SSNP121 – Integration of the terms of contact in 2D and 3D

Summary:

This problem corresponds to a quasi-static analysis of a problem of mechanics with contact without friction. One is interested particularly here in integration of the terms of contact (*patch-test*). It is a question of studying two identical blocks with a grid differently and subjected to symmetrical imposed displacements.

This test comprises six modelings in 2D (linear elements SEG2):

- modeling a: METHODE= 'CONTINUE'. The method of integration by subelements also proposed by Bathe [bib1] is used with three subelements,
- modeling b: METHODE= 'CONTRAINTE',
- modeling C: METHODE= 'PENALISATION',
- modeling G: METHODE= 'CONTINUE'. An alternative of modeling A where one tests the initial activation of the statute of contact.
- modeling L: METHODE= 'GCP',
- modeling P: METHODE= 'CONTINUE'. An alternative of modeling G where the algorithm of penalization of the contact is tested.

a modeling in 2D (linear elements SEG2 in with respect to quadratic elements SEG3):

- modeling H: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements SEG2 in with respect to elements SEG3,

six modelings in 3D (quadratic elements):

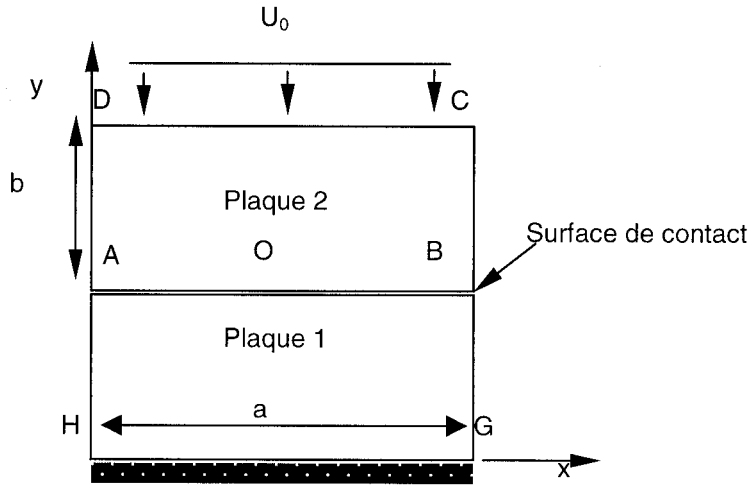
- modeling D: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements QUAD8 in with respect to elements QUAD8,
- modeling E: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements TRIA6 in with respect to elements TRIA6,
- modeling F: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements TRIA6 in with respect to elements QUAD8.
- modeling Q: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements QUAD9 in with respect to elements QUAD9, meshs 3D are HEXA27,
- modeling R: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements TRIA6 in with respect to elements TRIA6, meshs 3D are PENTA18,

and four modelings in 3D (linear elements in with respect to quadratic elements):

- modeling I: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements QUAD4 in with respect to elements QUAD8,
- modeling J: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements TRIA3 in with respect to elements TRIA6,
- modeling K: METHODE= 'CONTINUE'. Surfaces of contact are made up of elements TRIA3 in with respect to elements QUAD8.

1 Problem of reference

1.1 Geometry



Length $a=2\,m$.
Width $b=1\,m$.
O not medium of the segment AB (origin of the reference mark).

1.2 Properties of materials

Plates 1 and 2:
Poisson's ratio: 0.0
Young modulus: $2.10^6\,N/m^2$

1.3 Boundary conditions and loadings

Plate 1 is blocked:
- On HG $DX=0$ and $DY=0$.

Plate 2 is subjected to an imposed displacement:
- On CD : $DY=U_0=-0.1\,m$ and $DX=0$.

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution, analytical, can be deduced from a very simple calculation. The Poisson's ratio being null, the uniaxial deformation is written $\varepsilon = U_0 / HD = -0.1/2.$ The pressure is worth then $E\,\varepsilon = -10^5\,Pa$.

2.2 Results of reference

The contact pressure is constant and equal to $-10^5\,Pa$ on all the surface of contact. In the same way vertical displacement (according to y) is constant on the surface of contact and equal to $U_0/2 = -0.05\,\mathrm{m}$.

2.3 Bibliographical reference

1. NR. EL-ABBASI and K.J. BATHE: "*Stability and Patch Test Performance of Contact Discretizations and has New Algorithm Solution*", Computers & Structures, 79,1473-1486, 2001

3 Modeling A

3.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method CONTINUOUS for the treatment of CONTACT with integration of the type 'SIMPSON2'.

3.2 Characteristics of the grid

Many nodes: 313
Many meshs and types: 265 QUAD4 and 132 SEG2

The grids of 2 surfaces of contact are incompatible. 12 finite elements SEG2 are laid out on the initial surface of contact of plate 1 and only 11 on surface of contact of other surface.
By activating the keyword SIMPSON2 three subelements are used for the integration of the terms of contact.

3.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $N14$	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point A	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point B	– 1.E+5	'ANALYTICAL'	1%
DY with the node $N14$	-0.05	'ANALYTICAL'	1%
DY at the point A	-0.05	'ANALYTICAL'	1%
DY at the point B	-0.05	'ANALYTICAL'	1%

4 Modeling B

4.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method CONSTRAINT for the treatment of CONTACT.

4.2 Characteristics of the grid

One uses the same grid as for preceding modeling.

Many nodes: 313
Many meshs and types: 265 QUAD4 and 132 SEG2

4.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
SIYY with the node $N14$	– 1.E+5	'ANALYTICAL'	1%
SIYY at the point A	– 1.E+5	'ANALYTICAL'	6.1%
SIYY at the point B	– 1.E+5	'ANALYTICAL'	6.1%
DY with the node $N14$	-0.05	'ANALYTICAL'	1%
DY at the point A	-0.05	'ANALYTICAL'	1,67%
DY at the point B	-0.05	'ANALYTICAL'	1,67%

4.4 Remarks

The discrete formulations do not check it *patch-test* contrary to the continuous formulation, this is why the tolerances are looser.

5 Modeling C

5.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method PENALIZATION with a coefficient of penalization of 1.E7 for the treatment of the contact.

5.2 Characteristics of the grid

One uses the same grid as for preceding modeling.

Many nodes: 313
Many meshs and types: 265 QUAD4 and 132 SEG2

5.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
SIYY with the node $N14$	– 1.E+5	'ANALYTICAL'	2,13%
SIYY at the point A	– 1.E+5	'ANALYTICAL'	7.5%
SIYY at the point B	– 1.E+5	'ANALYTICAL'	7.5%
DY with the node $N14$	-0.05	'ANALYTICAL'	2,13%
DY at the point A	-0.05	'ANALYTICAL'	0,7%
DY at the point B	-0.05	'ANALYTICAL'	0,7%

5.4 Remarks

The discrete formulations do not check it *patch-test* contrary to the continuous formulation, this is why the tolerances are looser.

6 Modeling D

6.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT. Surfaces of contact in opposite consist of elements QUAD8.

6.2 Characteristics of the grid

Many nodes: 850
Many meshs and types: 128 HEXA20 and 64 QUAD8

6.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node *A21*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A22*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A23*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A24*	– 1.E+5	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point *A21*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A22*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A23*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A24*	-0.05	'ANALYTICAL'	0,1%

7 Modeling E

7.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT. Surfaces of contact in opposite consist of elements TRIA6.

7.2 Characteristics of the grid

Many nodes: 1010
Many meshs and types: 256 PENTA15 and 128 TRIA6

7.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $A21$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A22$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A23$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A24$	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point $A21$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A22$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A23$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A24$	-0.05	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%

8 Modeling F

8.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT. Surfaces of contact in opposite consist of elements TRIA6 in with respect to meshs QUAD8.

8.2 Characteristics of the grid

Many nodes: 930
Many meshs and types: 64 HEXA20, 128 PENTA15, 32 QUAD8 and 64 TRIA6

8.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node *A21*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A22*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A23*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A24*	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point *A21*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A22*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A23*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A24*	-0.05	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%

8.4 Remarks

The surface of contact slave is with a grid in TRIA6 and surfaces it main contact is with a grid in QUAD8. A use with elements QUAD8 for surface slave and TRIA6 for surface Master does not satisfy the conditions of compatibility necessary to the good integration of the terms of contact [R5.03.52]. In a general way, if one correctly does not apprehend this concept of compatibility, one advises with the user not informed to use the same elements for the grid of surfaces main and slave.

9 Modeling G

9.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method CONTINUOUS for the treatment of CONTACT with integration of the type SIMPSON2.

9.2 Characteristics of the grid

Many nodes: 313
Many meshs and types: 265 QUAD4 and 132 SEG2

9.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $N14$	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point A	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point B	– 1.E+5	'ANALYTICAL'	1%
DY with the node $N14$	-0.05	'ANALYTICAL'	1%
DY at the point A	-0.05	'ANALYTICAL'	1%
DY at the point B	-0.05	'ANALYTICAL'	1%

9.4 Remarks

In this modeling, the loading is a pressure imposed on the higher plate (and not a displacement). The 2 approaches are perfectly equivalent, however the use of a pressure forces here to block the movements of rigid body (according to DZ), that is done by declaring a contact initial (CONTACT_INIT).

10 Modeling H

10.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method CONTINUOUS for the treatment of CONTACT between linear mixed elements and quadratic elements.

10.2 Characteristics of the grid

Many nodes: 721
Many meshs and types: 144 QUAD4, 121 QUAD8, 48 SEG2 and 44 SEG3

The grids are incompatible. 12 finite elements SEG2 are laid out on the initial surface of contact of the plate slave and only 11 finite elements SEG3 on the surface of main contact.
By activating the keyword NCOTES2 , a diagram of the Newton-Dimensions type coupled to a technique of subdivision in subelements was used for the integration of the terms of contact.

10.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $N14$	– 1.E+5	'ANALYTICAL'	0,5%
LAGS_C at the point A	– 1.E+5	'ANALYTICAL'	0,5%
LAGS_C at the point B	– 1.E+5	'ANALYTICAL'	0,5%
DY with the node $N14$	-0.05	'ANALYTICAL'	0,5%
DY at the point A	-0.05	'ANALYTICAL'	0,5%
DY at the point B	-0.05	'ANALYTICAL'	0,5%

11 Modeling I

11.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT between linear mixed elements and quadratic elements.

11.2 Characteristics of the grid

Many nodes: 227
Many meshs and types: 16 HEXA20, 25 HEXA8, 32 QUAD8 and 50 QUAD4

The grids are incompatible. Surfaces of contact consist of 5 elements QUAD4 out of screw - with-screw of 4 elements QUAD8. The diagram of integration used is of Newton-Dimensions type coupled to a technique of subdivision in subelements.

11.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node *A21*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A22*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A23*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A24*	– 1.E+5	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point *A21*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A22*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A23*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A24*	-0.05	'ANALYTICAL'	0,1%

12 Modeling J

12.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT between linear mixed elements and quadratic elements.

12.2 Characteristics of the grid

Many nodes: 630
Many meshs and types: 128 PENTA6, 128 PENTA15, 64 TRIA3 and 64 TRIA6

The grids are compatible. Surfaces of contact consist of elements TRIA3 in with respect to elements TRIA6. The diagram of integration used is of Newton-Dimensions type.

12.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node *A21*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A22*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A23*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A24*	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point *A21*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A22*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A23*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A24*	-0.05	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%

13 Modeling K

13.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT for the linear/quadratic mixed elements.

13.2 Characteristics of the grid

Many nodes: 550
Many meshs and types: 64 HEXA20, 128 PENTA6, 32 QUAD8 and 64 TRIA3

The grids are compatible. Surfaces of contact consist of elements TRIA3 in with respect to elements QUAD8. The diagram of integration used is of Newton-Dimensions type.

13.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $A21$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A22$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A23$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A24$	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point $A21$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A22$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A23$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A24$	-0.05	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%

13.4 Remarks

The surface of contact slave is with a grid in TRIA3 and surfaces it main contact is with a grid in QUAD8. A use with elements QUAD8 for surface slave and TRIA3 for surface Master does not satisfy the conditions of compatibility necessary to the good integration of the terms of contact [R5.03.52].

14 Modeling L

14.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method GCP for the treatment of CONTACT.

14.2 Characteristics of the grid

One uses the same grid as for modeling A.

Many nodes: 313
Many meshs and types: 265 QUAD4 and 132 SEG2

14.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
SIYY with the node $N14$	– 1.E+5	'ANALYTICAL'	2,13%
SIYY at the point A	– 1.E+5	'ANALYTICAL'	7.5%
SIYY at the point B	– 1.E+5	'ANALYTICAL'	7.5%
DY with the node $N14$	-0.05	'ANALYTICAL'	2.13%
DY at the point A	-0.05	'ANALYTICAL'	0,7%
DY at the point B	-0.05	'ANALYTICAL'	0,7%

14.4 Remarks

The discrete formulations do not check it *patch-test* contrary to the continuous formulation, this is why the tolerances are looser.

15 Modeling P

15.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method CONTINUOUS for the treatment of CONTACT with integration of the type SIMPSON2. The formulation of the contact is penalized, the coefficient of penalization is of 1.0E16.

15.2 Characteristics of the grid

Many nodes: 313
Many meshs and types: 265 QUAD4 and 132 SEG2

15.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $N14$	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point A	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point B	– 1.E+5	'ANALYTICAL'	1%
DY with the node $N14$	-0.05	'ANALYTICAL'	1%
DY at the point A	-0.05	'ANALYTICAL'	1%
DY at the point B	-0.05	'ANALYTICAL'	1%

15.4 Remarks

In this modeling, the loading is a pressure imposed on the higher plate (and not a displacement). The 2 approaches are perfectly equivalent, however the use of a pressure forces here to block the movements of rigid body (according to DZ), that is done by declaring a contact initial (CONTACT_INIT).

16 Modeling Q

16.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT. Surfaces of contact in opposite consist of elements QUAD9.

16.2 Characteristics of the grid

Many nodes: 850
Many meshs and types: 128 HEXA27 and 64 QUAD9

16.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node *A21*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A22*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A23*	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point *A24*	– 1.E+5	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point *A21*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A22*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A23*	-0.05	'ANALYTICAL'	0,1%
DZ at the point *A24*	-0.05	'ANALYTICAL'	0,1%

16.4 Remarks

In this modeling, meshs are used HEXA27 who were transformed by the operator CREA_MAILLAGE.

17 Modeling R

17.1 Characteristics of modeling

A modeling is used 3D for the solid elements with the method CONTINUOUS for the treatment of CONTACT. Surfaces of contact in opposite consist of elements TRIA6.

17.2 Characteristics of the grid

Many nodes: 1458
Many meshs and types: 256 PENTA18, 128 TRIA6

17.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $A21$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A22$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A23$	– 1.E+5	'ANALYTICAL'	0,1%
LAGS_C at the point $A24$	– 1.E+5	'ANALYTICAL'	0,1%
MAX of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
MIN of the LAGS_C on surface	– 1.E+5	'ANALYTICAL'	0,1%
DZ at the point $A21$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A22$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A23$	-0.05	'ANALYTICAL'	0,1%
DZ at the point $A24$	-0.05	'ANALYTICAL'	0,1%

17.4 Remarks

In this modeling, meshs are used PENTA18 who were transformed by the operator CREA_MAILLAGE.

18 Modeling S

18.1 Characteristics of modeling

A modeling is used D_PLAN for the solid elements with the method CONTINUOUS for the treatment of CONTACT. One tests the method of PENALIZATION with generalized Newton.

18.2 Characteristics of the grid

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

18.3 Sizes tested and results

Identification	Value of reference	Type of reference	Tolerance
LAGS_C with the node $N14$	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point A	– 1.E+5	'ANALYTICAL'	1%
LAGS_C at the point B	– 1.E+5	'ANALYTICAL'	1%
DY with the node $N14$	-0.05	'ANALYTICAL'	1%
DY at the point A	-0.05	'ANALYTICAL'	1%
DY at the point B	-0.05	'ANALYTICAL'	1%

18.4 Remarks

In this modeling, meshs are used PENTA18 who were transformed by the operator CREA_MAILLAGE.

19 Summary of the results

One seeks on this very simple example (known under the name of *patch-test*) to test a novel method of integration of the terms of contact based on the subdivision by subelements available only for the formulation 'CONTINUES'. This technique aims to attenuate the amplitude of oscillation of the contact pressure. In the case studied here, the pressure is constant on all the surface of contact (let us notice that the Poisson's ratio is null).

One notes thus that with the discrete formulations 'FORCED' and 'PENALIZATION' the solution has nonphysical oscillations of about 6 to 7%. By using the method 'CONTINUES', with a diagram of integration adapted the oscillations disappear almost completely and the got results are very close to the reference solution (<0,5%).