PERF005 - Contact of Hertz between two half-spheres

Summarized:

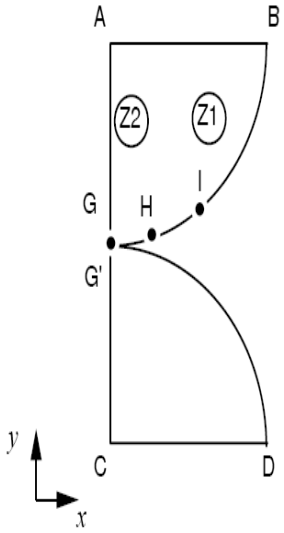
The purpose of this benchmark is to 3D measure the performances of an elastic design with contact.

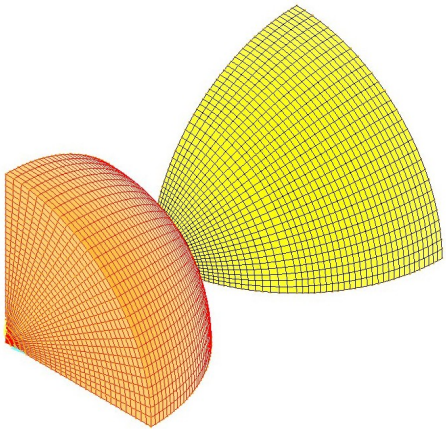
The three modelizations carried out are the following ones:

•Modelization a: mesh PENTA6, $1.3\,E4$ degrees of freedom, 64 nodes of contact, STAT_NON_LINE ("MULT_FRONT", "STRESS")
•Modelization b: mesh PENTA6, $9.1\,E4$ degrees of freedom, 222 nodes of contact, STAT_NON_LINE ("MULT_FRONT", "STRESS")
•Modelization C: mesh PENTA6, $4.9\,E5$ degrees of freedom, 697 nodes of contact, STAT_NON_LINE ("MULT_FRONT", "STRESS")
•Modelization D: mesh PENTA6, $1.3\,E4$ degrees of freedom, 64 nodes of contact, STAT_NON_LINE ("PCG", "CONTINUE")
•Modelization E: mesh PENTA6, $9.1\,E4$ degrees of freedom, 222 nodes of contact, STAT_NON_LINE ("PCG", "CONTINUE")
•Modelization F: mesh PENTA6, $4.9\,E5$ degrees of freedom, 697 nodes of contact, STAT_NON_LINE ("PCG", "CONTINUE")

1 Problem of reference

1.1 Geometry





•Radius: $R=50\,mm$

1.2 Properties of the 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 stress σ_{yy} to 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} to the point G (analytical solution)
$\sigma_{yy}=-2798.3\ MPa$

2.3 Uncertainties

analytical Solution

2.4 Bibliographical reference

[1] G. DUMONT: “The method of the active stresses applied to the unilateral contact” Notes HI-75/93/016.

3 Modelization A

3.1 Characteristic of the modelization A

Modelization 3D:

Many nodes	3 770		
Number of meshes	8 964	Are:	
		SEG2	208
		TRIA3	1 652
		QUAD4	688
		TETRA4	192
		PENTA6	5 952
		PYRAM5	272

3.2 Results

Not	Quantity	Reference (MPa)	Tolerance (%)
G1	*SIYY*	−2.7983E3	0.16

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

4 Modelization B

4.1 Characteristic of the modelization B

Modelization 3D:

Many nodes 27760
Number of meshes 60996 Are:

SEG2	424
TRIA3	6492
QUAD4	2912
TETRA4	768
PENTA6	49472
PYRAM5	928

4.2 Results

Not	Quantity	Reference (MPa)	Tolerance (%)
G1	*SIYY*	−2.7983E3	0.05

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

5 Modelization C

5.1 Characteristic of the modelization C

Modelization 3D:

Many nodes 154 666
Number of meshes 326 854 Are:

SEG2	766
TRIA3	21 280
QUAD4	9 240
TETRA4	2 632
PENTA6	290 080
PYRAM5	2 856

5.2 Results

Not	Quantity	Reference (MPa)	Tolerance (%)
G1	*SIYY*	−2.7983E3	0.05

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

6 Modelization D

6.1 Characteristic of the modelization D

Modelization 3D:

Many nodes	3 770		
Number of meshes	8 964	Are:	
		SEG2	208
		TRIA3	1 652
		QUAD4	688
		TETRA4	192
		PENTA6	5 952
		PYRAM5	272

6.2 Results

Not	Quantity	Reference (MPa)	Tolerance (%)
G1	*SIYY*	−2.7983E3	0.16

This modelization is during modelization A by means of a contact method different here "CONTINUE" as well as a different linear solver here "PCG".

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

The results are identical to those of modelization A.

7 Modélisation E

7.1 Characteristic of the modelization E

Modelization 3D:

Many nodes 27760
Number of meshes 60996 Are:

SEG2	424
TRIA3	6492
QUAD4	2912
TETRA4	768
PENTA6	49472
PYRAM5	928

7.2 Results

Not	Quantity	Reference (MPa)	Tolerance (%)
G1	*SIYY*	−2.7983E3	0.05

This modelization is during modelization B by means of a contact method different here "CONTINUE" as well as a different linear solver here "PCG".

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

The results are identical to those of the modelization B.

8 Modelization F

8.1 Characteristic of the modelization F

Modelization 3D:

Many nodes	154666	
Number of meshes	326854	Are:

SEG2	766
TRIA3	21280
QUAD4	9240
TETRA4	2632
PENTA6	290080
PYRAM5	2856

8.2 Results

Not	Quantity	Reference (MPa)	Tolerance (%)
G1	*SIYY*	−2.7983E3	0.05

This modelization is during modelization C by means of a contact method different here "CONTINUE" as well as a different linear solver here "PCG".

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

The results are identical to those of the modelization C.

9 Summary of the results

Machine	Aster	MOD.	Nb DDL	Memory (Mo)		Time execution (STAT_NON_LINE) (dry)			
				Used	Minimum	USER	SYSTEM	USER+SYS	ELAPSED
Linux 64 bits (ia64) “Bull”	10.1	A	13370	41	25	7.54	1.82	9.36	9.44
		B	91092	164.124		209.37	77.42	286.79	288.79
		C	488954	1299	1065	5605.98	5637.46	11243.44	11271.70
		D	13542	63	38	41.67	2.57	44.24	44.36
		E	91756	383	232	500.57	25.30	525.87	526.82
		F	491014	2047	1239	5453.84	355.82	5809.66	5878.49

One notes that the method of contact continues associated with a preconditioned conjugate gradient 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.