SSNV128 - Plate with contact and friction on a Summarized rigid

level:

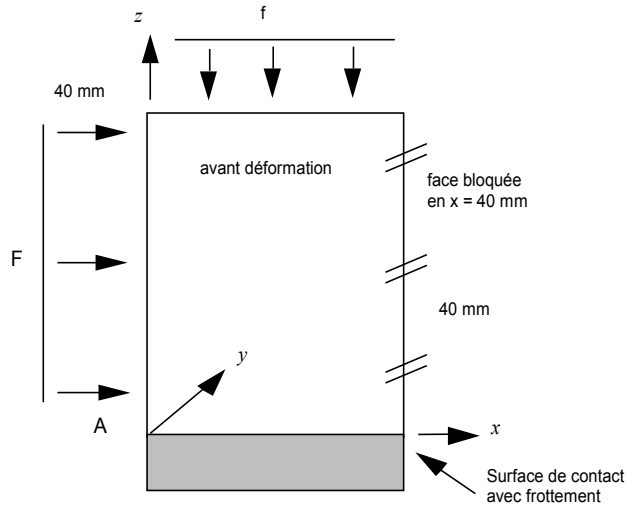
This problem corresponds to a quasi-static analysis of a problem of mechanics with contact and friction. A square plate is compressed on an indeformable level where it undergoes forces of contact and friction. This test leans on results 2D resulting from an average of codes.

This test comprises modelizations making it possible to test:

- modelizations 2D (QUAD4, QUAD8, TRIA3 and TRIA6) and the modelizations 3D (HEXA8, HEXA20, HEXA27, PENTA6, PENTA15, TETRA4 and TETRA10),
- algorithms of processing of the contact with " LAGRANGIAN" friction, "PENALIZATION" and "CONTINUE",
- the geometrical reactualization of the contact
- various options of the algorithm of pairing
- various options specific to the case of friction

1 Problem of reference

1.1 Geometry



Side of the plate (square) $a=0,04\ m$.

Position of the points of reference under contact surface (m)

	x	y	z
A	0	0	0
B	0,00125	0	0
C	0,005	0	0
D	0,0075	0	0
E	0,01125	0	0
R	0,03875	0	0

1.2 Properties of the materials

Plates:

Poisson's ratio: $0,2$
Young modulus: $1,3*10^{11}\ N.m^{-2}$

Frame (only if it is modelled by of the same elements dimension than the plate) :

Poisson's ratio: 0.2
Young modulus: $10^{16}\ N.m^{-2}$

The coefficient of kinetic friction under the rigid plane is $\mu=1$.

1.3 Boundary conditions and loadings

the frame, when it is of dimension $N-1$ compared to the dimension of the plate, is blocked:

- by a complete fixed support.

The frame, when it is of the same dimension than the plate, is blocked:

- in the plane $x=40\ mm$ for displacements according to x (symmetry of the problem);
- by a fixed support of its lower face.

The plate is blocked:

- in the plane $x=40\ mm$ for displacements according to x (symmetry of the problem);
- according to Y with the node located at the intersection of, the face symmetry plane of contact and plane $Z=0$ to prevent rigid body motions.

In 3D, to bring back itself to a problem 2D:

- following displacement Z is blocked for all the nodes.

The plate is subjected to two distributed pressures:

- a vertical acting on the face of the top: $f=-5*10^{7}N.mm^{-2}$;
- horizontal acting on the face initially in $x=0$ $F=15*10^{7}N.mm^{-2}$.

2 Reference solution

2.1 Method of calculating

the reference solution comes of results obtained by an average on other computer codes [bib1].

2.2 Quantities and results of reference

tangential Displacements (according to x) to the points $A\,B\,C\,D\,E$ of contact surface (external reference).

Statute of contact, clearance and reaction of contact at the point R for certain modelizations (NON-regression).

Contact pressures at the points $A\,B\,C\,D\,E$ contact surface for the modelizations with wear (NON-regression).

2.3 Uncertainties on the Important

solution (average of codes).

2.4 Bibliographical reference

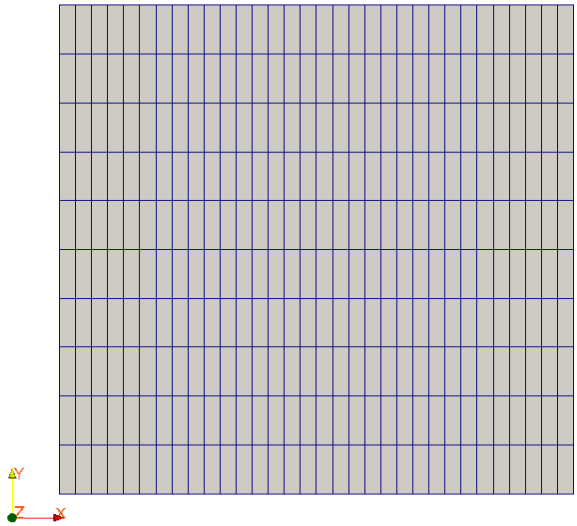
[1] R.A. FEIJOO H.J.C. BARBOSA and N. ZOUAIN “Numerical formulations for contact problems with friction” Newspaper of Theorical and Applied Mechanics GAUTHIER-VILLARS. Modelization

3 A Characteristic

3.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

3.2 of the mesh Many



nodes: 396 Number of meshes
and types: 320 QUAD4 for the plate and 32 SEG2 for the frame. Quantities

3.3 tested and results the First

computation (“LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	to urgent
DX point A “NON_REGRESSION -2.0	” 1,138	E-5 1,0E	- 9% at urgent
JEU point R “NON_REGRESSION 1.0	” 0.1,0	E	- 12 formula
$CONT$ formulates R formulates 1.0	” 1.1,0	E	- 5% formula
RN formulate R formulates 1.0	” 1,049	E+5 1,0E	- 5% at urgent
DX point A “SOURCE_EXTERNE 1.0	” 2,86	E-5 5,0%	formulates
DX point B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX point C formulates 1.0	” 2,28	E-5 5,0%	formulates

DX point D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Second

computation ("LAGRANGIAN" algorithm, solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (master-slave norm, controlled geometrical reactualization, algorithm "PENALIZATION ", solver "MULT_FRONT ") Identification

Standard	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

computation (master-slave norm, controlled geometrical reactualization, algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formula
DX formulate B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	One also

test projection by considering the penultimate slave node on the right. Standard

identification	of reference Value of reference	Tolerance	PROJ
_X of VALE_CONT time formulates 1.0	" 3,88	E-002 1,0E	- 6% PROJ
_Y of VALE_CONT time formulate 1.0	" 0,00	E+000 1,0E	- 6% Remarks

3.4

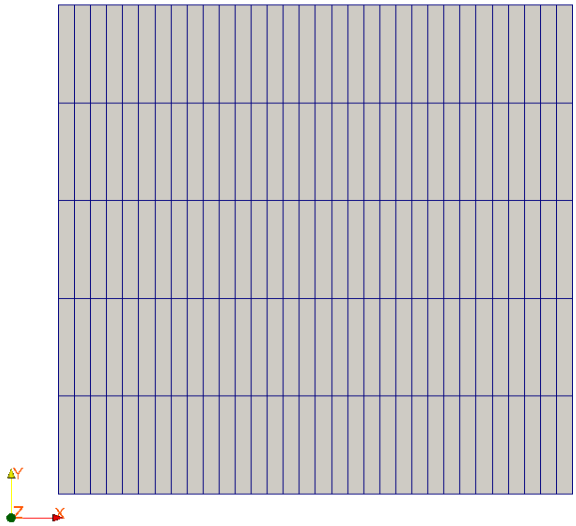
the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results.
The results got in penalization (coefficient of penalization about) are $a*E$ close to the results with dualisation of contact-friction. Modelization

4 B Characteristic

4.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

4.2 of the mesh Many



nodes: 558 Number of meshes
and types: 160 QUADS 8 for the plate and 1 SEG3 for the frame. Quantities

4.3 tested and results the First

computation (controlled geometrical reactualization, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (controlled geometrical reactualization, "LAGRANGIAN" algorithm, solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (not of geometrical reactualization, algorithm "PENALIZATION ", solver "MULT_FRONT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulate
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

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Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formula E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

4.4

the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results.

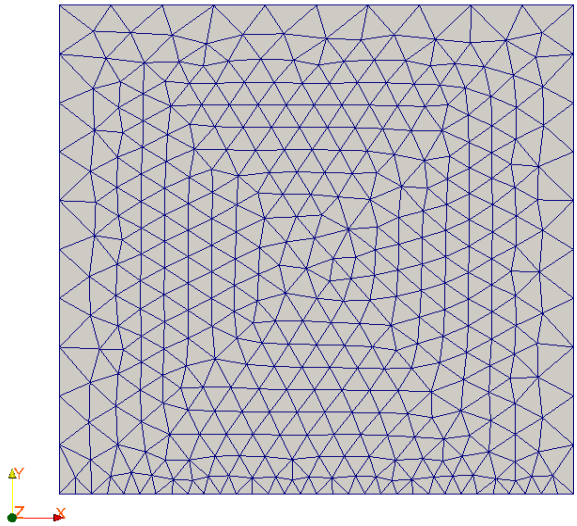
The results got in penalization (coefficient of penalization of friction about formula $a*E$ close to the results with dualisation of contact-friction. The computation
without geometrical reactualization the assumption of small slidings validates here. Modelization

5 C Characteristic

5.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

5.2 of the mesh Many



nodes: 431 Number of meshes
and types: 732 SORTED 3 for the plate and 32 SEG2 for the frame. Quantities

5.3 tested and results the First

computation (not of geometrical reactualization, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (not of geometrical reactualization, “LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value	of reference Tolerance	at
DX urgent A “ 1.0	2,86 E-5	5,0% formulates	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Third

computation (algorithm “PENALIZATION ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulate C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Fourth

computation (algorithm “PENALIZATION ”, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

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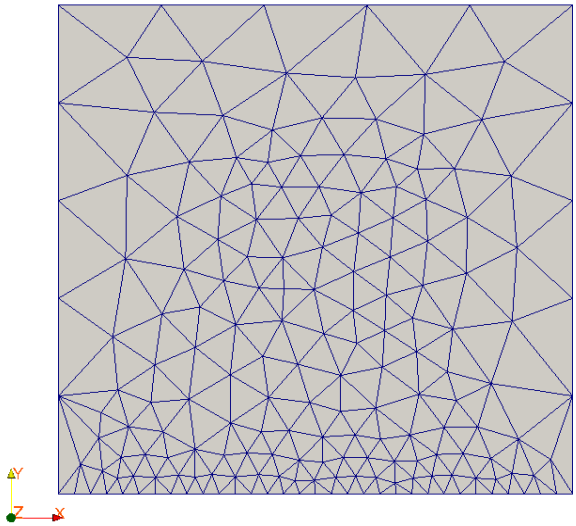
the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results.
The results got in penalization (coefficient of penalization of friction about formula $a*E$ close to the results with dualisation of contact-friction. The computation
without geometrical reactualization the assumption of small slidings validates here. Modelization

6 D Characteristic

6.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

6.2 of the mesh Many



nodes: 763 Number of meshes
and types: 325 SORTED 6 for the plate and 32 SEG3 for the frame. Quantities

6.3 tested and results the First

computation (controlled geometrical reactualization, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (controlled geometrical reactualization, “LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Third

computation (nodal pairing, normal slave, algorithm “PENALIZATION ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formula
DX formulate C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Fourth

computation (nodal pairing, normal slave, algorithm “PENALIZATION ”, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulate
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

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the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results.

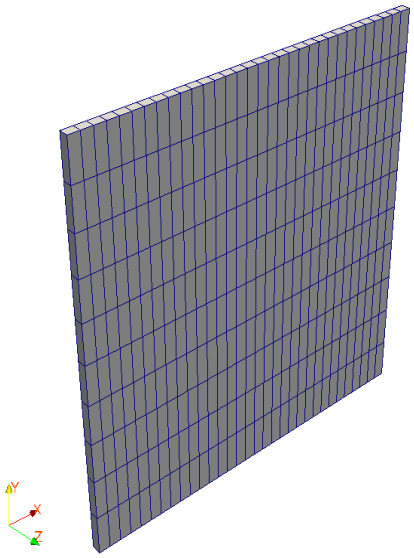
The results got in penalization (coefficient of penalization of friction about formula $a*E$ close to the results with dualisation of contact-friction. Modelization

7 E Characteristic

7.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

7.2 of the mesh Many



nodes: 792 Number of meshes
and types: 320 HEXA 8 for the plate and 32 QUAD4 for the frame. Quantities

7.3 tested and results the First

computation (controlled geometrical reactualization, nodal pairing, normal slave, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	″ 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	″ 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	″ 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	″ 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	″ 1,5E	- 5 5,0%	the Second

computation (controlled reactualization geometrical, nodal pairing, normal slave, “LAGRANGIAN” algorithm, solver “LDLT ”) Identification

Standard	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (controlled geometrical reactualization, nodal pairing, algorithm "PENALIZATION ", solver "MULT_FRONT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formula
DX formulate B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

computation (controlled geometrical reactualization, nodal pairing, algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formula
DX formulate D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

7.4

the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results.
The results got in penalization (coefficient of penalization of friction about formula $a*E$ close to the results with dualisation of contact-friction. The problem

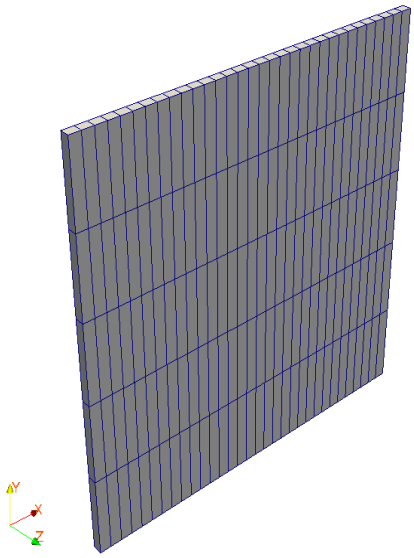
3D gives many results identical to 2D following the blocking of the degrees of freedom according to. Modelization DZ

8 F Characteristic

8.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

8.2 of the mesh Many



nodes: 1316 Number of meshes
and types: 160 HEXA20 for the plate and 1 QUAD 8 for the frame. Quantities

8.3 tested and results the First

computation (controlled geometrical reactualization, normal slave, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (controlled geometrical reactualization, normal slave, “LAGRANGIAN” algorithm, solver “LDLT ”) Identification

Type	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (algorithm "PENALIZATION ", solver "MULT_FRONT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formula
DX formulate C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

computation (algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

8.4

the results got in this modelization 3D quadratic are different from those obtained in the preceding modelizations while remaining in the tolerance of 5%. This difference is explained by meshes contact surfaces of the type QUAD 8 which are not adapted (what explains emitted alarm). The linear solver does not affect the results.

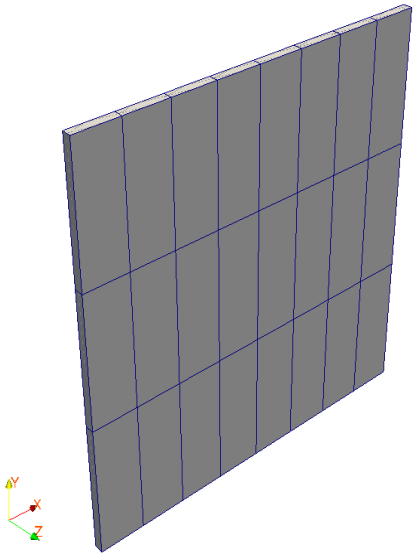
The results got in penalization are very close to the results with dualisation of contact-friction. The difference with the preceding modelizations is a higher coefficient of penalization (coefficient of penalization of large friction in front of formula $a*E$ The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

9 G Characteristic

9.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

9.2 of the mesh Many



nodes: 408 Number of meshes
and types: 24 HEXA 27 for the plate and 8 QUADS 9 for the frame. Quantities

9.3 tested and results the First

computation (“LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	the Second

computation (“LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	the Third

computation (controlled reactualization geometrical, nodal pairing, normal slave, algorithm "PENALIZATION ", solver "MULT _FRONT") Identification

Standard	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	the Fourth

computation (controlled geometrical reactualization, nodal pairing, normal slave, algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	Remarks

9.4

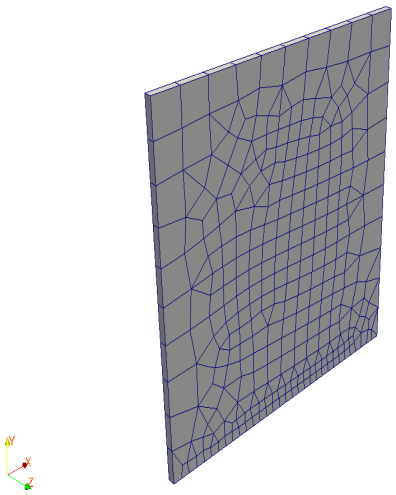
the results got in this modelization 3D quadratic are closer to the reference than the preceding modelization in consequence of the use of meshes QUAD 9 on the edge of contact.
The results got in penalization are very close to the results with dualisation of contact-friction. The difference with the preceding modelizations is a higher coefficient of penalization (coefficient of penalization of large friction in front of formula $a*E$ The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

10 H Characteristic

10.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

10.2 of the mesh Many



nodes: 670 Number of meshes
and types: 279 HEXA 8 and 44 PENTA 6 for the plate and 1 QUAD4 for the frame. Quantities

10.3 tested and results the First

computation (controlled geometrical reactualization, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (controlled geometrical reactualization, “LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (algorithm "PENALIZATION ", solver "MULT_FRONT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulate 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

computation (algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	-5 5,0%	Remarks

10.4

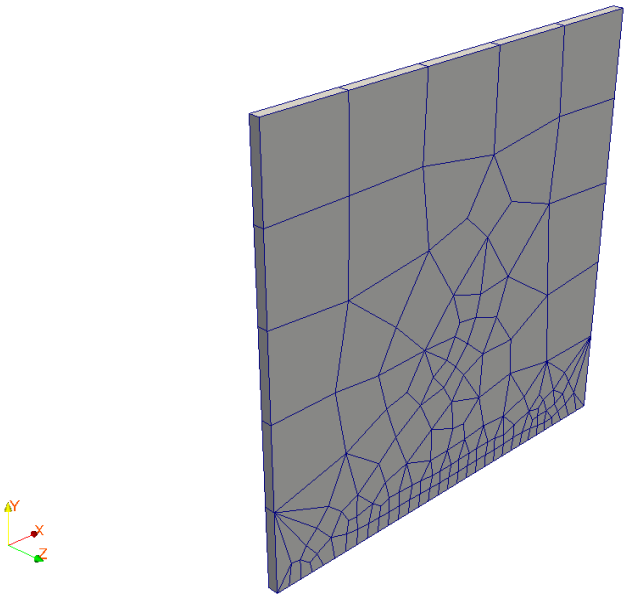
the results got in this modelization 3D with a mixed mesh not structured are close to the reference.
The results got in penalization are very close to the results with dualisation of contact-friction. The difference with the preceding modelizations is a higher coefficient of penalization (coefficient of penalization of large friction in front of formula $a*E$ The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

11 I Characteristic

11.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

11.2 of the mesh Many



nodes: 1297 Number of meshes
and types: 121 HEXA20 and 37 PENTA 15 for the plate and 32 QUADS 8 for the frame. Quantities

11.3 tested and results the First

computation (nodal pairing, normal slave, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (nodal pairing, normal slave, "LAGRANGIAN" algorithm, solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (controlled geometrical reactualization, algorithm "PENALIZATION ", solver "MULT_FRONT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

computation (controlled geometrical reactualization, algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulate
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

11.4

the results got in this modelization 3D quadratic are different from those obtained in the preceding modelizations while remaining in the tolerance of 5%. This difference is explained by meshes contact

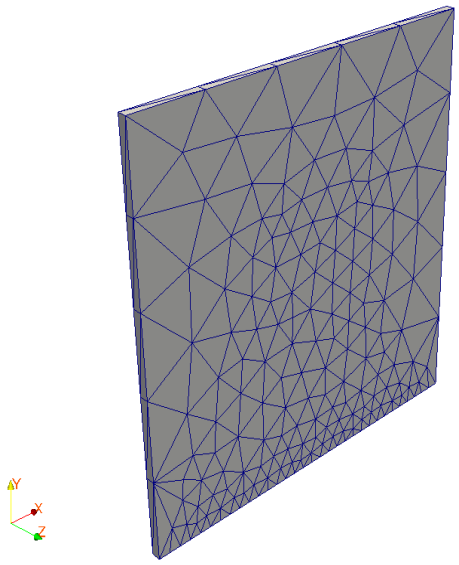
surfaces of the type QUAD 8 which are not adapted (what explains emitted alarm). The linear solver does not affect the results.
The results got in penalization are very close to the results with dualisation of contact-friction. The difference with the preceding modelizations is a higher coefficient of penalization (coefficient of penalization of large friction in front of formula $a*E$ The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

12 J Characteristic

12.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

12.2 of the mesh Many



nodes: 441 Number of meshes
and types: 980 TETRA 4 and 64 SORTED 3 for the frame. Quantities

12.3 tested and results the First

computation (controlled geometrical reactualization, nodal pairing, normal slave, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (controlled reactualization geometrical, nodal pairing, normal slave, “LAGRANGIAN” algorithm, solver “LDLT ”) Identification

Standard	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Third

computation (algorithm "PENALIZATION ", solver "MULT_FRONT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulate
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Fourth

computation (algorithm "PENALIZATION ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulate
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

12.4

the results got in this modelization 3D with a mesh not structured are less good than for the preceding modelizations but remain close to the reference. That can be explained by the mesh of the thickness which does not respect the symmetry of the problem (tetrahedrons).
The results got in penalization are very close to the results with dualisation of contact-friction. The difference with the preceding modelizations is a higher coefficient of penalization (coefficient of penalization of large friction in front of formula $a*E$ The problem

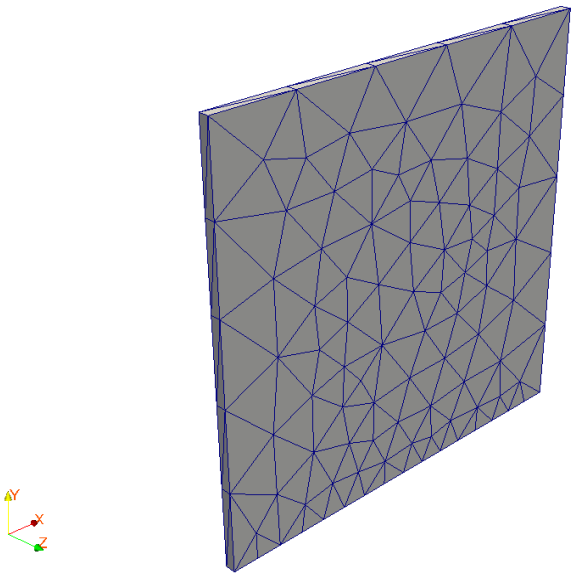
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

13 K Characteristic

13.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Four computations are carried out with options of pairing, contact algorithms and linear solvers different. Characteristics

13.2 of the mesh Many



nodes: 1236 Number of meshes
and types: 526 TETRA 10 for the plate and 32 SORTED 6 for the frame. Quantities

13.3 tested and results the First

computation (“LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	the Second

computation (“LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	the Third

computation (controlled geometrical reactualization, nodal pairing, algorithm “PENALIZATION ”, solver “MULT_FRONT ”) Standard

identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	the Fourth

computation (controlled geometrical reactualization, nodal pairing, algorithm “PENALIZATION ”, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	Remarks

13.4

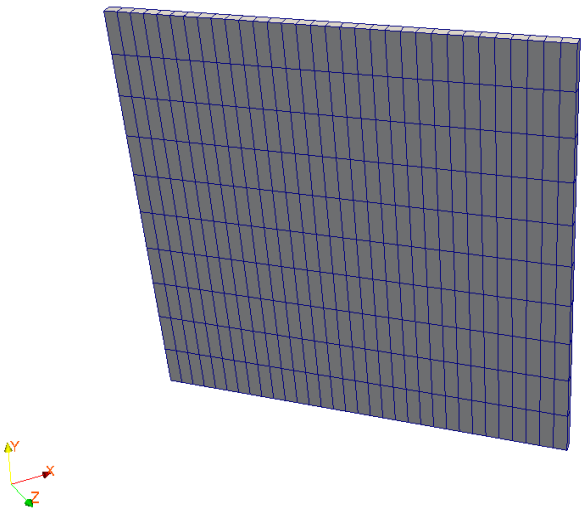
the results got in this modelization 3D quadratic not structured are close to the reference.
The results got in penalization are very close to the results with dualisation of contact-friction. The difference with the preceding modelizations is a higher coefficient of penalization (coefficient of penalization of large friction in front of formula $a*E$ The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

14 L Characteristic

14.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Two computations are carried out with different linear solvers. This modelization derives from the modelization E, the only difference lies in mesh: it is turned of 45° around. Characteristics Oy

14.2 of the mesh Many



nodes: 792 Number of meshes
and types: 320 HEXA 8 for the plate and 32 QUAD4 for the frame. Quantities

14.3 tested and results the First

computation (“LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	the Second

computation (“LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulate
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

14.4

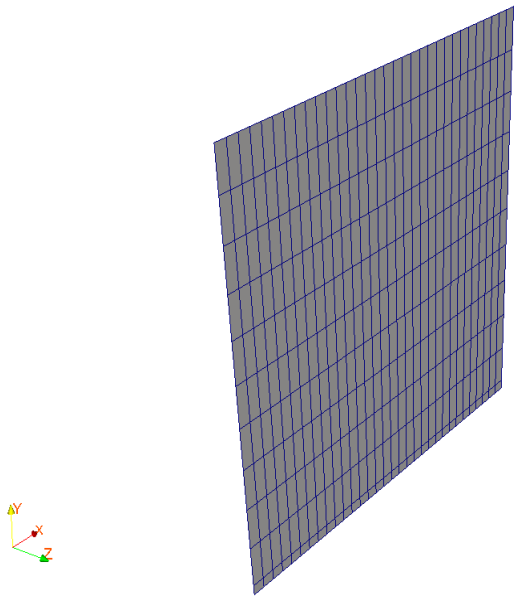
the got results are identical to those of the modelization E and close to the external source with 5% close (average of codes). The linear solver does not affect the results. The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ this test validates independence with the mesh (after rotation). Modelization

15 M Characteristic

15.1 of the modelization The modelization

is D_PLAN , the frame is represented by a quasi-rigid solid of material. Two computations are carried out with different linear solvers. Characteristics

15.2 of the mesh Many



nodes: 429 Number of meshes
and types: 320 QUAD4 for the plate and 32 QUAD4 for the frame. Quantities

15.3 tested and results the First

computation (controlled geometrical reactualization, formulation “CONTINUE ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
JEU formulates R formulates 1.0	” 0.1,0	E	- 12 formula
$CONT$ formulates R formulates 1.0	” 1.1,0	E	- 5% formula
RN formulates R formulates 1.0	” 1,049	E+5 1,0E	- 5% formula
DX formulate A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates

DX formulates D formulates 1.0	_EXTERNE" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	the Second

computation (controlled geometrical reactualization, formulation "CONTINUE ", solver "LDLT ") Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

15.4

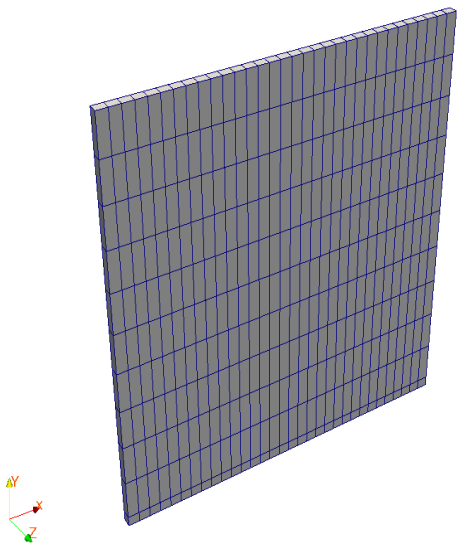
the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. The formulation
continues gives results identical to the discrete formulation. The modelization
frame by a very stiff material in front of the material of the plate gives results equivalent to the case of the rigid frame whose only edge is represented. The problem
3D gives many results identical to 2D following the blocking of the degrees of freedom according to formula DZ

16 N Characteristic

16.1 of the modelization The modelization

is 3D, the frame is represented by a quasi-rigid solid of material. Characteristics

16.2 of the mesh Many



nodes: 858 Number of meshes
and types: 320 HEXA 8 for the plate and 32 HEXA 8 for the frame. Quantities

16.3 tested and results the First

computation (controlled geometrical reactualization, formulation “CONTINUE ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

16.4

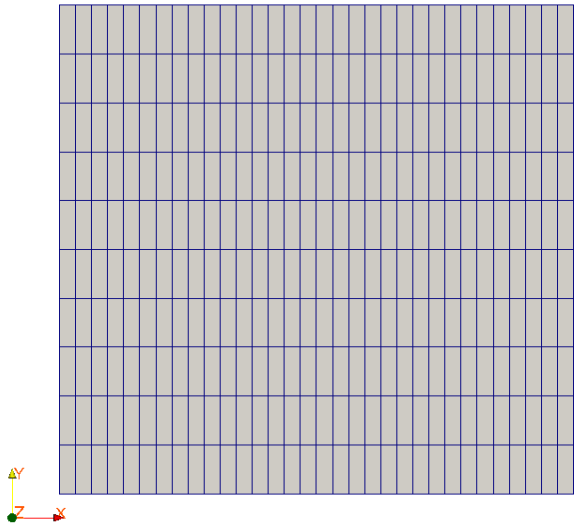
the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. The formulation
continues gives results identical to the discrete formulation. The modelization
frame by a very stiff material in front of the material of the plate gives results equivalent to the case of the rigid frame whose only edge is represented. Modelization

17 O Characteristic

17.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Two computations are carried out with different linear solvers. Characteristics

17.2 of the mesh Many



nodes: 396 Number of meshes
and types: 320 QUAD4 for the plate and 32 SEG2 for the frame. Quantities

17.3 tested and results the First

computation (initial geometry, “LAGRANGIAN” algorithm, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	to urgent
DX point A “SOURCE_EXTERNE 1.0	” 2,86	E-5 5,0%	to urgent
DX point B “SOURCE_EXTERNE 1.0	” 2,72	E-5 5,0%	to urgent
DX point C “SOURCE_EXTERNE 1.0	” 2,28	E-5 5,0%	to urgent
DX point D “SOURCE_EXTERNE 1.0	” 1,98	E-5 5,0%	to urgent
DX point E “SOURCE_EXTERNE 1.0	” 1,5E	- 5 5,0%	the Second

computation (initial geometry, “LAGRANGIAN” algorithm, solver “LDLT ”) Standard

Identification	of reference Value of reference	Tolerance	formulate
DX formulates A formulates 1.0	" 2,86	E-5 5,0%	formulates
DX formulate B formulates 1.0	" 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	" 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	" 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	" 1,5E	- 5 5,0%	Remarks

17.4

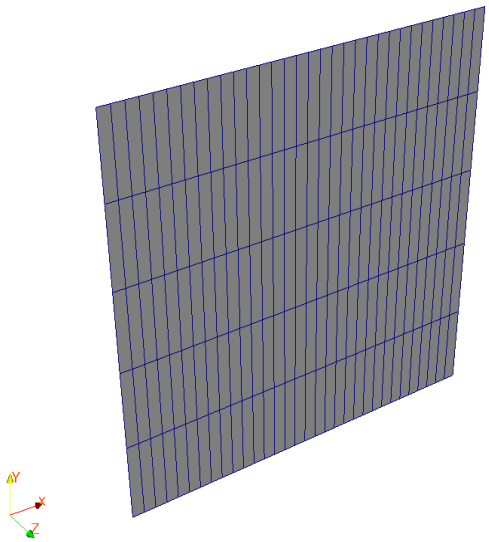
the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. This
modelization solved in initial geometry validates also the assumption of small slidings of this test. Modelization

18 P Characteristic

18.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Characteristics

18.2 of the mesh Many



nodes: 620 Number of meshes
and types: 160 QUADS 8 for the plate and 32 SEG3 for the frame. Quantities

18.3 tested and results the First

computation (formulation “CONTINUE ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	One also

test projection by considering the last slave node on the right. Standard

identification	of reference Value of reference	Tolerance	PROJ

_X of VALE_CONT time formulates 1.0	" 4,00	E-002 1,0E	- 6% PROJ
_Y of VALE_CONT time formulate 1.0	" 0,00	E+000 1,0E	- 6% Remarks

18.4

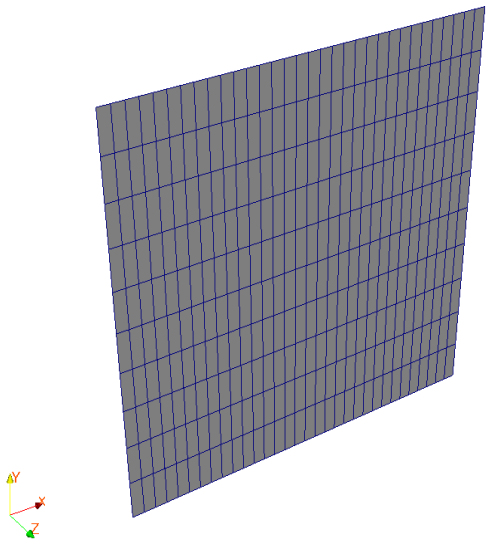
the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. The formulation
continues gives results identical to the discrete formulation. Modelization

19 Q Characteristic

19.1 of the modelization The modelization

is D_PLAN , only the edge of the frame is represented. Characteristics

19.2 of the mesh Many



nodes: 396 Number of meshes
and types: 320 QUAD4 for the plate and 32 SEG2 for the frame. Quantities

19.3 tested and results the First

computation (formulation “CONTINUE ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

19.4

the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. This

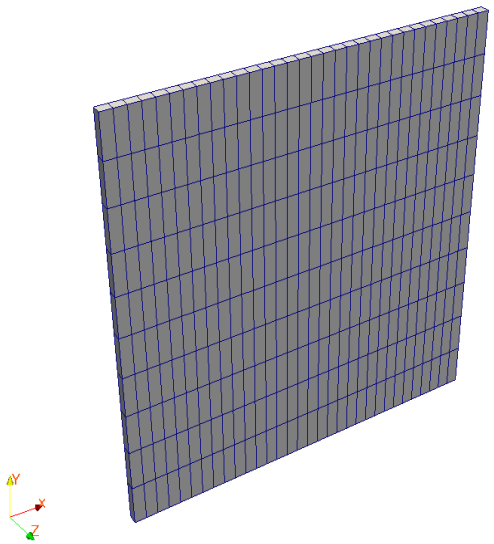
modelization validates the exclusion of nodes only of the resolution of friction in continuous formulation. Modelization

20 R Characteristic

20.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Characteristics

20.2 of the mesh Many



nodes: 792 Number of meshes
and types: 320 HEXA 8 for the plate and 32 QUAD4 for the frame. Quantities

20.3 tested and results the First

computation (formulation “CONTINUE ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

20.4

the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. This

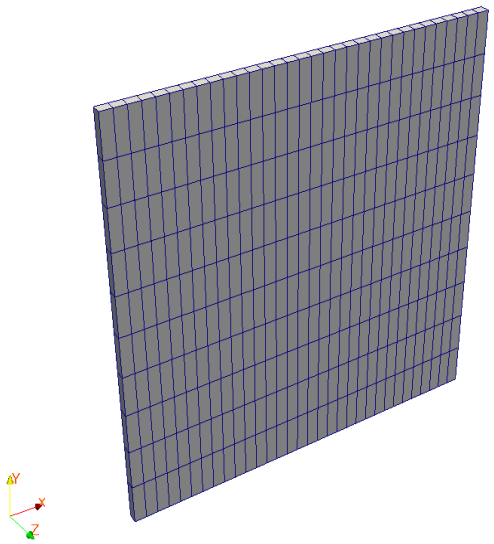
modelization validates in 3D the exclusion of nodes only of the resolution of friction in continuous formulation. Modelization

21 W Characteristic

21.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Characteristics

21.2 of the mesh Many



nodes: 792 Number of meshes
and types: 320 HEXA 8 for the plate and 32 QUAD4 for the frame. Quantities

21.3 tested and results the First

computation (formulation “CONTINUE ”, algorithm “PENALIZATION”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

21.4

the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. This

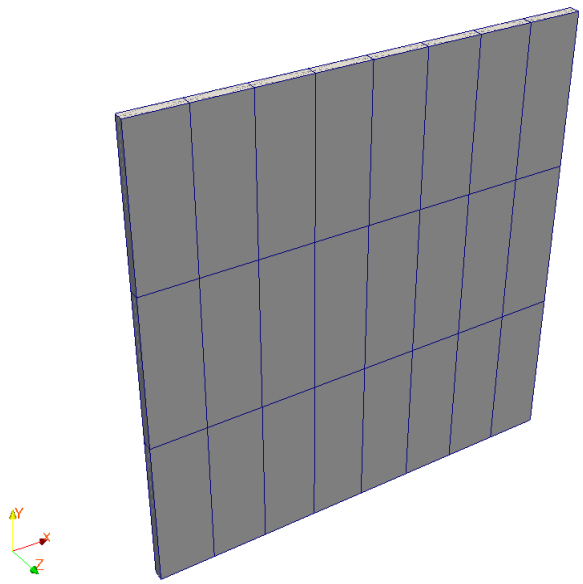
modelization validates the formulation penalized of the contact continuous. The coefficients of penalization are selected so as to find same the results as in classical formulation. Modelization

22 X Characteristic

22.1 of the modelization The modelization

is 3D, only the edge of the frame is represented. Characteristics

22.2 of the mesh Many



nodes: 408 Number of meshes
and types: 24 HEXA 27 for the plate and 8 QUADS 9 for the frame. Quantities

22.3 tested and results the First

computation (formulation “CONTINUE ”, solver “MULT_FRONT ”) Standard

Identification	of reference Value of reference	Tolerance	formulates
DX formulates A formulates 1.0	” 2,86	E-5 5,0%	formulates
DX formulates B formulates 1.0	” 2,72	E-5 5,0%	formulates
DX formulates C formulates 1.0	” 2,28	E-5 5,0%	formulates
DX formulates D formulates 1.0	” 1,98	E-5 5,0%	formulates
DX formulates E formulates 1.0	” 1,5E	- 5 5,0%	Remarks

22.4

the got results are close to the external source with 5% close (average of codes). The linear solver does not affect the results. Summary

23 of the results

the results got on all the modelizations of this case test are satisfactory, as well in 2D as in 3D. On the points, A and B C , one D obtains an error relative lower than 1% compared to the results of the GRECO. On the other hand, for the point, E the relative error, about 2,5%, remains acceptable. From

a time point of view computing, one notes that the method by penalization is in general faster than the Lagrangian method. One notes, on the other hand, an ease of use of the Lagrangian method (cf Doc. [U2.04.04]) compared to the penalized method, since the convergence and the quality of the results got by this last method are conditioned by the coefficient of penalization. From

a qualitative point of view: in 2D

- , one notes a positive effect on the results of the quadratic mesh compared to the linear mesh (cf modelizations A and B), in 3D
- , one notes that computations with quadratic mesh does not improve the results. This is explained by the fact why one decreased by 50% the number of meshes compared to the linear mesh to have an equivalent number of nodes. In all the cases only the use of meshes TETRA10 or HEXA27 is recommended in discrete formulation, meshes the HEXA20 needing to be linearized (they thus lose their interest). As regards

the modelization L, inclined plate, one notes a good convergence and satisfactory results. Lastly,

for the continuous method (modelizations M, N, P, Q, R, V, W and X), one obtains in 3D results with relative errors slightly more important than those obtained by the methods Lagrangian and penalized. These errors come from blocking following the direction DZ which is not complete in continuous formulation in the modelizations which do not use functionality SANS `_GROUP_NO_FR of exclusion` of the nodes of friction.