETRA10.



10.3 Sizes tested and results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1	$SIYY$	$-2.7983\text{E}3$	6
G1_2	$SIYY$	$-2.7983\text{E}3$	6

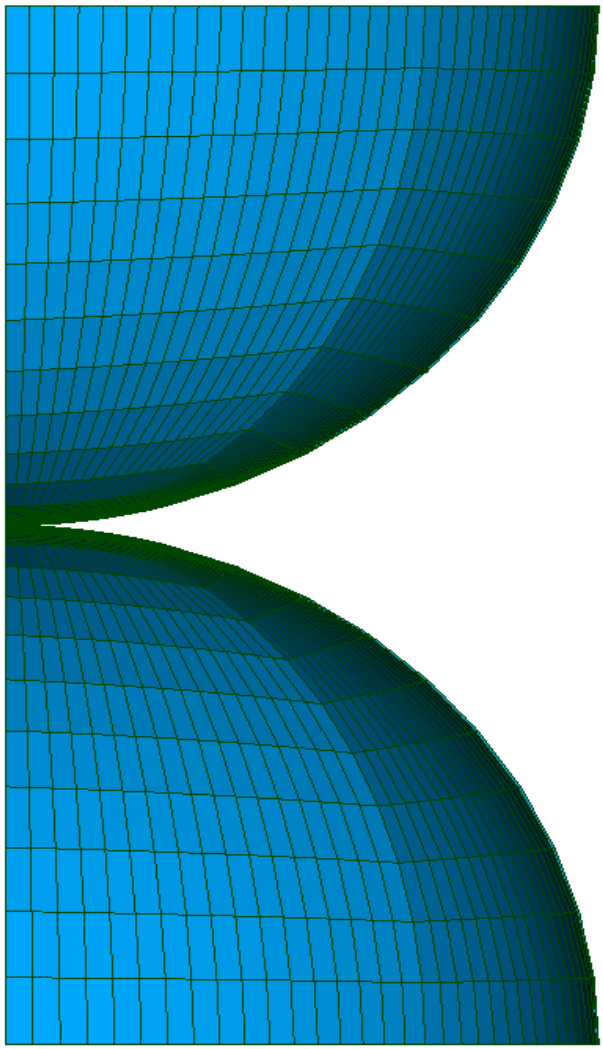
11 Modeling I

11.1 Characteristics of modeling

A modeling is used 3D. The contact is treated with Mortar pairing, ALGO_CONT=LAC and cutting LAKE.

11.2 Characteristics of the grid

The grid contains 26421 elements of the type HEXA8.



11.3 Sizes tested and results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1	$SIYY$	$-2.7983E3$	6
G1_2	$SIYY$	$-2.7983E3$	7

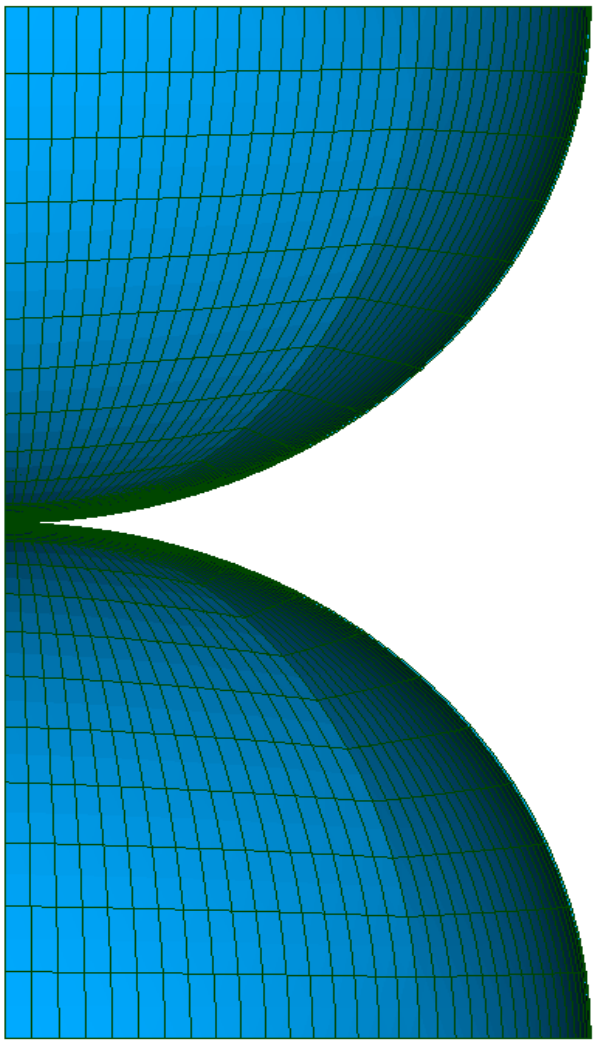
12 Modeling J

12.1 Characteristics of modeling

A modeling is used 3D. The contact is treated with Mortar pairing, ALGO_CONT=LAC and cutting LAKE.

12.2 Characteristics of the grid

The grid contains 26421 elements of the type HEXA20.



12.3 Sizes tested and results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1	$SIYY$	$-2.7983E3$	6
G1_2	$SIYY$	$-2.7983E3$	6

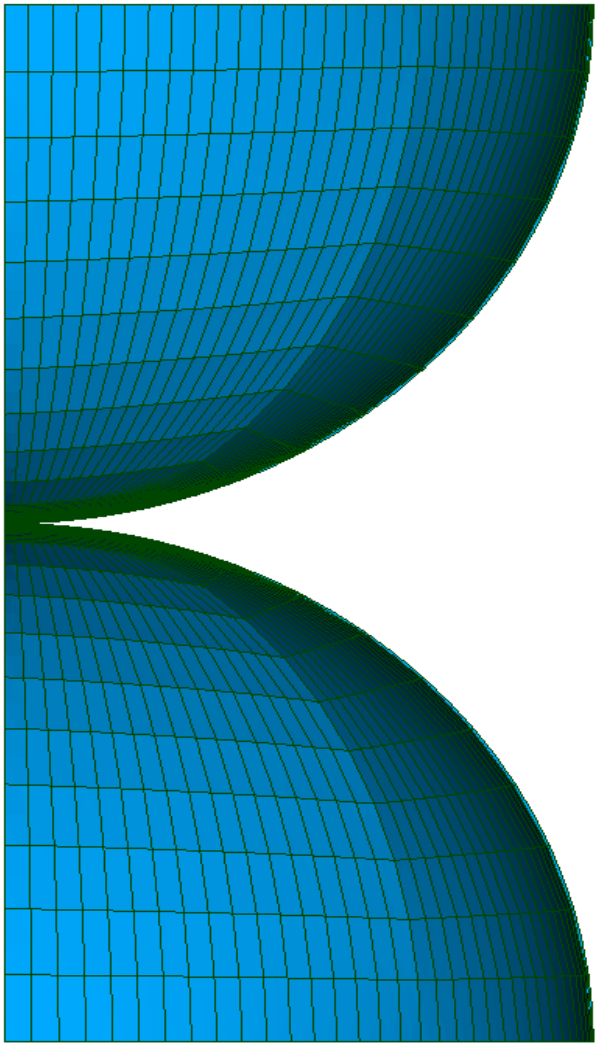
13 Modeling K

13.1 Characteristics of modeling

A modeling is used 3D. The contact is treated with Mortar pairing, ALGO_CONT=LAC and cutting LAKE.

13.2 Characteristics of the grid

The grid contains 26421 elements of the type HEXA27.



13.3 Sizes tested and results

NotS	Size	Reference (MPa)	Tolerance (%)
G1_1	$SIYY$	$-2.7983E3$	6
G1_2	$SIYY$	$-2.7983E3$	6

14 Summary of the results

Modelings	With	B	C	D	E	F
Type of grid	Linear	Linear	Linear	Linear	Linear	Linear
Number of ddl	14,176	95,712	485,380	14,348	96,376	487,481
Many meshs	9,484	64,020	324,470	9,484	64,020	324,470
Formulation of the contact	Discrete	Discrete	Discrete	Continuous	Continuous	Continuous
Many connections of contact	64	222	721	64	222	721
Memory used (Mo)	130	473	3 751	172	730	2 725
Total time (S)	3,95	91,24	1 804,67	7,53	75,74	582,69
Time STAT_NON_LINE (S)	3,20	87,98	1 778,54	6,78	72,44	556,03
Solvor	MULT_FRONT	MULT_FRONT	MULT_FRONT	GCPC	GCPC	GCPC

Modelings	G	H	I	J	K
Type of grid	Linear Tetrahedron	Quadratic Tetrahedron	Linear Hexahedron	Quadratic Hexahedron	Biquadratic Hexahedron
Number of ddl	50780	333306	97544	375578	701029
Many meshs	84336	84336	33172	33172	33172
Formulation of the contact	LAKE	LAKE	LAKE	LAKE	LAKE
Many connections of contact	270	284	135	135	135
Total time (S)	56.81	349.73	89.40	829.97	1894.52
Time STAT_NON_LINE (S)	38,607	329,00	81.18	821.33s	1890.34
Solvor	MUMPS	MUMPS	MUMPS	MUMPS	MUMPS

It is noted that the method of contact continues associated with a combined gradient prepacked by an incomplete factorization with level 1 makes it possible to obtain very good performances since the size of the problem (in term of ddls total and contact) grows.