

SSNP303 - Element in plane stress and tension - perfect Plasticity

Abstract:

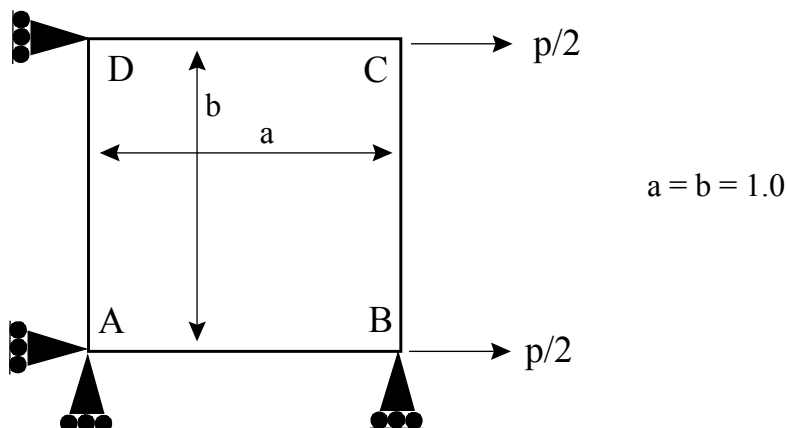
This test of nonlinear quasi-static mechanics 2D consists in charging three shell elements (standard of element MECPQU4). The 4 nodes are common to the 3 elements. The elements have different properties (perfect plasticity) to obtain a suitable curve of tension. This test is drawn from guide NAFEMS.

The goal is to compare the various methods of the Newton-Raphson type making it possible to solve the system of equations nonlinear (NEWTON: (MATRICE "elastic") and NEWTON: (MATRICE "TANGENTE") with REAC_INCR and REAC_ITER). The selected convergence criterion corresponds to 0.01% residual force (RESI_GLOB_RELA).

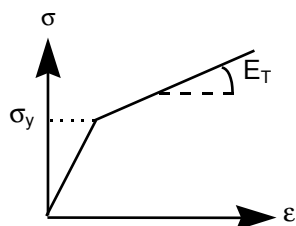
The modelization is carried out with plane elements of type MECPQU4.

1 Problem of reference

1.1 Geometry



1.2 Material properties



Matériau 1	Matériau 2	Matériau 3
$E = 100000 \text{ MPa}$	$E = 60000 \text{ MPa}$	$E = 40000 \text{ MPa}$
$\nu = 0.25$	$\nu = 0.25$	$\nu = 0.25$
$\sigma_y = 3 \text{ MPa}$	$\sigma_y = 6 \text{ MPa}$	$\sigma_y = 8 \text{ MPa}$
$E_T = 0.0$	$E_T = 0.0$	$E_T = 0.0$

1.3 Boundary conditions and loadings

Point: A $u_x = 0.$

$u_y = 0.$

Point: B $u_y = 0.$

Point: D $u_x = 0.$

Loading by a force $P/2$ on the point B and C . The force P is increased in 6 stages in the following way:

Force P	3.00	6.00	9.00	12.95	15.00	16.93
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2 Reference solution

2.1 Method of calculating used for the reference solution

the results considered as reference were obtained by the SAMCEF software by means of 60 increments for each stage of loading. The characteristics of the various methods of resolution are the following ones:

- A Use of the elastic matrix.
- B Use of the tangent matrix; this one is revalued only with the first iteration of each increment (REAC_INCR = 1 and REAC_ITER = 0). It is the method of Newton modified.
- C Use of the tangent matrix; this one is revalued with each iteration of each increment (REAC_INCR = 1 and REAC_ITER = 1). It is the method of Newton classical.

2.2 Results of reference

Results got with 60 increments for each stage of loading

Forces	Element 1		Element 2		Element 3	
	σ^{xx}	σ^{yy}	σ^{xx}	σ^{yy}	σ^{xx}	σ^{yy}
3.00	1.500000D+00	6.938894D-18	9.000000D-01	-1.040834D-17	6.000000D-01	-6.938894D-18
6.00	3.000000D+00	4.861944D-13	1.800000D+00	-2.081668D-17	1.200000D+00	-3.469447D-18
9.00	3.147155D+00	3.199571D-01	3.511707D+00	-1.900098D-01	2.341138D+00	-1.279828D-01
12.95	3.252919D+00	5.950074D-01	5.814267D+00	-3.523377D-01	3.878832D+00	-2.380030D-01
15.00	3.213822D+00	4.873069D-01	6.017834D+00	3.174572D-02	5.768340D+00	-5.231355D-01
16.93	3.209297D+00	4.753345D-01	6.149462D+00	3.048490D-01	7.571241D+00	-7.863557D-01

2.3 Uncertainty on the solution

Uncertainty lower than 1 % .

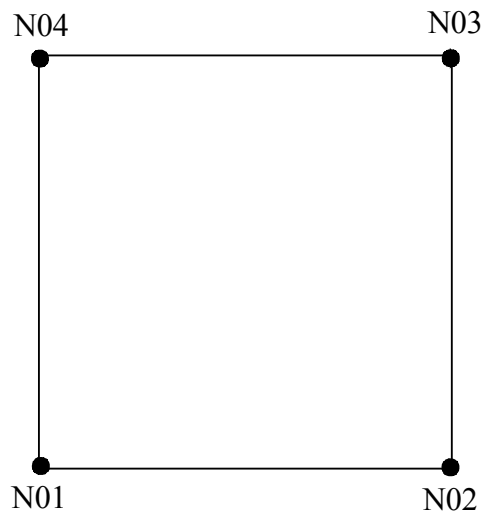
2.4 Bibliographical references

- 1) Fundamental tests for two and three dimensional, small strain, elastoplastic finite element analysis, 1987, NAFEMS

3 Modelization A

3.1 Characteristic of the modelization A

Use of elements QUAD4



Modelization in plane stresses: C_PLAN

the loading and the boundary conditions are modelled by:

- DDL_IMPO: (Node NO1 DX = 0, DY = 0)
(Node NO2 DY = 0)
(Node NO4 DX = 0)
- of the forces imposed on the nodes NO2 and NO3 .

3.2 Characteristics of the mesh

Many nodes: 4

Number of meshes and types: 3 MECQU4

3.3 Quantities tested and results

Identification	Time	Reference	Aster	% difference
<i>SIXX</i> (mesh 1)	1	1,500000E+00	1,500000E+00	0
<i>SIYY</i> (mesh 1)	1	6,938894E-18	1,291047E-14	0
<i>SIXX</i> (mesh 2)	1	9,000000E-01	9,000000E-01	0
<i>SIYY</i> (mesh 2)	1	- 1,040834E-17	- 1,509903E-14	0
<i>SIXX</i> (mesh 3)	1	6,000000E-01	6,000000E-01	0
<i>SIYY</i> (mesh 3)	1	- 6,938894E-18	- 2,107830E-14	0
<i>SIXX</i> (mesh 1)	2	3,000000E+00	3,000000E+00	0
<i>SIYY</i> (mesh 1)	2	4,861944E-13	1,359551E-13	0
<i>SIXX</i> (mesh 2)	2	1,800000E+00	1,800000E+00	0
<i>SIYY</i> (mesh 2)	2	- 2,081668E-17	- 1,093097E-13	0
<i>SIXX</i> (mesh 3)	2	1,200000E+00	1,200000E+00	0
<i>SIYY</i> (mesh 3)	2	- 3,469447E-18	- 1,007126E-13	0
<i>SIXX</i> (mesh 1)	3	3,147155E+00	3,145788E+00	- 0,043
<i>SIYY</i> (mesh 1)	3	3,199571E-01	3,167040E-01	- 1,017
<i>SIXX</i> (mesh 2)	3	3,511707E+00	3,512527E+00	0,023
<i>SIYY</i> (mesh 2)	3	- 1,900098E-01	- 1,900224E-01	0,007
<i>SIXX</i> (mesh 3)	3	2,341138E+00	2,341685E+00	0,023
<i>SIYY</i> (mesh 3)	3	- 1,279828E-01	- 1,266816E-01	- 1,017
<i>SIXX</i> (mesh 1)	4	3,252919E+00	3,250728E+00	- 0,067
<i>SIYY</i> (mesh 1)	4	5,950074E-01	5,887464E-01	- 1,052
<i>SIXX</i> (mesh 2)	4	5,814267E+00	5,816159E+00	0,033
<i>SIYY</i> (mesh 2)	4	- 3,523377E-01	- 3,521695E-01	- 0,048
<i>SIXX</i> (mesh 3)	4	3,878832E+00	3,882391E+00	0,092
<i>SIYY</i> (mesh 3)	4	- 2,380030E-01	- 2,364650E-01	- 0,646
<i>SIXX</i> (mesh 1)	5	3,213822E+00	3,214367E+00	0,017
<i>SIYY</i> (mesh 1)	5	4,873069E-01	4,887527E-01	0,297
<i>SIXX</i> (mesh 2)	5	6,017834E+00	6,015985E+00	- 0,031
<i>SIYY</i> (mesh 2)	5	3,174572E-02	3,209818E-02	1,11
<i>SIXX</i> (mesh 3)	5	5,768340E+00	5,769681E+00	0,023
<i>SIYY</i> (mesh 3)	5	- 5,231355E-01	- 5,207413E-01	- 0,458
<i>SIXX</i> (mesh 1)	6	3,209297E+00	3,210194E+00	0,028
<i>SIYY</i> (mesh 1)	6	4,753345E-01	4,777143E-01	0,501
<i>SIXX</i> (mesh 2)	6	6,149462E+00	6,146791E+00	- 0,043
<i>SIYY</i> (mesh 2)	6	3,048490E-01	3,052330E-01	0,126
<i>SIXX</i> (mesh 3)	6	7,571241E+00	7,572486E+00	0,016
<i>SIYY</i> (mesh 3)	6	- 7,863557E-01	- 7,826545E-01	- 0,471

3.4 Remarks

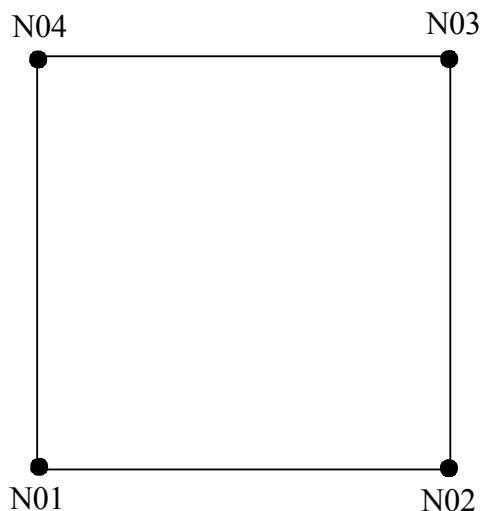
to obtain a correct accuracy, it is necessary to impose a significant number of increments for each stage of loading (60 increments).

The nombre of iterations is equal to 411.

4 Modelization B

4.1 Characteristic of the modelization B

Use of elements QUAD4



4.2 Characteristics of the mesh

Many nodes: 4

Number of meshes and types: 3 MECPQU4

Modelization in plane stresses: C_PLAN

the loading and the boundary conditions are modelled by:

- DDL_IMPO: (Node NO1 DX = 0, DY = 0)
(Node NO2 DY = 0)
(Node NO4 DX = 0)
- of the forces imposed on the nodes NO2 and NO3 .

4.3 Quantities tested and results

Identification	Time	Reference	Aster	% difference
<i>SIXX</i> (mesh 1)	1	1,500000E+00	1,500000E+00	0.000
<i>SIYY</i> (mesh 1)	1	6,938894E-18	1,351398E-14	0.000
<i>SIXX</i> (mesh 2)	1	9,000000E-01	9,000000E-01	0.000
<i>SIYY</i> (mesh 2)	1	- 1,040834E-17	- 2,142673E-14	0.000
<i>SIXX</i> (mesh 3)	1	6,000000E-01	6,000000E-01	0.000
<i>SIYY</i> (mesh 3)	1	- 6,938894E-18	- 2,924612E-14	0.000
<i>SIXX</i> (mesh 1)	2	3,000000E+00	3,000000E+00	0.000
<i>SIYY</i> (mesh 1)	2	4,861944E-13	9,617834E-14	0.000
<i>SIXX</i> (mesh 2)	2	1,800000E+00	1,800000E+00	0.000
<i>SIYY</i> (mesh 2)	2	- 2,081668E-17	- 8,301280E-14	0.000
<i>SIXX</i> (mesh 3)	2	1,200000E+00	1,200000E+00	0.000
<i>SIYY</i> (mesh 3)	2	- 3,469447E-18	- 9,360717E-14	0.000
<i>SIXX</i> (mesh 1)	3	3,147155E+00	3,145788E+00	- 0.043
<i>SIYY</i> (mesh 1)	3	3,199571E-01	3,167038E-01	- 1.017
<i>SIXX</i> (mesh 2)	3	3,511707E+00	3,512527E+00	0.023
<i>SIYY</i> (mesh 2)	3	- 1,900098E-01	- 1,900225E-01	0.007
<i>SIXX</i> (mesh 3)	3	2,341138E+00	2,341685E+00	0.023
<i>SIYY</i> (mesh 3)	3	- 1,279828E-01	- 1,266817E-01	- 1.017
<i>SIXX</i> (mesh 1)	4	3,252919E+00	3,250686E+00	- 0.069
<i>SIYY</i> (mesh 1)	4	5,950074E-01	5,886265E-01	- 1.072
<i>SIXX</i> (mesh 2)	4	5,814267E+00	5,816233E+00	0.034
<i>SIYY</i> (mesh 2)	4	- 3,523377E-01	- 3,520332E-01	- 0.086
<i>SIXX</i> (mesh 3)	4	3,878832E+00	3,883081E+00	0.110
<i>SIYY</i> (mesh 3)	4	- 2,380030E-01	- 2,365921E-01	- 0.593
<i>SIXX</i> (mesh 1)	5	3,213822E+00	3,214343E+00	0.016
<i>SIYY</i> (mesh 1)	5	4,873069E-01	4,886891E-01	0.284
<i>SIXX</i> (mesh 2)	5	6,017834E+00	6,015971E+00	- 0.031
<i>SIYY</i> (mesh 2)	5	3,174572E-02	3,207056E-02	1.023
<i>SIXX</i> (mesh 3)	5	5,768340E+00	5,769686E+00	0.023
<i>SIYY</i> (mesh 3)	5	- 5,231355E-01	- 5,207599E-01	- 0.454
<i>SIXX</i> (mesh 1)	6	3,209297E+00	3,210140E+00	0.026
<i>SIYY</i> (mesh 1)	6	4,753345E-01	4,775720E-01	0.471
<i>SIXX</i> (mesh 2)	6	6,149462E+00	6,146788E+00	- 0.043
<i>SIYY</i> (mesh 2)	6	3,048490E-01	3,052260E-01	0.124
<i>SIXX</i> (mesh 3)	6	7,571241E+00	7,573072E+00	0.024
<i>SIYY</i> (mesh 3)	6	- 7,863557E-01	- 7,827984E-01	- 0.452

4.4 Remarks

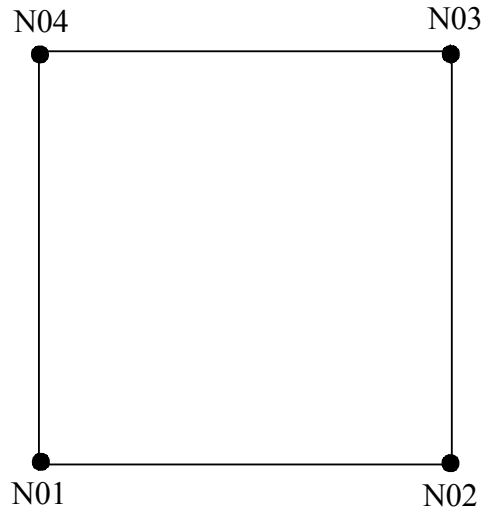
Idem modelization A concerning the number of increments on the accuracy of the results.

The nombre of iterations is equal to 361.

5 Modelization C

5.1 Characteristic of the modelization C

Use of elements QUAD4



5.2 Characteristics of the mesh

Many nodes: 4

Number of meshes and types: 3 MEC PQU4

Modelization in plane stresses: C_PLAN

the loading and the boundary conditions are modelled by:

- DDL_IMPO: (Node NO1 DX = 0, DY = 0)
(Node NO2 DX = 0, DY = 0)
(Node NO4 DX = 0)
- of the forces imposed on the nodes NO2 and NO3 .

5.3 Quantities tested and results

Identification	Time	Reference	Aster	% difference
<i>SIXX</i> (mesh 1)	1	1,500000E+00	1,500000E+00	0
<i>SIYY</i> (mesh 1)	1	6,938894E-18	1,351398E-14	0
<i>SIXX</i> (mesh 2)	1	9,000000E-01	9,000000E-01	0
<i>SIYY</i> (mesh 2)	1	- 1,040834E-17	- 2,142673E-14	0
<i>SIXX</i> (mesh 3)	1	6,000000E-01	6,000000E-01	0
<i>SIYY</i> (mesh 3)	1	- 6,938894E-18	- 2,924612E-14	0
<i>SIXX</i> (mesh 1)	2	3,000000E+00	3,000000E+00	0
<i>SIYY</i> (mesh 1)	2	4,861944E-13	9,617834E-14	0
<i>SIXX</i> (mesh 2)	2	1,800000E+00	1,800000E+00	0
<i>SIYY</i> (mesh 2)	2	- 2,081668E-17	- 8,301280E-14	0
<i>SIXX</i> (mesh 3)	2	1,200000E+00	1,200000E+00	0
<i>SIYY</i> (mesh 3)	2	- 3,469447E-18	- 9,360717E-14	0
<i>SIXX</i> (mesh 1)	3	3,147155E+00	3,145788E+00	- 0,043
<i>SIYY</i> (mesh 1)	3	3,199571E-01	3,167040E-01	- 1,017
<i>SIXX</i> (mesh 2)	3	3,511707E+00	3,512527E+00	0,023
<i>SIYY</i> (mesh 2)	3	- 1,900098E-01	- 1,900224E-01	0,007
<i>SIXX</i> (mesh 3)	3	2,341138E+00	2,341685E+00	0,023
<i>SIYY</i> (mesh 3)	3	- 1,279828E-01	- 1,266816E-01	- 1,017
<i>SIXX</i> (mesh 1)	4	3,252919E+00	3,250686E+00	- 0,069
<i>SIYY</i> (mesh 1)	4	5,950074E-01	5,886268E-01	- 1,072
<i>SIXX</i> (mesh 2)	4	5,814267E+00	5,816233E+00	0,034
<i>SIYY</i> (mesh 2)	4	- 3,523377E-01	- 3,520328E-01	- 0,087
<i>SIXX</i> (mesh 3)	4	3,878832E+00	3,883081E+00	0,11
<i>SIYY</i> (mesh 3)	4	- 2,380030E-01	- 2,365919E-01	- 0,593
<i>SIXX</i> (mesh 1)	5	3,213822E+00	3,214343E+00	0,016
<i>SIYY</i> (mesh 1)	5	4,873069E-01	4,886892E-01	0,284
<i>SIXX</i> (mesh 2)	5	6,017834E+00	6,015971E+00	- 0,031
<i>SIYY</i> (mesh 2)	5	3,174572E-02	3,207066E-02	1,024
<i>SIXX</i> (mesh 3)	5	5,768340E+00	5,769686E+00	0,023
<i>SIYY</i> (mesh 3)	5	- 5,231355E-01	- 5,207598E-01	- 0,454
<i>SIXX</i> (mesh 1)	6	3,209297E+00	3,210140E+00	0,026
<i>SIYY</i> (mesh 1)	6	4,753345E-01	4,775721E-01	0,471
<i>SIXX</i> (mesh 2)	6	6,149462E+00	6,146788E+00	- 0,043
<i>SIYY</i> (mesh 2)	6	3,048490E-01	3,052262E-01	0,124
<i>SIXX</i> (mesh 3)	6	7,571241E+00	7,573072E+00	0,024
<i>SIYY</i> (mesh 3)	6	- 7,863557E-01	- 7,827982E-01	- 0,452

5.4 Remarks

Idem modelization A concerning the number of increments on the accuracy of the results.

The nombre of iterations is equal to 360.

6 Summary of the results

a significant number of increments is necessary to obtain a correct accuracy: for information, ten increments per stage of loading are not sufficient.