SSNP14 - Plate in traction-shearing - Von Mises (kinematic work hardening)

Summary:

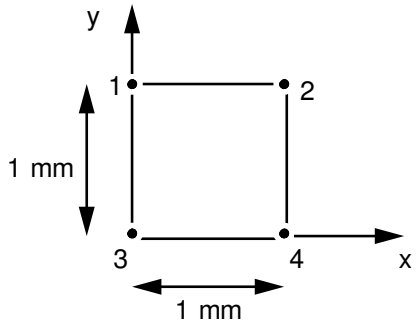
This test $2D$ plane constraints quasi-static, from guide VPCS, enters within the framework of the validation of the relations of elastoplastic behavior. An element of volume, consisted of a plastic material with linear kinematic work hardening, is subjected at the same time to a shearing and tractive effort.

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

1 Problem of reference

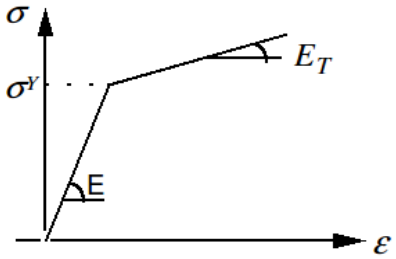
1.1 Geometry

The constraints and deformations are homogeneous in the element of volume. This one can be represented by an element plan or voluminal, for example:



1.2 Material properties

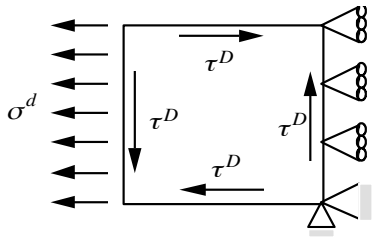
Elastoplastic law of behaviour to linear kinematic work hardening.



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

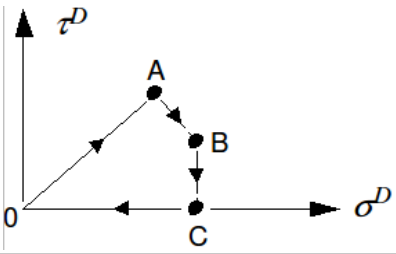
1.3 Boundary conditions and loadings

The element of volume is blocked according to Ox along the side $[2,4]$ while being subjected to a traction 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 constraint is fixed by the way of loading (piloting in constraint), 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 deformation:

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

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

Note:

$$\left|\ \varepsilon^p_{xx}+\varepsilon^p_{yy}+\varepsilon^p_{zz}=0 \text{ and } \varepsilon^p_{yy}=\varepsilon^p_{zz} \text{ thus } \varepsilon^p_{yy}=\varepsilon^p_{zz}=\frac{-\varepsilon^p_{xx}}{2}\right.$$

then the constraint of recall:

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

Moreover, to obtain a correct precision, 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 calculations. It is obtained like average of the results of several codes.

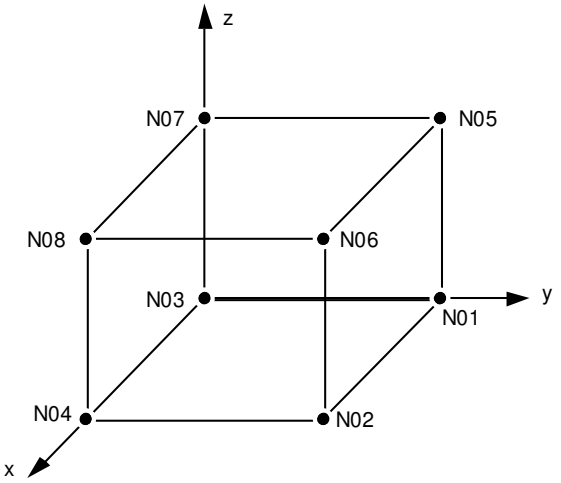
2.3 Bibliographical references

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

3 Modeling A

3.1 Characteristics of modeling

Modeling used is 3D.



The loading and the boundary conditions are modelled by:

•DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)

•imposed surface forces (keyword FORCE_FACE) on the faces (meshs of skin) $(1,5,6,2)$, $(1,5,7,3)$, $(3,4,8,7)$ and $(4,8,6,2)$.

3.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 1 HEXA8 + 4 QUAD4 (faces)

3.3 Sizes tested and results

Identification	Moments	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 point of Gauss (DERA_ELGA), and with the node N_2 (DERA_ELNO).

Identification	Type of reference	Value of reference
DCHA_V at moment 0.1	'NON_REGRESSION'	0.877871
RADI_V at moment 1.5	'NON_REGRESSION'	0
ERR_RADI at moment 1.5	'NON_REGRESSION'	0,0125766

Moreover, in one second series of calculations, one tests the indicator of error due to nonthe radiality of the loading: starting from a coarse temporal discretization (2 increments on the ways AB and BC , and an increment on the others), one activates the subdivision of the step of time 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.

results are:

VMIS_CINE_LINE and VMIS_ECMI_LINE

Identification	Moments	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	Moments	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 indicator of error in radiality provides the same result:

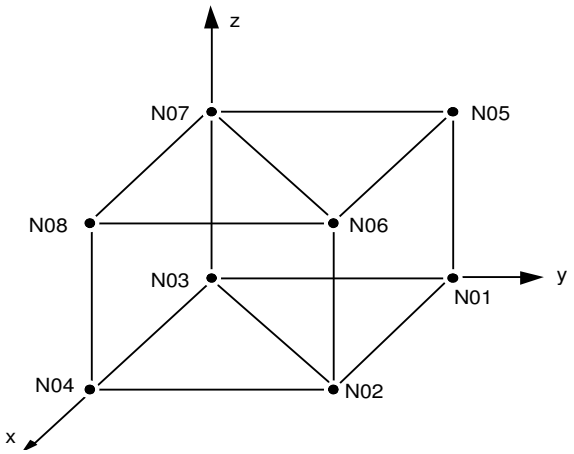
Identification	Type of reference	Value of reference
ERR_RADI at moment 1.5	'NON_REGRESSION'	0.011798
ERR_RADI at moment 2.5	'NON_REGRESSION'	0.01956

The use of the criterion of radiality to on the whole refine automatically the step of time led to 56 pas de time, against 64 in the first case (with 30 increments on AB and BC), for a result of equivalent quality (error of approximately 1.2% to t=1.5, and 2% with t=2.5).

4 Modeling B

4.1 Characteristics of modeling

Modeling used is 3D .



The loading and the boundary conditions are modelled by:

•DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)

•imposed surface forces (keyword FORCE_FACE) on the faces (meshs of skin) $(1,5,6,2)$, $(1,5,7,3)$, $(3,4,8,7)$ and $(4,8,6,2)$.

4.2 Characteristics of the grid

Many nodes: 8
Many meshs and types: 1 PENTA6 + 4 QUAD4 (faces)

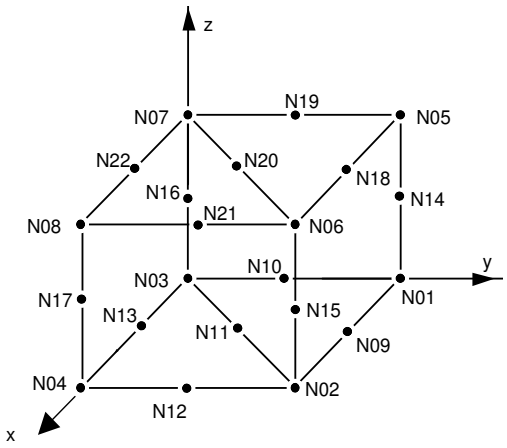
4.3 Sizes tested and results

Identification	Moments	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 Modeling C

5.1 Characteristics of modeling

Modeling used is 3D .



The loading and the boundary conditions are modelled by:

•DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
DDL_IMPO: (NODE: N15, DX: 0.)
DDL_IMPO: (NODE: N21, DX: 0.)
DDL_IMPO: (NODE: N17, DX: 0.)
DDL_IMPO: (NODE: N12, DX: 0.)

•imposed surface forces (keyword FORCE_FACE) on the faces (meshs 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 grid

Number of nodes : 22
Many meshs and types: 1 PENTA15 + 4 QUAD8 (faces)

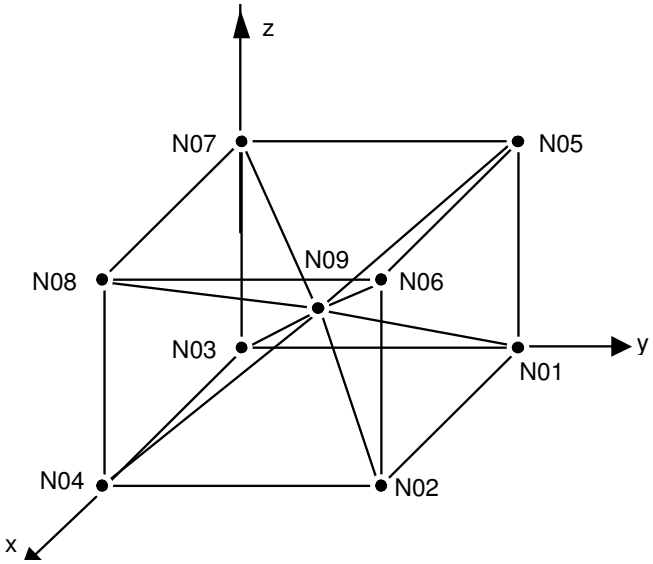
5.3 Sizes tested and results

Identification	Moments	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 Modeling D

6.1 Characteristics of modeling

Modeling used is 3D .



The loading and the boundary conditions are modelled by:

- DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
  DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
  DDL_IMPO: (NODE: N02, DX: 0.)
  DDL_IMPO: (NODE: N06, DX: 0.)
- imposed surface forces (keyword FORCE_FACE) on the faces (meshs of skin) $(1,5,6,2)$, $(1,5,7,3)$, $(3,4,8,7)$ and $(4,8,6,2)$.

6.2 Characteristics of the grid

Many nodes: 9
Many meshs and types: 6 PYRAM5 and 4 QUAD4 (faces)

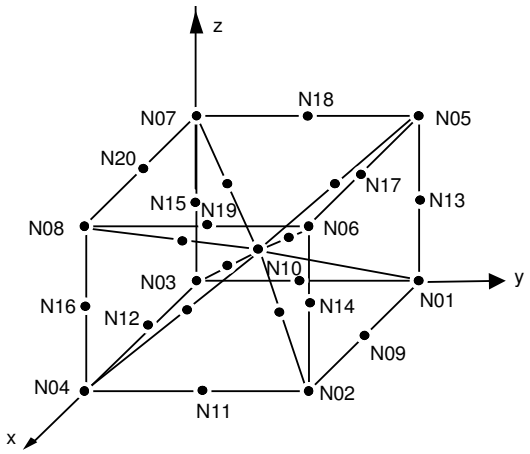
6.3 Sizes tested and results

Identification	Moments	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 Modeling E

7.1 Characteristics of modeling

Modeling used is 3D .



The loading and the boundary conditions are modelled by:

•DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
DDL_IMPO: (NODE: N11, DX: 0.)
DDL_IMPO: (NODE: N14, DX: 0.)
DDL_IMPO: (NODE: N16, DX: 0.)
DDL_IMPO: (NODE: N19, DX: 0.)

•imposed surface forces (keyword FORCE_FACE) on the faces (meshs 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 grid

Many nodes: 29
Many meshs and types: 6 PYRAM13 and 4 QUAD8 (faces)

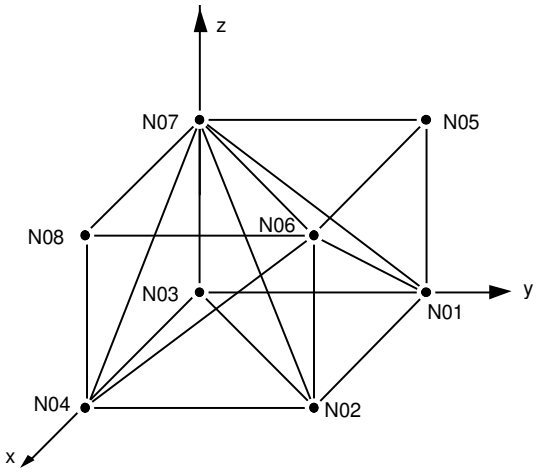
7.3 Sizes tested and results

Identification	Moments	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 Modeling F

8.1 Characteristics of modeling

Modeling used is 3D .



The loading and the boundary conditions are modelled by:

•DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)

•imposed surface forces (keyword FORCE_FACE) on the faces (meshs 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 grid

Many nodes: 8
Many meshs and types: 6 TETRA4 and 8 TRIA3 (faces)

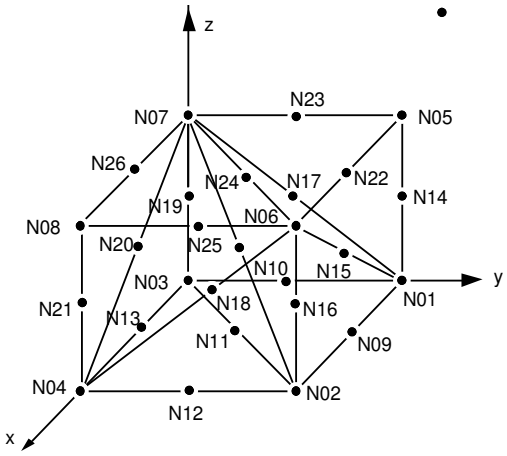
8.3 Sizes tested and results

Identification	Moments	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 Modeling G

9.1 Characteristics of modeling

Modeling used is 3D .



The loading and the boundary conditions are modelled by:

•DDL_IMPO: (NODE: N04, DX: 0. , DY: 0.)
DDL_IMPO: (NODE: N08, DX: 0. , DY: 0. , DZ: 0.)
DDL_IMPO: (NODE: N02, DX: 0.)
DDL_IMPO: (NODE: N06, DX: 0.)
DDL_IMPO: (NODE: N12, DX: 0.)
DDL_IMPO: (NODE: N16, DX: 0.)
DDL_IMPO: (NODE: N18, DX: 0.)
DDL_IMPO: (NODE: N21, DX: 0.)
DDL_IMPO: (NODE: N25, DX: 0.)

•imposed surface forces (keyword FORCE_FACE) on the faces (meshs of skin) $(1,14,5,22,6,15)$, $(1,9,2,16,6,15)$, $(1,14,5,23,7,17)$, $(1,10,3,19,7,17)$, $(3,13,4,20,7,19)$, $(4,20,7,26,8,21)$, $(2,12,4,18,616)$ and $(4,18,6,25,8,21)$.

9.2 Characteristics of the grid

Many nodes: 26
Many meshs and types: 6 TETRA10 and 8 TRIA6 (faces)

9.3 Sizes tested and results

Identification	Moments	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%.