SSNP14 - Plate in tension-shears - Von Mises (kinematic hardening)

Summarized:

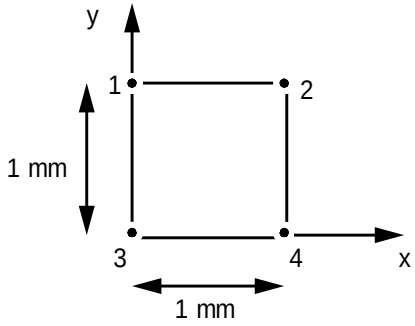
This test 2D plane stresses quasi-static, from guide VPCS, enters the frame of the elastoplastic validation of the behavior models. A volume element, made up of a plastic material with linear kinematic hardening, is subjected at the same time to a shears and tractive effort.

The principal interest of this test lies in the nonradial character of the loading.

1 Problem of reference

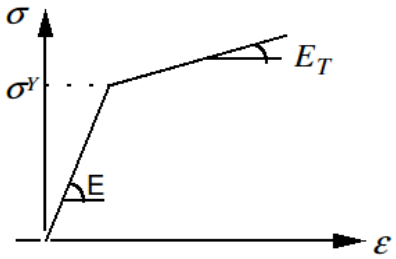
1.1 Geometry

the stresses and strains are homogeneous in the volume element. This one can be represented by a plane or voluminal element, for example:



1.2 Material properties

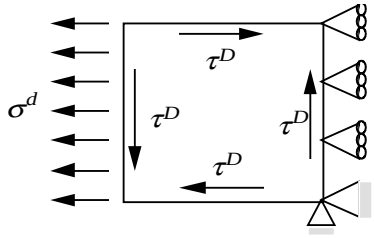
Elastoplastic constitutive law with linear kinematic hardening.



$E = 195000\ MPa$
$\nu = 0.3$
$\sigma^Y = 181\ MPa$
$E_T = 1930\ MPa$

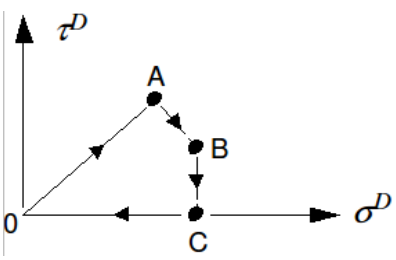
1.3 Boundary conditions and loadings

the volume element is blocked according to Ox along the side $[2,4]$ while being subjected to a tension σ^D and a shearing force τ^D.



The way of loading is the following:

	σ^D	τ^D
	(MPa)	(MPa)
A	151.2	93.1
B	257.3	33.1
C	259.3	0



2 Reference solution

2.1 Method of calculating used for the reference solution

the stress is fixed by the way of loading (control in stress), that is to say:

$$\sigma=\begin{bmatrix}\sigma^D & \tau^D & 0\\ \tau^D & 0 & 0\\ 0 & 0 & 0\end{bmatrix}$$

One from of deduced the elastic share from the strain:

$$\varepsilon^e=\frac{1}{E}\begin{bmatrix}\sigma^D & (1+\nu)\tau^D & 0\\ (1+\nu)\tau^D & -\nu\sigma^D & 0\\ 0 & 0 & -\nu\sigma^D\end{bmatrix}$$

If it is supposed now that one knows the total deflection ε , then one can deduce the plastic strain from it: $\varepsilon^p=\varepsilon-\varepsilon^e$

Note:

$\varepsilon^p_{xx}+\varepsilon^p_{yy}+\varepsilon^p_{zz}=0$ *and* $\varepsilon^p_{yy}=\varepsilon^p_{zz}$ *thus* $\varepsilon^p_{yy}=\varepsilon^p_{zz}=\frac{-\varepsilon^p_{xx}}{2}$

then the stress of recall:

$\chi=C\,\varepsilon^p$ with $\frac{2}{3C}=\frac{1}{E^T}-\frac{1}{E}$ C : constant of Prager

Moreover, to obtain a correct accuracy, it is necessary to use significant a enough number of increments for the way AB , in fact, at least 30 in this case. In the same way for the way BC .

2.2 Results of reference

the data of the total deflection ε is necessary for preceding computations. It is obtained like average of the results of several codes.

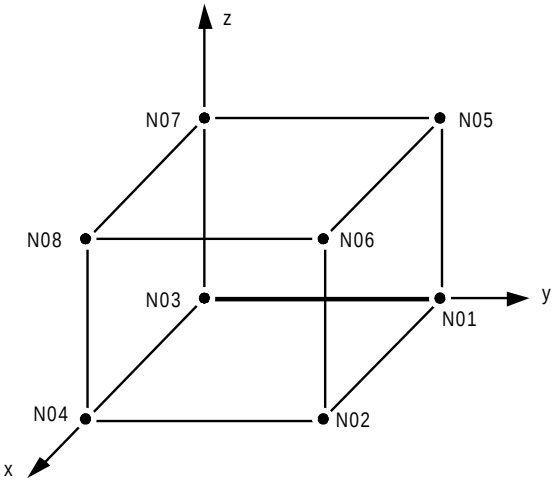
2.3 Bibliographical references

[1] Guides Validation of the Software packages of Structural analysis - SFM. Technical AFNOR

3 Modelization A

3.1 Characteristic of the modelization

The modelization used is 3D.



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)
- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,5,6,2)$ $(1,5,7,3)$, $(3,4,8,7)$ and $(4,8,6,2)$.

3.2 Characteristics of the mesh

Many nodes: 8
Number of meshes and types: 1 HEXA8 + 4 QUAD4 (sides)

3.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
ϵ_{xx}	A	NON_REGRESSION	1.48297 E-2
ϵ_{xy}	A	NON_REGRESSION	1.36014 E-2
X_{xx} =V1	A	NON_REGRESSION	18.26
X_{xy} =V4	A	NON_REGRESSION	1.68688 E+1
ϵ_{xx}	B	NON_REGRESSION	4.066 E-2
ϵ_{xy}	B	NON_REGRESSION	1.978 E-2
ϵ_{xx}	C	NON_REGRESSION	4.4103 E-2
ϵ_{xy}	C	NON_REGRESSION	1.8913 E-2

Indicators of discharge in a Gauss point (DERA_ELGA), and to node N_2 (DERA_ELNO).

Standard	identification of reference	Value of reference
DCHA_V to time 0.1	"NON_REGRESSION"	0.877871

RADI_V to time 1,5	"NON_REGRESSION"	0
ERR_RADI to time 1,5	"NON_REGRESSION"	0.0125766

Moreover, in one second series of computations, one tests the error indicator due to nonthe radiality of the loading: from a coarse temporal discretization (2 increments on the ways AB and BC, and an increment on the others), one activates the subdivision of time step if the error due to nonthe radiality exceeds 2% (RESI_RADI_RELA=0.02). This test is carried out for 3 equivalent behaviors: VMIS_CINE_LINE, VMIS_ECMI_LINE, VMIS_CIN2_CHAB.

The results are:

VMIS_CINE_LINE and VMIS_ECMI_LINE

Identification	Times	Type of Reference	Reference	Tolerance
ϵ_{xx}	A	AUTRE_ASTER	1.48297 E-2	0.10%
ϵ_{xy}	A	AUTRE_ASTER	1.36014 E-2	0.10%
X_{xx} =V1	A	AUTRE_ASTER	18.26	0.10%
X_{xy} =V4	A	AUTRE_ASTER	1.68688 E+1	0.10%
ϵ_{xx}	B	AUTRE_ASTER	4.066 E-2	0.10%
ϵ_{xy}	B	AUTRE_ASTER	1.978 E-2	0.10%
ϵ_{xx}	C	AUTRE_ASTER	4.4103 E-2	0.10%
ϵ_{xy}	C	AUTRE_ASTER	1.8913 E-2	0.10%

VMIS_CIN1_CHAB

Identification	Times	Type of Reference	Reference	Tolerance
ϵ_{xx}	A	AUTRE_ASTER	1.48297 E-2	1.00%
ϵ_{xy}	A	AUTRE_ASTER	1.36014 E-2	1.00%
X_{xx} =V1	A	AUTRE_ASTER	18.26	1.00%
X_{xy} =V4	A	AUTRE_ASTER	1.68688 E+1	1.00%
ϵ_{xx}	B	AUTRE_ASTER	4.066 E-2	1.00%
ϵ_{xy}	B	AUTRE_ASTER	1.978 E-2	1.00%
ϵ_{xx}	C	AUTRE_ASTER	4.4103 E-2	1.00%
ϵ_{xy}	C	AUTRE_ASTER	1.8913 E-2	1.00%

For the three behaviors, the error indicator in radiality provide the same one result:

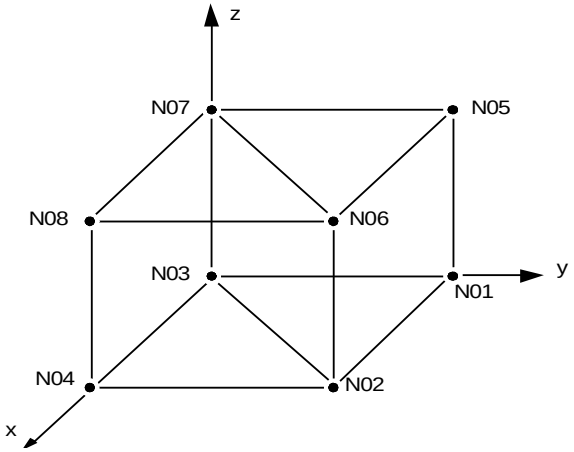
Standard	identification of reference	Value of reference
ERR_RADI to time 1,5	"NON_REGRESSION"	0.011798
ERR_RADI to time 2,5	"NON_REGRESSION"	the 0.01956

use of the criterion of radiality to refine automatically time step led to 56 time step to the total, against 64 in the first case (with 30 increments on AB and BC), for result of equivalent quality (error of approximately 1,2% to t=1.5, and 2% with t=2.5).

4 Modelization B

4.1 Characteristic of the modelization

The modelization used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N04, DX: 0. , DY: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)
- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,5,6,2)$ $(1,5,7,3)$, $(3,4,8,7)$ and $(4,8,6,2)$.

4.2 Characteristics of the mesh

Many nodes: 8
Number of meshes and types: 1 PENTA6 + 4 QUAD4 (sides)

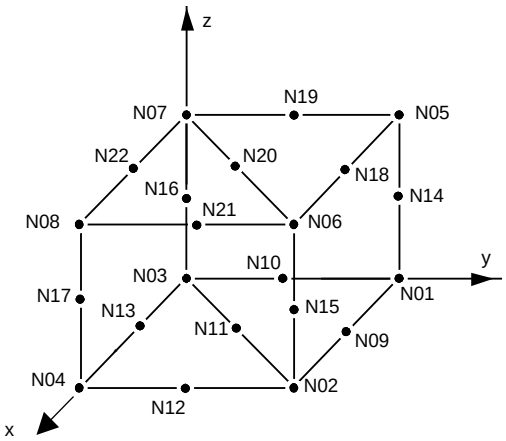
4.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
σ_{xx}	A	NON_REGRESSION	151.2
σ_{xy}	A	NON_REGRESSION	93.1
ϵ_{xx}	A	NON_REGRESSION	1.48297 E-2
ϵ_{xy}	A	NON_REGRESSION	1.36014 E-2
χ_{xx}	A	NON_REGRESSION	1.82640 E+1
χ_{xy}	A	NON_REGRESSION	1.68688 E+1
χ_{yy}	A	NON_REGRESSION	– 0.91320 E+1
ϵ_{xx}	B	NON_REGRESSION	4.0444 E-2
ϵ_{xy}	B	NON_REGRESSION	1.9917 E-2
ϵ_{xx}	C	NON_REGRESSION	4.4177 E-2
ϵ_{xy}	C	NON_REGRESSION	1.9205 E-2
ϵ_{xx}	O	NON_REGRESSION	4.2848 E-2
ϵ_{xy}	O	NON_REGRESSION	1.9203 E-2

5 Modelization C

5.1 Characteristic of the modelization

The modelization used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N04, DX: 0. , DY: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N15, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N21, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N17, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N12, DX: 0.)
- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,14,5,18,6,15,2,9)$ $(1,14,5,19,7,16,3,10)$, $(3,13,4,17,8,22,7,16)$ and $(4,17,8,21,6,15,2,12)$.

5.2 Characteristics of the mesh

Many nodes: 22
Number of meshes and types: 1 PENTA15 + 4 QUAD8 (sides)

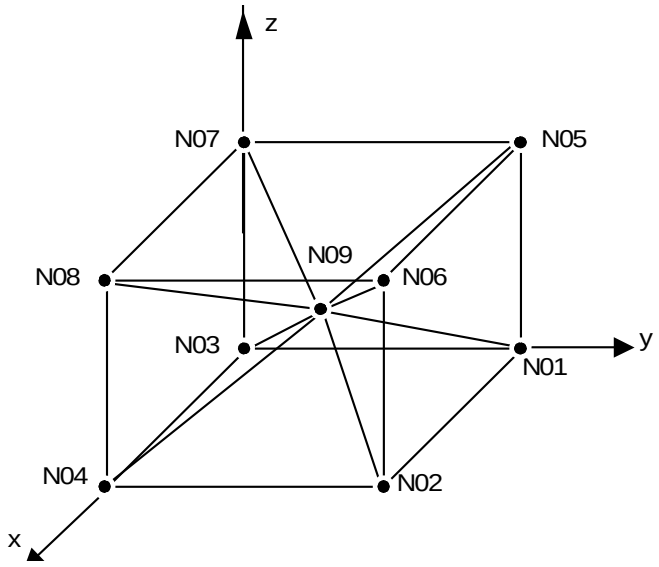
5.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
σ_{xx}	A	NON_REGRESSION	151.2
σ_{xy}	A	NON_REGRESSION	93.1
ε_{xx}	A	NON_REGRESSION	1.48297 E-2
ε_{xy}	A	NON_REGRESSION	1.36014 E-2
X_{xx}	A	NON_REGRESSION	1.82640 E+1
X_{xy}	A	NON_REGRESSION	1.68688 E+1
X_{yy}	A	NON_REGRESSION	– 0.91320 E+1
ε_{xx}	B	NON_REGRESSION	4.0444 E-2
ε_{xy}	B	NON_REGRESSION	1.9917 E-2
ε_{xx}	C	NON_REGRESSION	4.4177 E-2
ε_{xy}	C	NON_REGRESSION	1.9205 E-2
ε_{xx}	O	NON_REGRESSION	4.2848 E-2
ε_{xy}	O	NON_REGRESSION	1.9203 E-2

6 Modelization D

6.1 Characteristic of the modelization

The modelization used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N04, DX: 0. , DY: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)
- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,5,6,2)$ $(1,5,7,3)$, $(3,4,8,7)$ and $(4,8,6,2)$.

6.2 Characteristics of the mesh

Many nodes: 9
Number of meshes and types: 6 PYRAM5 and 4 QUAD4 (sides)

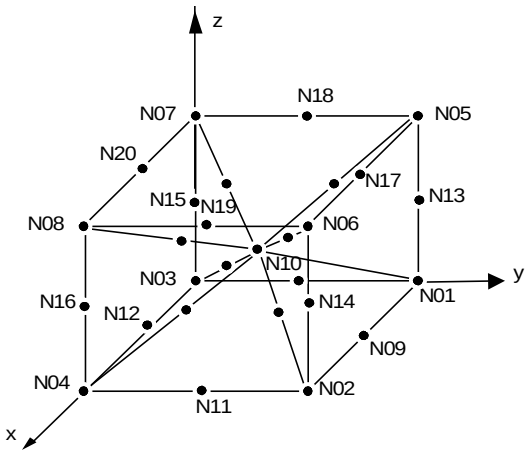
6.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
σ_{xx}	A	NON_REGRESSION	151.2
σ_{xy}	A	NON_REGRESSION	93.1
ϵ_{xx}	A	NON_REGRESSION	1.48297 E-2
ϵ_{xy}	A	NON_REGRESSION	1.36014 E-2
χ_{xx}	A	NON_REGRESSION	1.82640 E+1
χ_{xy}	A	NON_REGRESSION	1.68688 E+1
χ_{yy}	A	NON_REGRESSION	– 0.91320 E+1
ϵ_{xx}	B	NON_REGRESSION	4.0444 E-2
ϵ_{xy}	B	NON_REGRESSION	1.9917 E-2
ϵ_{xx}	C	NON_REGRESSION	4.4177 E-2
ϵ_{xy}	C	NON_REGRESSION	1.9205 E-2
ϵ_{xx}	O	NON_REGRESSION	4.2848 E-2
ϵ_{xy}	O	NON_REGRESSION	1.9203 E-2

7 Modelization E

7.1 Characteristic of the modelization

The modelization used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N04, DX: 0. , DY: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N11, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N14, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N16, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N19, DX: 0.)
- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,13,5,17,6,14,2,9)$ $(1,13,5,18,7,15,3,10)$, $(3,12,4,16,8,10,7,15)$ and $(4,16,8,19,6,14,2,11)$.

7.2 Characteristics of the mesh

Many nodes: 29
Number of meshes and types: 6 PYRAM13 and 4 QUAD8 (sides)

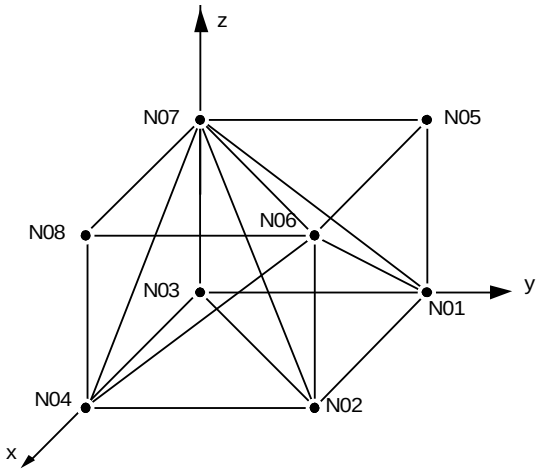
7.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
σ_{xx}	A	NON_REGRESSION	151.2
σ_{xy}	A	NON_REGRESSION	93.1
ϵ_{xx}	A	NON_REGRESSION	1.48297 E-2
ϵ_{xy}	A	NON_REGRESSION	1.36014 E-2
χ_{xx}	A	NON_REGRESSION	1.82640 E+1
χ_{xy}	A	NON_REGRESSION	1.68688 E+1
χ_{yy}	A	NON_REGRESSION	– 0.91320 E+1
ϵ_{xx}	B	NON_REGRESSION	4.0444 E-2
ϵ_{xy}	B	NON_REGRESSION	1.9917 E-2
ϵ_{xx}	C	NON_REGRESSION	4.4177 E-2
ϵ_{xy}	C	NON_REGRESSION	1.9205 E-2
ϵ_{xx}	O	NON_REGRESSION	4.2848 E-2
ϵ_{xy}	O	NON_REGRESSION	1.9203 E-2

8 Modelization F

8.1 Characteristic of the modelization

The modelization used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N04, DX: 0. , DY: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
  DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)

- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,5,6)$ $(1,2,6)$ $(1,5,7)$ $(1,3,7)$ $(3,4,7)$ $(4,7,8)$, $(2,4,6)$ and $(4,6,8)$.

8.2 Characteristics of the mesh

Many nodes: 8

Number of meshes and types: 6 TETRA4 and 8 TRIA3 (sides)

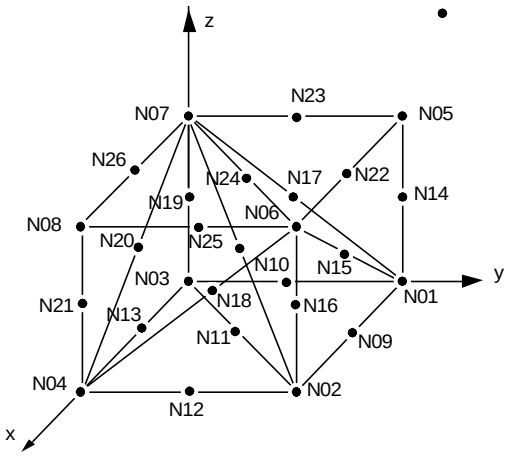
8.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
σ_{xx}	A	NON_REGRESSION	151.2
σ_{xy}	A	NON_REGRESSION	93.1
ϵ_{xx}	A	NON_REGRESSION	1.48297 E-2
ϵ_{xy}	A	NON_REGRESSION	1.36014 E-2
χ_{xx}	A	NON_REGRESSION	1.82640 E+1
χ_{xy}	A	NON_REGRESSION	1.68688 E+1
χ_{yy}	A	NON_REGRESSION	– 0.91320 E+1
ϵ_{xx}	B	NON_REGRESSION	4.0444 E-2
ϵ_{xy}	B	NON_REGRESSION	1.9917 E-2
ϵ_{xx}	C	NON_REGRESSION	4.4177 E-2
ϵ_{xy}	C	NON_REGRESSION	1.9205 E-2
ϵ_{xx}	O	NON_REGRESSION	4.2848 E-2
ϵ_{xy}	O	NON_REGRESSION	1.9203 E-2

9 Modelization G

9.1 Characteristic of the modelization

The modelization used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N04, DX: 0. , DY: 0.)

DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N02, DX: 0.)
DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N06, DX: 0.)
DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N12, DX: 0.)
DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT PROFILE OF THE EXCLU TYPE NODE: N16, DX: 0.)

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DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT
   PROFILE OF THE EXCLU TYPE NODE: N18, DX: 0.)
DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT
   PROFILE OF THE EXCLU TYPE NODE: N21, DX: 0.)
DDL_IMPO: (THE NODE IS OUTSIDE THE FIELD OF DEFINITION WITH A RIGHT
   PROFILE OF THE EXCLU TYPE NODE: N25, DX: 0.)
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- of the surface forces imposed (key word FORCE_FACE) on the sides (meshes of skin) $(1,14,5,22,6,15)$ $(1,9,2,16,6,15)$ $(1,14,5,23,7,17)$ $(1,10,3,19,7,17)$ $(3,13,4,20,7,19)$ $(4,20,7,26,8,21)$, $(2,12,4,18,6,16)$ and $(4,18,6,25,8,21)$.

9.2 Characteristics of the mesh

Many nodes: 26
Number of meshes and types: 6 TETRA10 and 8 TRIA6 (sides)

9.3 Quantities tested and results

Identification	Times	Type of Reference	Reference
σ_{xx}	A	NON_REGRESSION	151.2
σ_{xy}	A	NON_REGRESSION	93.1
ϵ_{xx}	A	NON_REGRESSION	1.48297 E-2
ϵ_{xy}	A	NON_REGRESSION	1.36014 E-2
χ_{xx}	A	NON_REGRESSION	1.82640 E+1
χ_{xy}	A	NON_REGRESSION	1.68688 E+1
χ_{yy}	A	NON_REGRESSION	– 0.91320 E+1
ϵ_{xx}	B	NON_REGRESSION	4.0444 E-2
ϵ_{xy}	B	NON_REGRESSION	1.9917 E-2
ϵ_{xx}	C	NON_REGRESSION	4.4177 E-2
ϵ_{xy}	C	NON_REGRESSION	1.9205 E-2
ϵ_{xx}	O	NON_REGRESSION	4.2848 E-2
ϵ_{xy}	O	NON_REGRESSION	1.9203 E-2

10 Summary of the results

the results are identical whatever the type of selected element. The results are close to the reference solution since the variations are overall lower than 1.52%.