SSNV505 - Contact of 2 beams in large displacements

Summarized:

This test represents a computation of contact without friction between two beams in large displacements subjected to a specific displacement. Initially the beams are not in contact. Once the established contact, the two beams slip one on the other.

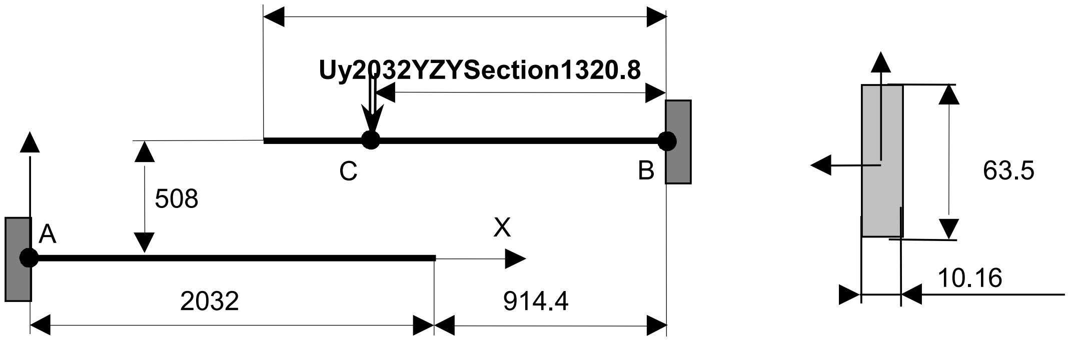
Result analyzed is the normal reaction of contact according to displacement. The results got with various modelizations are compared.

- Modelization A : the structure is modelled with elements of COQUE_3D associated with a mesh QUAD9, with the FORCED method.
- Modelization B : the structure is modelled in $3D$ plane strains using elements HEXA8, with the FORCED method.
- Modelization C : the structure is modelled in $2D$ plane strains using elements QUAD4, with the FORCED method.
- Modelization D : the structure is modelled in $3D$ plane strains using elements HEXA8, with the continuous method .
- Modelization E : the structure is modelled in $2D$ plane strains using elements QUAD4, with the continuous method .
- Modelization F : the structure is modelled in $2D$ using beam elements POU_D_E (meshes SEG2), with the methods LAGRANGIAN (with friction) and CONTINUE. This modelization and the following one is distinguished from the preceding ones, in what they are carried out in small transformations.
- Modelization G : the structure is modelled in $2D$ using beam elements POU_D_E (meshes SEG2), with the method LAGRANGIAN. This modelization validates the possibility of taking into account the radius of the section of beam like fictitious clearance.
- Modelization H : the structure is modelled in $2D$ using beam elements POU_D_TGM (meshes SEG2), with the methods LAGRANGIAN (with friction) and CONTINUE. This modelization is carried out in large displacements.
- Modelization I : the structure is modelled in $3D$ using shell elements DKT (meshes QUAD4), with the continuous method . This modelization carried out in small transformations validates the good taking into account of a fictitious clearance for the structural elements.

1 Problem of reference

1.1 Geometry

the geometrical data are indicated in millimetres $[\mathrm{mm}]$:



1.2 Properties of the material

$E=6.8948\times10^{3}\,MPa$	Modulus Young
$\nu=0.3333$	Poisson's ratio
$\mu=0.$	Coefficient of kinetic friction

1.3 Boundary conditions and loadings

- Boundary conditions: Sections at the points A and B clamped
- Loading: vertical displacement of point: C $d=-790\,mm$

1.4 Initial conditions

Without object.

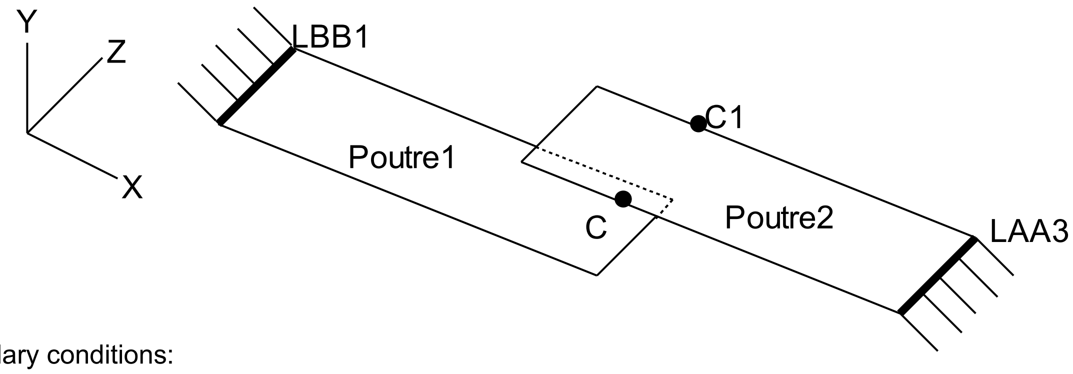
2 Reference solution

2.1 Method of calculating used for the reference solution

One does not have reference solution, one makes only tests of NON-regression.

3 Modelization A

3.1 Characteristic of modelization



Boundary conditions:

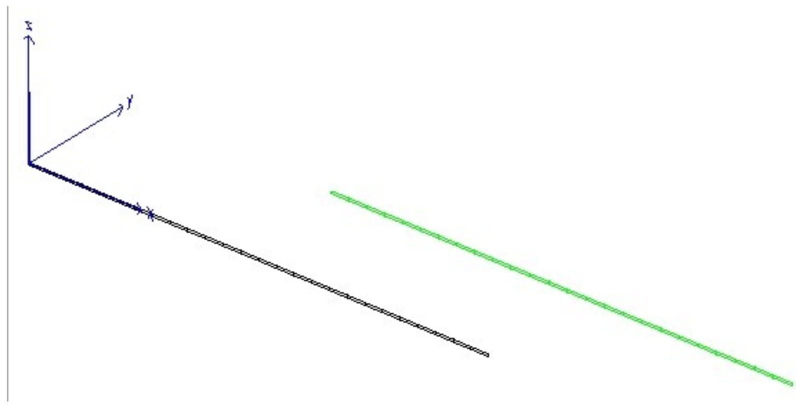
This modelization is carried out in `COQUE_3D`. In fact, the finite elements used are `QUAD9`. The boundary conditions are the following ones:

- sides $LAA3$ and $LBB1$: $DX = DY = DZ = DRX = DRY = DRZ = 0$
- Nodes tops C and $C1$: $DY = -790\,mm$
- All the nodes tops of structure: $DZ = 0$, $DRX = 0$

Conditions of contact:

- surface main: mesh group $POUTRE1$ minus the mesh group whose edge is embedded according to $LBB1$,
- surface slave: mesh group $POUTRE2$ minus the mesh group whose edge is embedded according to $LAA3$.

3.2 Characteristics of the mesh



Many nodes:	261
Number of meshes:	158
`SEG3`	107
`QUAD8`	51

3.3 Quantities tested and results

One test the reaction to the displacement imposed on the shell. To obtain it, one calculates the reactions to the fixed supports in $LBB1$ and $LAA3$.

One makes only 80% loading to limit the time of the benchmark.

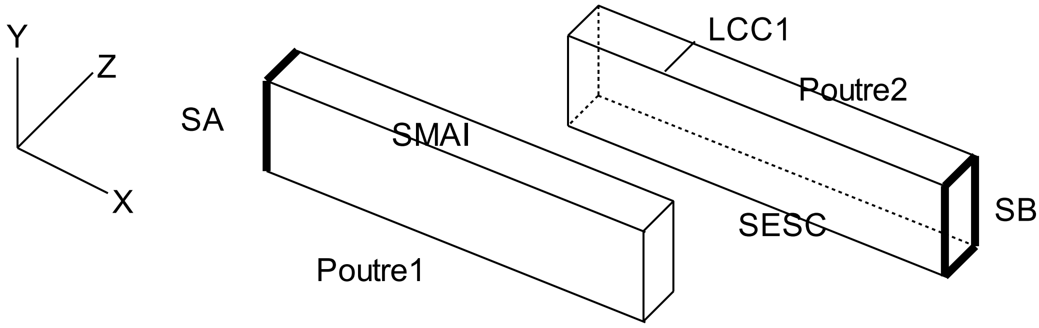
Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	313.96515859657	"NON_REGRESSION"	0.10%
Reaction	0.4	1220.6114997884	"NON_REGRESSION"	0.10%
Reaction	0.6	2456.8221137607	"NON_REGRESSION"	0.10%
Reaction	0.8	2067.7188799695	"NON_REGRESSION"	0.10%

3.4 Remarks

This modelization gives results very close to the modelization beam (modelization H) but different from the modelizations 3D : it is perfectly normal because the contact is specific with the structural elements.

4 Modelization B

4.1 Characteristic of the modelization



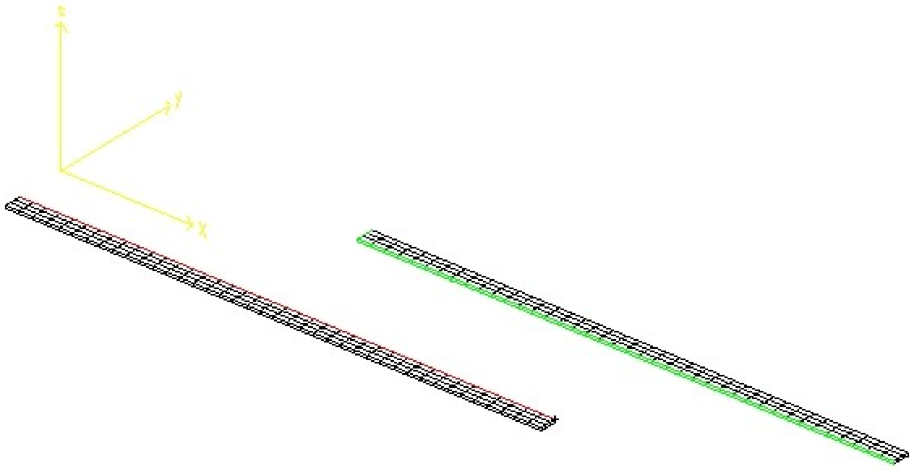
Boundary conditions:

- Surfaces SA and SB : $DX=DY=DZ=0$
- Lines $LCC1$: $DY=-790\,mm$
- All the nodes tops of structure: $DZ=0$

Conditions of contact:

- surface main: mesh group $SMAI$
- surfaces slave: characteristics $SESC$

4.2 mesh group of the mesh



Many nodes:	662
Number of meshes:	1247
POI1	1
SEG2	351
QUAD4	655
HEXA8	240

4.3 Quantities tested and results

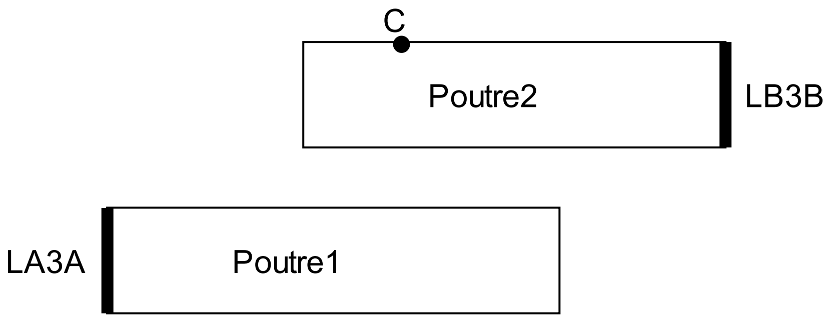
One test the reaction to the displacement imposed on $POUTRE2$. To obtain it, one calculates the reactions to the fixed supports in SA and SB .

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	436.995	"NON_REGRESSION"	0.10%
Reaction	0.4	1668.34	"NON_REGRESSION"	0.10%
Reaction	0.6	3258.69	"NON_REGRESSION"	0.10%
Reaction	0.8	2737.16	"NON_REGRESSION"	0,10%
Reaction	1.0	3095.24	"NON_REGRESSION"	0.10%

5 Modelization C

5.1 Characteristic of the modelization

The modelization is done in 2D plane strains to find blocking in DZ imposed on the model 3D.



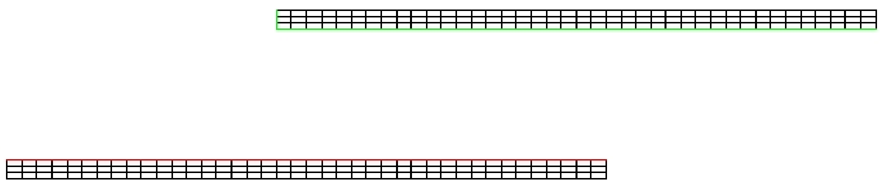
Boundary conditions:

- sides $LA3A$ and $LB3B$: $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface main: group of mesh $SMAI$
- surfaces slave: group of mesh $SESC$

5.2 Characteristics of the mesh



Number of meshes:	415
SEG2	175
QUAD4	240

5.3 Quantities tested and results

One test the reaction to the displacement imposed on the shell. To obtain it, one calculates the reactions to the fixed supports in $LB3B$ and $LA3A$

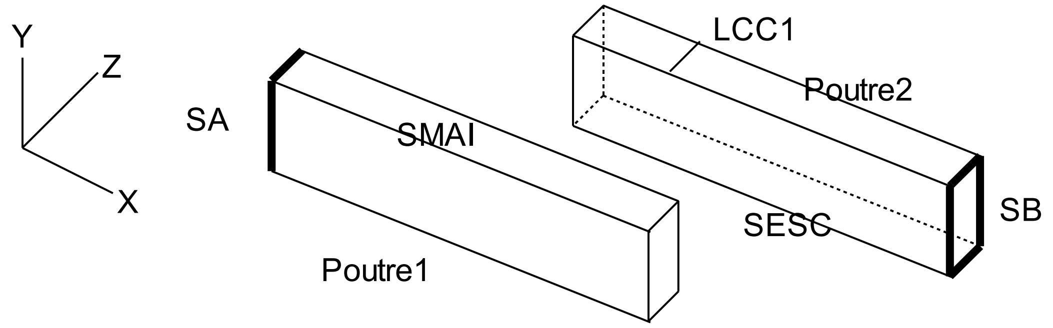
Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	43.5668	"NON_REGRESSION"	0.10%
Reaction	0.4	169.598	"NON_REGRESSION"	0.10%
Reaction	0.6	323.491	"NON_REGRESSION"	0,16%
Reaction	0.8	267.162	"NON_REGRESSION"	0,10%
Reaction	1.0	309.623	"NON_REGRESSION"	0.10%

5.4 Notices

to obtain in $2\mathrm{D}$ results comparable to the results $3\mathrm{D}$, it is necessary to multiply the preceding reactions by the width of the beam, that is to say $10.16\,mm$.

6 Modelization D

6.1 Characteristic of the modelization



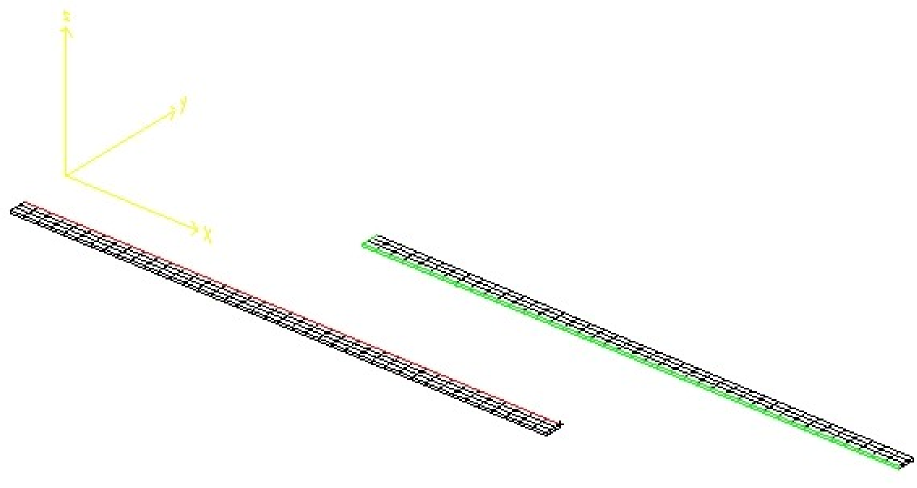
Boundary conditions:

- Surfaces SA and SB : $DX=DY=DZ=0$
- Line $LCC1$: $DY=-790\,mm$
- All the nodes tops of structure: $DZ=0$

Conditions of contact:

- surface main: mesh group $SMAI$
- surfaces slave: characteristics $SESC$

6.2 mesh group of the mesh



Many nodes:	662
Number of meshes:	1247
POI1	1
SEG2	351
QUAD4	655
HEXA8	240

6.3 Quantities tested and results

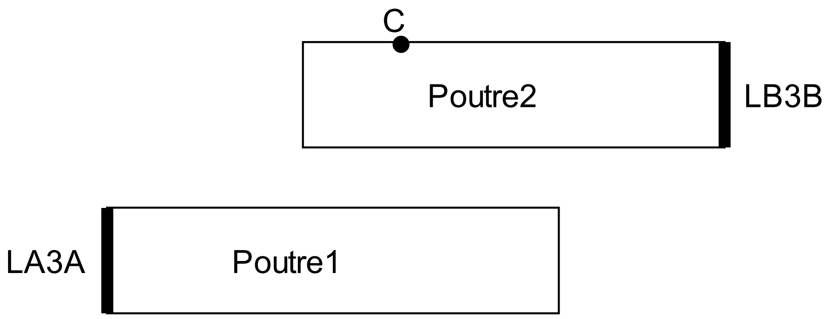
One test the reaction to the displacement imposed on *POUTRE2* . To obtain it, one calculates the reactions to the fixed supports in *SA* and *SB* . The percentage of difference indicates the difference between this modelization and the equivalent modelization with the FORCED method.

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	436.995	"NON_REGRESSION"	0.10%
Reaction	0.4	1668.34	"NON_REGRESSION"	0.10%
Reaction	0.6	3264.54	"NON_REGRESSION"	0,15%
Reaction	0.8	2737.16	"NON_REGRESSION"	0,20%
Reaction	1.0	3095.24	"NON_REGRESSION"	0.10%

7 Modelization E

7.1 Characteristic of the modelization

The modelization is done in $2\mathrm{D}$ plane strains to find blocking in DZ imposed on the model $3\mathrm{D}$.



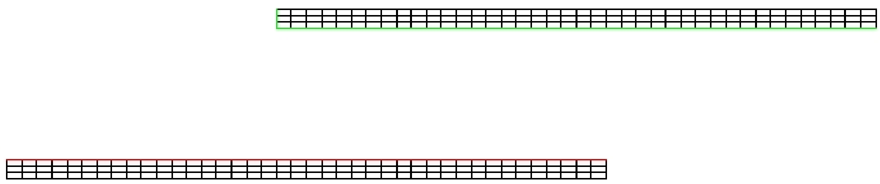
Boundary conditions:

- sides $LA3A$ and $LB3B$: $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface main: group of mesh $SMAI$
- surfaces slave: group of mesh $SESC$

7.2 Characteristics of the mesh



Number of meshes:	415
SEG2	175
QUAD4	240

7.3 Quantities tested and results

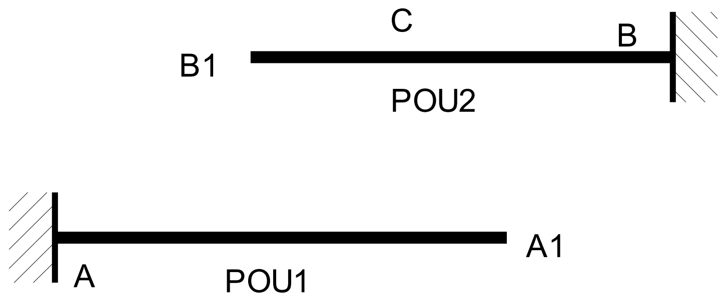
One test the reaction to the displacement imposed on the shell. To obtain it, one calculates the reactions to the fixed supports in $LB3B$ and $LA3A$. The percentage of difference indicates the difference between this modelization and the equivalent modelization with the FORCED method.

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	43.5668	"NON_REGRESSION"	0.10%
Reaction	0.4	169.598	"NON_REGRESSION"	0.10%
Reaction	0.6	323.491	"NON_REGRESSION"	0,16%
Reaction	0.8	267.162	"NON_REGRESSION"	0,20%
Reaction	1.0	309.623	"NON_REGRESSION"	0.10%

8 Modelization F

8.1 Characteristic of the modelization

One carries out here a modelization using elements beam in $3\mathrm{D}$. The strains being plane in the plane (DX, DY) , one imposes $DZ=0$ on the model $3\mathrm{D}$. The goal of this benchmark is to compare the strain of the beams with a formulation in small rotations with that obtained with large rotations. The first model is of course abusive (forgery) compared to the second (true), but makes it possible to illustrate the difference of the results got in one or the other case. The true motivation of this benchmark is however of the contact to display an example of validation between beams with taking into account of fictitious clearances.



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface main: group of mesh $POU1$
- surfaces slave: group of mesh $POU2$

8.2 Characteristics of the mesh

Number of meshes: 80
`SEG2` 80

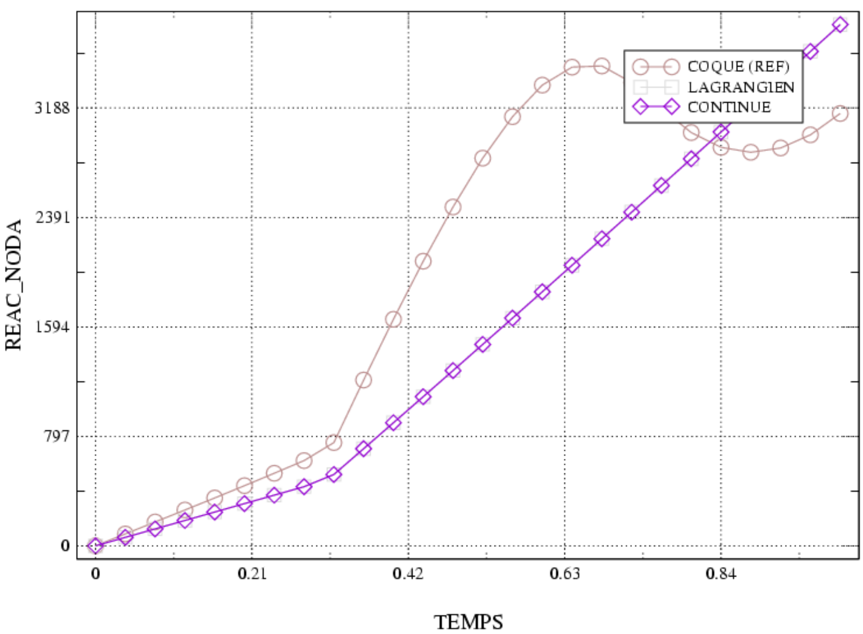
8.3 Quantities tested and results

One test the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to the fixed supports in A and B. The percentage of difference indicates the difference between this modelization and the equivalent modelization with the LAGRANGIAN `method`.

On the curve of bottom, one represented the force at the point B (fixed support of the higher beam) according to the evolution of the loading. One compares the methods Lagrangian and continuous with the solution obtained in large displacements. It appears that the two methods give almost identical results, but that the latter differ notably from those obtained in large displacements. This point is rather logical, since in the frame of the small disturbances in which computations were carried out, one neglects the terms of strain of the second order, which as one notes it are not negligible in great transformations.

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	307.48396428348	"NON_REGRESSION"	0.10%
Reaction	0.4	1251.4883178276	"NON_REGRESSION"	0.10%
Reaction	0.6	3023.9182463545	"NON_REGRESSION"	0,15%
Reaction	0.8	4829.5740249543	"NON_REGRESSION"	0,20%
Reaction	1.0	6656.1413705692	"NON_REGRESSION"	0.10%

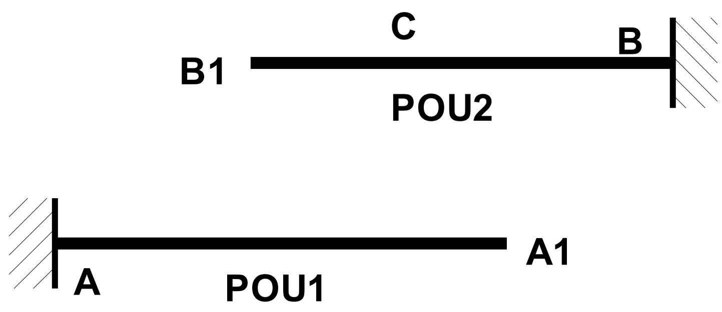
SSNV505F: NODAL REACTIONS



9 Modelization G

9.1 Characteristic of the modelization

One carries out here a modelization using elements beam in $3D$. The strains being plane in the plane (DX, DY) , one imposes $DZ=0$ on the model $3D$. The goal of this benchmark is to validate the taking into account of the real section of the beam, that the user informed by keyword "POUTRE" in AFFE_CARA_ELEM.



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface main: group of mesh $POU1$
- surfaces slave: group of mesh $POU2$

Characteristics of beam:

1) tubular section of radius $31.75\,mm$ and thickness $1\,mm$

9.2 Characteristics of the mesh

Number of meshes:	80
SEG2	80

9.3 Quantities tested and results

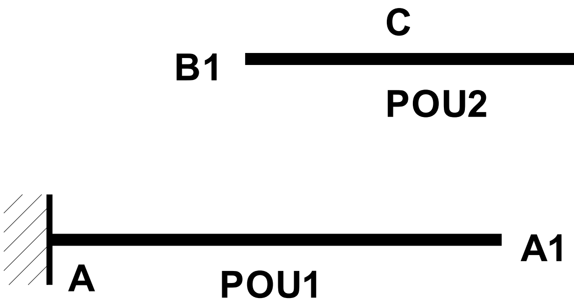
One test the reaction to the displacement imposed on the beam. One compares the case where the section of the beam entered via a constant clearance DIST_ESCL and the case where one takes into account the real section via keyword DIST_POUTRE.
Finally one also compares the formulation continues with the discrete formulation if the real section is taken into account via keyword DIST_POUTRE.

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.16	245.987	"AUTRE_ASTER"	0.10%
Reaction	0.4	1251.49	"AUTRE_ASTER"	0.10%

10 Modelization H

10.1 Characteristic of the modelization

One carries out here a modelization using elements beam in $3D$. The strains being plane in the plane (DX, DY) , one imposes $DZ=0$ on the model $3D$. Contrary to the preceding modelizations of beam, one uses here an element able to take into account large displacements (multifibre elements, [R3.08.09]).



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface main: group of mesh $POU1$
- surfaces slave: group of mesh $POU2$

10.2 Characteristics of the mesh

Number of meshes: 80
SEG2 80

10.3 Quantities tested and results

One test the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to the fixed supports in A and B. Two modelizations with respectively LAGRANGIAN method and continuous method are the object of tests of NON-regression.

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	311.885	"NON_REGRESSION"	0.10%
Reaction	0.4	1208.97	"NON_REGRESSION"	0.10%
Reaction	0.6	2414.53	"NON_REGRESSION"	0.10%
Reaction	0.8	2095.62	"NON_REGRESSION"	0.10%
Reaction	1.0	2442.544	"NON_REGRESSION"	0.10%

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	311.885	"NON_REGRESSION"	0.10%
Reaction	0.4	1210.43	"NON_REGRESSION"	0.10%
Reaction	0.6	2432.31	"NON_REGRESSION"	0.10%
Reaction	0.8	2085.15	"NON_REGRESSION"	0.10%
Reaction	1.0	2342.33	"NON_REGRESSION"	0.10%

One also tests in this modelization the use of the normal slave for the writing of the conditions of contact.

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	311.885	"NON_REGRESSION"	0.10%
Reaction	0.4	1273.768	"NON_REGRESSION"	0.10%
Reaction	0.6	3036.885	"NON_REGRESSION"	0.10%
Reaction	0.8	4817.154	"NON_REGRESSION"	0.10%
Reaction	0.94	6256.072	"NON_REGRESSION"	0.10%

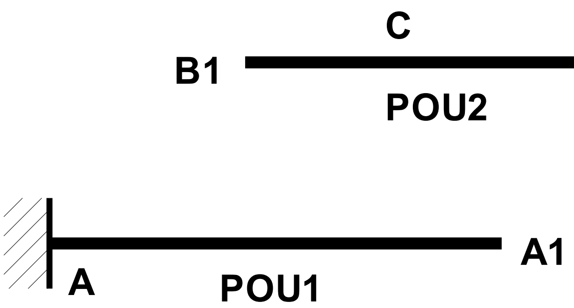
10.4 Remarks

One notes the very good agreement between the results got in large displacements by a model shell (modelization A) and a model beam (this modelization).
One will on the other hand notice that these two modelizations give results different from a modelization $3D$, that is with description of the contact at the end of beam which is specific in the modelizations of structures.
One in addition notes in this modelization that certain tests are the object of NON-regression: it is because the response of structure when the normal slave is used differs from the case where the norm Master is used (same way as if one inverts surfaces Masters and slaves).

11 Modelization I

11.1 Characteristic of the modelization

One carries out here a modelization using shell elements in $3D$. The strains being plane in the plane (DX, DY) , one imposes $DZ=0$ on the model $3D$. The goal of this benchmark is to compare the strain of the plates with a formulation in small rotations with that obtained with large rotations. The first model is of course abusive (forgery) compared to the second (true), but makes it possible to illustrate the difference of the results got in one or the other case. The true motivation of this benchmark is however of the contact to display an example of validation between beams with taking into account of fictitious clearances.



Boundary conditions:

- Nodes A and B : $DX=DY=0$
- Nodes C : $DY=-790\,mm$

Conditions of contact:

- surface main: group of mesh $POU1$
- surfaces slave: group of mesh $POU2$

11.2 Characteristics of the mesh

Number of meshes: 90
QUAD4 90

11.3 Quantities tested and results

One test the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to the fixed supports in A and B . The tests are of NON-regression.

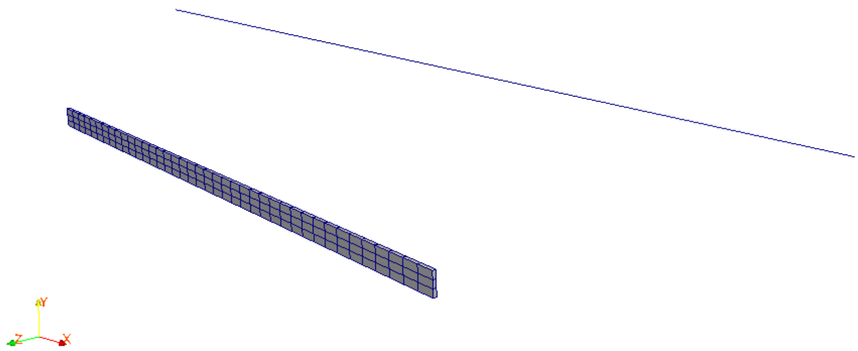
Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	345.91080450711	"NON_REGRESSION"	0.10%
Reaction	0.4	1407.8768333509	"NON_REGRESSION"	0.10%
Reaction	0.6	3401.7749540056	"NON_REGRESSION"	0,10%
Reaction	0.8	5432.9851518568	"NON_REGRESSION"	0,10%
Reaction	1.0	7487.5203886243	"NON_REGRESSION"	0.10%

One notes first of all that the results of the model plates under Assumption of the Small Disturbances (HPP) are very distant from those of the models in large displacements: as explained in the conclusions of the modelization F (beam in small disturbances models), it is normal.
It is noted that the results plates and beam (modelization F) differ rather largely in spite of an identical tendency. There still that can be explained by the following reason: the model plate leaves its frame of use because the thickness of the plates (of $63,5\,mm$ not modelled) is not small in front of two other dimensions (in particular in front $10,16\,mm$).

12 Modelization J

12.1 Characteristic of the modelization

One carries out here a modelization using elements beam and solid masses. The strains being plane in the plane (DX, DY), one imposes $DZ=0$ on the model. One uses here a beam element able to take into account large displacements (multifibre elements, [R3.08.09]).



12.2 Characteristics of the mesh

Many nodes: 369.
Number of meshes: 40 SEG2, 120 HEXA8.

12.3 Quantities tested and results

One tests the reaction to the displacement imposed on the beam. To obtain it, one calculates the reactions to the fixed supports in A and B. Two modelizations with respectively FORCED method and continuous method are the object of tests of NON-regression. Moreover the modelization CONTINUE is compared with the FORCED modelization.

The first computation (FORCED method)

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	311.88	"NON_REGRESSION"	0.10%
Reaction	0.4	1498.48	"NON_REGRESSION"	0.10%
Reaction	0.6	3042.17	"NON_REGRESSION"	0.10%
Reaction	0.8	2172	"NON_REGRESSION"	0.10%
Reaction	1.0	2159.73	"NON_REGRESSION"	0.10%

the Second computation (formulation CONTINUE)

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	311.88	"AUTRE_ASTER"	0.10%
Reaction	0.4	1498.48	"AUTRE_ASTER"	0.10%
Reaction	0.6	3042.17	"AUTRE_ASTER"	0.10%
Reaction	0.8	2172	"AUTRE_ASTER"	1,0%
Reaction	1.0	2159.73	"AUTRE_ASTER"	2,0%

Identification	Times	Standard	Reference of reference	Tolerance
Reaction	0.2	311.88	"NON_REGRESSION"	0.10%
Reaction	0.4	1498.49	"NON_REGRESSION"	0.10%
Reaction	0.6	3042.27	"NON_REGRESSION"	0.10%
Reaction	0.8	2191.47	"NON_REGRESSION"	0.10%
Reaction	0.94	2183.24	"NON_REGRESSION"	0.10%

12.4 Remarks

the results got between the two formulations of contact are close although they differ from a few percent at the end of the loading: these differences can be explained by the modelization of beam used (POU_D_TGM in large displacements) which is sensitive to the nombre of iterations of Newton (approximate formulation of large displacements). A refinement of time step must correct this variation. This modelization validates the contact between an edge and a facet for the two formulations of contact.

It is noted that the got results are different of the contact beam-beam and of the contact 3D-3D. The particular geometrical configuration of this test explains that (the contact zone is different in each case).

13 Summary of the results

the graph below presents the evolution of the component DY of the reaction force to the displacement imposed according to this last.

One notices a very good agreement between the various modelizations to $500\,mm$ then curve COQUE_3D (just as modelization POU_D_TGM) separates from $2D$ and from $3D$ before meeting with $700\,mm$. This variation is normal: it appears when the end of beam 2 is orthogonal with beam 1 (specific description of the contact *vs.* description $3D$).