COMP002 – Test of behaviors visco-élasto-plastics. Simulation in a material point

Summary:

This test implements a simulation of a way of loading in constraints or deformations in a material point, i.e. on a model such as the stress and strain states are homogeneous at any moment. It thus makes it possible to test a certain number of models of behavior visco-élasto-plastics, with an aim of checking the robustness of their digital integration, their insensitivity compared to a change of units, the good taking into account of the variables of order whose the coefficients depend on the model, invariance compared to a total rotation applied to the problem, the accuracy of the tangent matrix.

Modeling a: this modeling makes it possible to validate the model LEMAITRE in 3D.
Modeling b: this modeling makes it possible to validate the model VISC_CIN1_CHAB in 3D.
Modeling C: this modeling makes it possible to validate the model VISC_CIN2_CHAB in 3D.
Modeling D: this modeling makes it possible to validate the model VISC_ENDO_LEMA in 3D.
Modeling E: this modeling makes it possible to validate the model VISC_TAHERI in 3D.
Modeling F: this modeling makes it possible to validate the model VISC_ISOT_LINE in 3D.
Modeling G: this modeling makes it possible to validate the model VISC_ISOT_TRAC in 3D.
Modeling H: this modeling makes it possible to validate the model VISC_CIN2_MEMO in 3D.
Modeling I: this modeling makes it possible to validate the model VISCOCHAB in 3D.
Modeling J: this modeling makes it possible to validate the model MONOCRYSTAL in CPLAN and in 3D.
Modeling K: this modeling makes it possible to validate the model VMIS_JOHN_COOK in 3D.
Modeling L: this modeling makes it possible to validate the model HAYHURST in 3D.

1 Problem of reference

1.1 Geometry

Geometry (generated automatically in the macro-order SIMU_POINT_MAT [U4.51.12] is single and simple: it acts in $3D$ of a tetrahedron on side 1, and in $2D$ of a triangle on side 1, with the nodes of which one applies linear relations to obtain a homogeneous stress and strain state.

1.2 Properties of material

The characteristics of materials are defined for each behavior via the order DEFI_MATERIAU. The elastic characteristics and the elastic limit selected are those of standard steel 16MND5:

- $E=200\,000\,MPa$, $\nu=0.3$, $\sigma_y=437\,MPa.$

The other parameters describing the laws were selected starting from the CAS-tests of Code_Aster. The two following tables summarize the whole of the laws of Code_Aster considered and the parameters associated

Model.	**viscoplastic laws of ASTER**	**parameters selected**	**test retained for the choice of the parameters**
With	LEMAITRE	m = 5.6 Kinv=1/K= 3.2841e-4 N = 11	test ASTER ssna01a
B	VISC_CIN1_CHAB	SY = 437.0; Rinf = 758.0; B = 2.3; Cinf = 63767.0 Gamma0 = 341.0 1/m = 0 Kinv=1/K= 3.2841e-4 N = 11	work hardening: different data 16MND5 parameters: ssnv101c
C	VISC_CIN2_CHAB	SY = 437.0; Rinf = 758.0; B = 2.3; C1inf = 63767.0/2.0 C2inf = 63767.0/2.0 Gam1 = 341.0 Gam2 = 341.0 1/m = 0 1/K= 3.2841e-4 N = 11	Different work hardening given 16MND5 parameters ssnv101c Kinematic choice X1+X2= X of VMIS_CIN1_CHAB
D	VISC_ENDO_LEMA	SY=0.0 N=12.0 UN_SUR_M=1/9.0 UN_SUR_K=1/2110.0 R_D=6.3 A_D=3191.0	

E	VISC_TAHERI	SY = 437.0;
		Sinf = 758.0;
		alpha = 0.3;
		m = 0.1;
		has = 312.0;
		B = 30.0;
		c1 = -0,012;
		cinf = 0,065
			test ASTER ssnp101b

F	VISC_ISOT_LINE	SY=437 MPa, DSY=2024Mpa SIGM_0=6176. EPSI_0=3.31131121483e13 M=6.76	Test ssnl129 for the part VISC_SINH Data material 16MND5 for work hardening
G	VISC_ISOT_TRAC	traction diagram with 100°C of the 16 MND5 SIGM_0=6176. EPSI_0=3.31131121483e13 M=6.76	Test ssnl129 for the part VISC_SINH Data material 16MND5 for work hardening
H	VISC_CIN2_MEMO	R0=SY = 437.0; Q0 = 758.0-437.0; Qm=Q0+100 Mu=10 Eta=0.5 B = 2.3; C1inf = 63767.0/2.0 C2inf = 63767.0/2.0 Gam1 = 341.0 Gam2 = 341.0 1/m =0 1/K= 3.2841e-4 N = 11	Kinematic choice X1+X2= X of VMIS_CIN1_CHAB. Effect of memory.
I	VISCOCHAB	SY = 437.0; Rinf = 758.0; B = 2.3; C1inf = 63767.0/2.0 C2inf = 63767.0/2.0 Gam1 = 341.0 Gam2 = 341.0 1/m = 0 1/K= 3.2841e-4 N = 11 Q0 = 758.0-437.0; Qm=Q0+100 Mu=10 Eta=0.5	Work hardening: different data 16MND5 parameters ssnv101c Kinematic choice X1+X2= X of VMIS_CIN1_CHAB Effect of memory.
J	MONOCRYSTAL	viscoplastic laws of ASTER	Plastic parameters resulting from ssnv171. Orthotropic parameters resulting from SSLV120
K	VMIS_JOHN_COOK	YOUNG = 124000.e6; FISH = 0.34; A=90.e6 B=292.e6 C=0.025 N_PUIS=0.31 M_PUIS=1.09 EPSI0=10000.0 TROOM=298.0 TMELT=1083.0	
L	HAYHURST	YOUNG = 145000. ; FISH = 0.34; BIGA=9,7E-8 DELTA1=1.0, DELTA2=0.0, BIGA=9.707593E-08, H1ST=0.33, H2ST=1.0, K=9.69 H1=3.E4, H2=-280.0, SIG0=27.9317,	

		ALPHAD=0.5, EPS0=5.82516E-11	

1.3 Boundary conditions and loadings

1.3.1 Characteristics of the ways of loading

Two ways of loading were defined to treat the cases $3D$ and $2D$ plan. They are common to all the laws of behavior. Each one of them respects the following criteria:

- a cumulated plastic deformation, p , of 4 with 5% on the whole of the way,
- an increase in 1% cumulated plastic deformation p during a portion of the way,
- in the presence of viscosity, a speed of request in deformation respectively of 10^{-3}, 10^{-4} and $10^{-5}s^{-1}$. Those were evaluated in an approximate way by considering an equivalent deformation of 5% on the whole of the way: maybe of times of ways of 50.500 and 5000 seconds respectively for $v1$, $v2$ and $v3$. The restored tests correspond at a speed of $10^{-5}s^{-1}$.

This calibration was carried out on the law VMIS_ISOT_LINE, then deferred on the other laws.

The loading suggested varies in a way uncoupled each component from the tensor of the deformations by successive stage. One proposes a cyclic way charges discharge with it by covering the states with traction and compression as well as an inversion with the signs with shearings in order to test a broad range of values.

Schematically, it follows a course on 8 segments [O-A-B-C-O-C'-B'-A'-O] where the second part of the way [O-C'-B'-A'-O] is symmetrical compared to the origin of the first [O-A-B-C-O] .

1.3.2 Application of the requests

One under investigation brings back material point (by using the macro-order SIMU_POINT_MAT [U4.51.12]) by requesting a homogeneous element of manner while imposing:

•in $3D$, 6 components of the tensor of deformation:

$$\bar{\boldsymbol{\varepsilon}}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}$$

•in $2D$ three components of the tensor

$$\bar{\boldsymbol{\varepsilon}}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy}\\ \varepsilon_{xy} & \varepsilon_{yy}\end{bmatrix}$$

For a more general writing, the tensor of the deformations imposed will be broken up into a hydrostatic and deviatoric part on bases of shearing:

$$\bar{\boldsymbol{\varepsilon}}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy}\\ \varepsilon_{xy} & \varepsilon_{yy}\end{bmatrix}=p\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}+d\begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}+\varepsilon_{xy}\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix} \text{ in } 2D ,$$

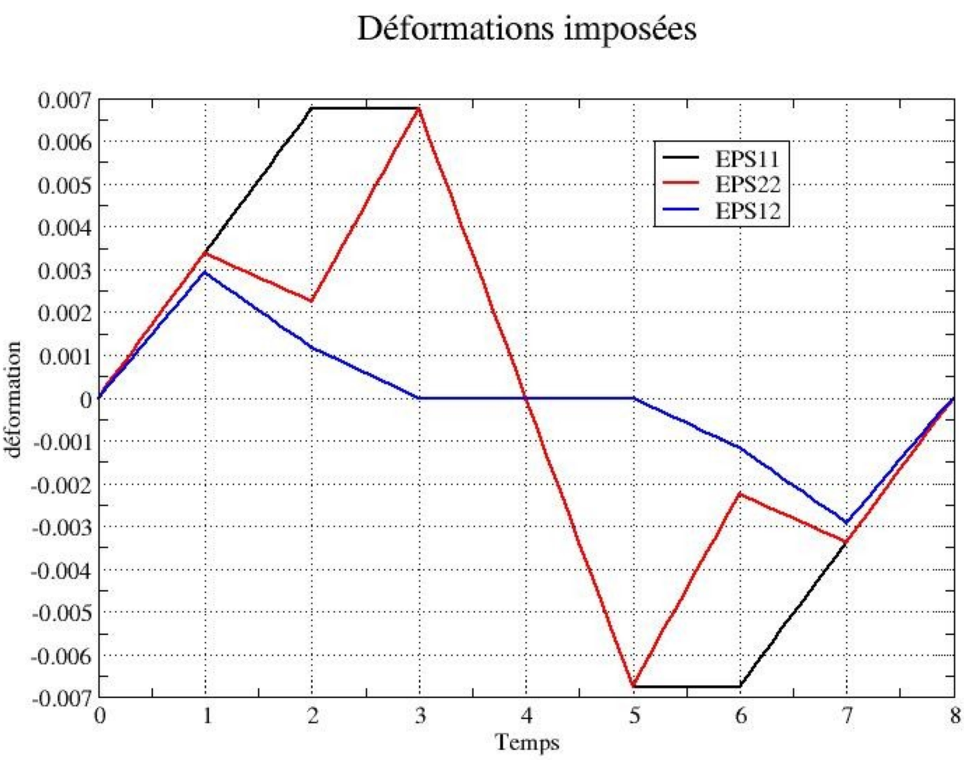
$$\bar{\boldsymbol{\varepsilon}}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}=p\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}+d_1\begin{bmatrix}1 & 0 & 0\\ 0 & -1 & 0\\ 0 & 0 & 0\end{bmatrix}+d_2\begin{bmatrix}0 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & -1\end{bmatrix}+\begin{bmatrix}0 & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & 0 & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & 0\end{bmatrix} \text{ in 3D.}$$

1.3.3 Description of the way of deformation imposed in 2D

The way applied is described in the table below, the values of deformations are gauged with respect to the elastic module:

time	1	2	3	4	5	6	7	8
Not loading	A	B	C	O	C'	B'	A'	O
$E.\varepsilon_{xx}$	675	1350	1350	0	-1350	-1350	-675	0
$E.\varepsilon_{yy}$	675	450	1350	0	-1350	-450	-675	0
$\frac{E}{(1+\nu)}\varepsilon_{xy}$	450	180	0	0	0	-180	-450	0
p	675	900	1350		-1350	-900	-675	0
d	0	0	450	0	0	-450	0	0

This way is illustrated by the following graph:

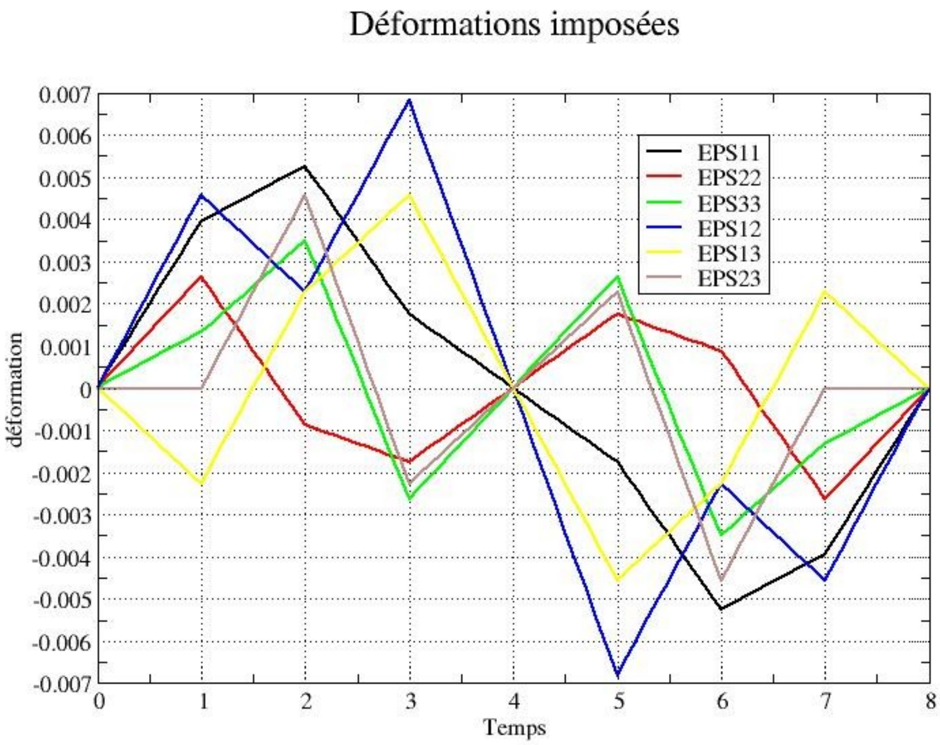


1.3.4 Description of the way of deformation imposed in 3D

The way applied is described in the table below, the values of deformations applied are gauged with respect to the elastic module:

N° segment	1	2	3	4	5	6	7	8
Segment	$0-A$	$A-B$	$B-C$	O	C'	B'	A'	O
$E.\varepsilon_{xx}$	787.5	1050	350	0	-350	-1050	-787.5	0
$E.\varepsilon_{yy}$	525.0	-175	-350	0	350	175	525	0
$E.\varepsilon_{zz}$	262.5	700	-525	0	525	-700	-262.5	0
$\frac{E}{(1+\nu)}\varepsilon_{xy}$	700	350	1050	0	-1050	-350	-700	0
$\frac{E}{(1+\nu)}\varepsilon_{xz}$	-350	350	700	0	-700	-350	700	0
$\frac{E}{(1+\nu)}\varepsilon_{yz}$	0	700	-350	0	350	-700	0	0
p	525	525	-175	0	175	-525	-525	0
d_1	262.5	525	525	0	-525	-525	-262.5	0
d_2	262.5	-175	350	0	-350	175	-262.5	0

This way is illustrated by the following graph:



1.4 Initial conditions

Worthless constraints and deformations.

2 Reference solution

This test proceeds, for each modeling, with an intercomparison between the reference solution (obtained with a step of very fine time), the solution with a fairly coarse discretization, the solution with effect of the temperature (or another variable of order), the solution by changing the system of units (Pa in MPa), and that obtained after rotation or symmetry.

2.1 Definition of the cases tests of robustness

One proposes 3 angles of analysis to test the robustness of the integration of the laws of behavior:

- studies of equivalent problems
- checking of the tangent matrix
- study of the discretization of the step of time

For each one of them, one studies the evolution the relative differences between several calculations using the same law but presenting parameters or different options of calculations. The exploitation relates to the invariants of the tensor of the constraints: trace of the tensor, constraint of Von-Put and the internal variables of scalar nature: generally it is cumulated plasticity.

The total convergence criteria are the values envisaged by default by Code_Aster. (`RESI_GLOB_RELA=10-6, ITER_GLOB_MAXI=10`). One adopted a usual diagram of Newton for the reactualization of the tangent matrix:
•calculation of the tangent matrix of prediction to each converged increment (`REAC_INC=1`)
•calculation of the coherent tangent matrix to each iteration of Newton (`REAC_ITER=1`).

2.2 Studies of equivalent problems

For a coarse discretization of the ways: 1 pas de time for each segment of the way, the solution obtained for each law is compared with 3 strictly equivalent problems for the state of the material point:

- Tpa , even way with a change of unit, one substitutes them Pa with MPa in the data materials and the possible parameters of the law,
- Trot, way by imposing the same tensor $\bar{\varepsilon}$ after a rotation: $\boldsymbol{R}\bar{\varepsilon}\boldsymbol{R}^T$ where $\boldsymbol{R}$ is a matrix of rotation. For the case $2\mathrm{D}$, the swing angle will be $\alpha=0.9$ radian, for the configuration $3\mathrm{D}$, one chose the angles of Euler with the arbitrary values { $\psi=0.9$ radian $\theta=0.7$ radian and $\phi=0.4$ radian },
- Tsym, way by imposing the tensor $\bar{\varepsilon}$ after a symmetry: permutation of the axes x and y in $2\mathrm{D}$, permutation of x in y , y in z and z in x in 3D.

For each one of these problems, the solution (invariants of the constraints, cumulated equivalent plastic deformation) must be identical to the basic solution, obtained with the same discretization in time. The value of reference of the variation is thus 0. That means in practice that the found variation must be about the precision machine is approximately 1.E-15.

2.3 Test of the tangent matrix

One also tests for each behavior the tangent matrix, by difference with the matrix obtained by disturbance. There still, the value of reference is 0.

2.4 Study of the discretization of the step of time

One studies the behavior of the integration of the laws according to the discretization. For the same modeling, therefore a given behavior, one studies several different discretizations in time here, while multiplying by 5 the number of steps of the way of loading. In the reference [1], the discretization is pushed up to 3125 increments per segment on the same principle. Here, to limit the duration of the tests, one limits oneself to 3 successive refinements. This led to the following discretization:

Many intervals per segment of loading	5	25
Number of total step on the whole of the way	40	200
Calculation	T1	Tréf reference solution

The reference solution, $T_{réf}$, that is obtained for $\mathrm{N}=25$, that is to say 200 pas for the totality of the way. These various solutions make it possible to judge sensitivity to the great steps of time and robustness of integration.
To reveal the speed of convergence according to the step of time, one defers here the solutions put forward in [1], until 3125 pas de time for each of the 8 segments of the way of loading.

2.4.1 Law LEMAITRE

Variations	N1	N5	N25	N125	N625	N3125
V1_N	3.15e-02	3.00e-02	1.35e-02	3.25e-03	5.74e-04	0.00e+00
VMIS	1.64e-02	1.33e-02	3.58e-03	7.95e-04	1.38e-04	0.00e+00
EXAM NERVES	2.25e-14	2.22e-14	2.18e-14	2.39e-14	3.36e-14	0.00e+00
SIXX	4.70e-02	4.09e-02	1.05e-02	2.16e-03	3.64e-04	0.00e+00
SIYY	2.30e-01	1.87e-01	4.64e-02	9.71e-03	1.65e-03	0.00e+00
SIZZ	9.71e-02	7.43e-02	1.78e-02	3.79e-03	6.47e-04	0.00e+00
SIXY	4.70e-02	7.04e-02	2.74e-02	5.40e-03	9.05e-04	0.00e+00
SIXZ	2.45e-01	2.23e-01	5.76e-02	1.19e-02	2.01e-03	0.00e+00
SIYZ	1.92e-01	1.36e-01	4.41e-02	9.03e-03	1.53e-03	0.00e+00

2.4.2 Law VISC_CIN1_CHAB v=10^{-5}

Variations (A2)	N1	N5	N25	N125	N625	N3125
V1_N	3.53e+00	1.14e+00	2.45e-01	4.78e-02	7.98e-03	0.00e+00
VMIS	7.83e-02	5.64e-02	2.35e-02	5.52e-03	9.60e-04	0.00e+00
EXAM NERVES	1.33e-14	1.37e-14	1.33e-14	1.18e-14	2.25e-14	0.00e+00
SIXX	1.27e-01	6.25e-02	2.89e-02	6.93e-03	1.21e-03	0.00e+00
SIYY	2.51e-01	9.65e-02	5.05e-02	1.26e-02	2.23e-03	0.00e+00
SIZZ	2.51e-01	4.71e-02	2.04e-02	5.53e-03	9.91e-04	0.00e+00
SIXY	1.32e-01	6.54e-01	2.32e-01	5.35e-02	9.32e-03	0.00e+00
SIXZ	9.85e-02	7.60e-02	3.21e-02	7.63e-03	1.34e-03	0.00e+00
SIYZ	6.24e+00	1.62e+00	9.91e-02	1.71e-02	3.05e-03	0.00e+00

2.4.3 Law VISC_CIN2_CHAB v=10^{-5}

Variations (A2)	N1	N5	N25	N125	N625	N3125
V1_N	3.53e+00	1.14e+00	2.45e-01	4.78e-02	7.98e-03	0.00e+00
VMIS	7.83e-02	5.64e-02	2.35e-02	5.52e-03	9.60e-04	0.00e+00
EXAM NERVES	1.33e-14	1.37e-14	1.33e-14	1.18e-14	2.25e-14	0.00e+00
SIXX	1.27e-01	6.25e-02	2.89e-02	6.93e-03	1.21e-03	0.00e+00
SIYY	2.51e-01	9.65e-02	5.05e-02	1.26e-02	2.23e-03	0.00e+00
SIZZ	2.51e-01	4.71e-02	2.04e-02	5.53e-03	9.91e-04	0.00e+00
SIXY	1.32e-01	6.54e-01	2.32e-01	5.35e-02	9.32e-03	0.00e+00
SIXZ	9.85e-02	7.60e-02	3.21e-02	7.63e-03	1.34e-03	0.00e+00
SIYZ	6.24e+00	1.62e+00	9.91e-02	1.71e-02	3.05e-03	0.00e+00

2.4.4 Law VISC_TAHERI v=10^{-5}

Variations (A2)	N1	N5	N25	N125	N625	N3125
V1_N	3.30e-02	4.17e-02	2.04e-02	5.14e-03	9.19e-04	0.00e+00
VMIS	8.29e-02	2.87e-02	7.27e-03	1.52e-03	2.59e-04	0.00e+00
EXAM NERVES	6.79e-14	6.78e-14	6.80e-14	6.70e-14	8.73e-14	0.00e+00
SIXX	8.71e-02	3.26e-02	8.47e-03	1.78e-03	3.03e-04	0.00e+00
SIYY	1.36e-01	5.39e-02	1.82e-02	4.69e-03	8.40e-04	0.00e+00
SIZZ	6.04e-02	3.26e-02	1.47e-02	3.85e-03	6.92e-04	0.00e+00
SIXY	1.68e+00	7.74e-01	2.08e-01	4.43e-02	7.57e-03	0.00e+00
SIXZ	5.37e-01	2.97e-01	9.61e-02	2.17e-02	3.77e-03	0.00e+00
SIYZ	2.43e-01	5.68e-01	3.11e-01	7.77e-02	1.38e-02	0.00e+00

2.5 Bibliographical references

1. P.LEVASSEUR: “Application Third party maintenance of the code _Aster” Checking of the robustness and the reliability of the integration of laws of behavior in ASTER. Report PRINCIPIA RET.693.127.01 December 2006.

3 Modeling A

3.1 Characteristics of modeling

The behavior tested is LEMAITRE , in 3D.

3.2 Sizes tested and results

Modeling 3D , $Theta=1$.

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_P	0	0	0	2.7	2.1	0
VMIS	0	0	0	7.1	0.1	0
TRACE	0	0	0	0	0	0

Tangent matrix, $Theta=1$

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	5.E-9

Modeling 3D , $Theta=0.5$

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_P	0	0	0	36	1.2	0
VMIS	0	0	0	10.97	3	0
TRACE	0	0	0	0	0	0

Tangent matrix, $Theta=0.5$

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	3.E-8

4 Modeling B

4.1 Characteristics of modeling

The behavior tested is VISC_CIN1_CHAB , in 3D.

4.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N10	N25	N50
V1_P	0	0	0	42.5	10.9	0
VMIS	0	0	0	3	1.1	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\text{Max}(\text{Ktgte}-\text{Kpert})$	2.2E-4

5 Modeling C

5.1 Characteristics of modeling

The behavior tested is VISC_CIN2_CHAB , in 3D.

5.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N10	N25	N50
V1_P	0	0	0	42.5	10.9	0
VMIS	0	0	0	3	1.1	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	2.12E-4

6 Modeling D

6.1 Characteristics of modeling

The behavior tested is VENDOCHAB , in 3D.

6.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_P	0	0	0	2.7	1.9	0
VMIS	0	0	0	6.9	0.7	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	0.07

7 Modeling E

7.1 Characteristics of modeling

The behavior tested is VISC_TAHERI , in 3D.

7.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_P	0	0	0	3.3	2.2	0
VMIS	0	0	0	7.6	2.2	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	2.6 E-5

8 Modeling F

8.1 Characteristics of modeling

The behavior tested is VISC_ISOT_LINE , in 3D.

8.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_P	0	0	0	2.5	0.96	0
VMIS	0	0	0	0.62	0.16	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	$1.6\ 10^{-6}$

9 Modeling G

9.1 Characteristics of modeling

The behavior tested is VISC_ISOT_TRAC , in 3D.

9.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_P	0	0	0	2.5	0.96	0
VMIS	0	0	0	1.1	0.12	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	$7.3\ 10^{-7}$

10 Modeling H

10.1 Characteristics of modeling

The behavior tested is VISC_CIN2_MEMO , in 3D.

10.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V1_p	0	0	0	2.65	0.72	0
VMIS	0	0	0	0,073	0,037	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	1.16 10 $^{-4}$

11 Modeling I

11.1 Characteristics of modeling

The behavior tested is VISCOCHAB , in 3D.

11.2 Sizes tested and results

Modeling 3D :

Variations (%)	T_Pa	T_sym	T_rot	N1	N5	N25
V13_p	0	0	0,647	2.64	0.72	0
VMIS	0	0	0.0497	0.0734	0,037	0
TRACE	0	0	0	0	0	0

Tangent matrix:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	$2.0\ 10^{-4}$

Note:

For this behavior there remains an error in the case of rotation.

12 Modeling J

12.1 Characteristics of modeling

The behavior tested is MONOCRYSTAL , in C_PLAN and in 3D.

12.2 Sizes tested and results

Modeling C_PLAN :

Variations (%)	T_Pa	T_rot	N1	N5	N25
V44_p	0	0	0,009	0..008	0
VMIS	0,022	0	0,022	0,004	0
TRACE	0,024	0	0,008	0,018	0

Modeling 3D :

Variations (%)	T_Pa	T_rot	N1	N5	N25
V13_p	0	0	0.07	0.02	0
VMIS	0	0.	0.13	0,018	0
TRACE	0	0	0.4	0.1	0

Tangent matrix 3D:

Variations	N25
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	0,024

Note:

Precision in the case C_PLAN is less good than in the case 3D in the case of load " Pa ". That is explained by the fact why the algorithm of Borst leads to the exact solution only after one relatively significant number of iterations. To avoid increasing time CPU of this test, the iterations (and the criterion of stop) of the method De Borst are taken here by default.

The other values are satisfactory (good convergence, and not of problem of robustness even for great steps of time).

This test makes it possible in particular to validate rotation for this anisotropic behavior.

13 Modeling K

13.1 Characteristics of modeling

The behavior tested is VMIS_JOHN_COOK , in 3D.

13.2 Sizes tested and results

Identification	Type of reference	Reference	Tolerance
ER_V1_Pa_1	ANALYTICAL	0.0	1.0E-10
ER_V1_Th_1	ANALYTICAL	0.0	1.0E-10
ER_V1_sym_1	ANALYTICAL	0.0	1.0E-10
ER_V1_rot_1	ANALYTICAL	0.0	1.0E-10
ER_V1_N1	ANALYTICAL	0.0	0.1
ER_V1_N5	ANALYTICAL	0.0	0.01
ER_V1_N25	ANALYTICAL	0.0	0.01
ER_VMIS_Pa_1	ANALYTICAL	0.0	1.6E-15
ER_VMIS_Th_1	ANALYTICAL	0.0	1.0E-10
ER_VMIS_sym_1	ANALYTICAL	0.0	1.0E-10
ER_VMIS_rot_1	ANALYTICAL	0.0	1.0E-10
ER_VMIS_N1	ANALYTICAL	0.0	1.1E-15
ER_VMIS_N5	ANALYTICAL	0.0	1.1E-15
ER_VMIS_N25	ANALYTICAL	0.0	0.01
ER_TRACE_Pa_1	ANALYTICAL	0.0	1.0E-10
ER_TRACE_Th_1	ANALYTICAL	0.0	1.0E-10
ER_TRACE_sym_1	ANALYTICAL	0.0	1.0E-10
ER_TRACE_rot_1	ANALYTICAL	0.0	1.0E-10
ER_TRACE_N1	ANALYTICAL	0.0	1.8E-15
ER_TRACE_N5	ANALYTICAL	0.0	1.2E-15
ER_TRACE_N25	ANALYTICAL	0.0	0,010
MAT_DIFF	ANALYTICAL	0.0	3.3E-10

14 Modeling L

14.1 Characteristics of modeling

The behavior tested is HAYHURST , in 3D. For this behavior, the only method of currently available integration is RUNGE_KUTTA. One thus does not test a tangent matrix.

14.2 Sizes tested and results

Identification	Type of reference	Reference	Tolerance
ER_V7_Pa_1	ANALYTICAL	0.0	1.0E-5
ER_V7_Th_1	ANALYTICAL	0.0	1.0E-5
ER_V7_sym_1	ANALYTICAL	0.0	1.0E-5
ER_V7_rot_1	ANALYTICAL	0.0	1.0E-5
ER_V7_N10	ANALYTICAL	0.0	1.0E-5
ER_V7_N30	ANALYTICAL	0.0	1.0E-5
ER_V7_N60	ANALYTICAL	0.0	1.0E-10
ER_VMIS_Pa_1	ANALYTICAL	0.0	1.0E-5
ER_VMIS_Th_1	ANALYTICAL	0.0	1.0E-5
ER_VMIS_sym_1	ANALYTICAL	0.0	1.0E-5
ER_VMIS_rot_1	ANALYTICAL	0.0	1.0E-5
ER_VMIS_N10	ANALYTICAL	0.0	1.0E-5
ER_VMIS_N30	ANALYTICAL	0.0	1.0E-5
ER_VMIS_N60	ANALYTICAL	0.0	1.0E-10
ER_TRACE_Pa_1	ANALYTICAL	0.0	1.0E-5
ER_TRACE_Th_1	ANALYTICAL	0.0	1.0E-5
ER_TRACE_sym_1	ANALYTICAL	0.0	1.0E-5
ER_TRACE_rot_1	ANALYTICAL	0.0	1.0E-5
ER_TRACE_N10	ANALYTICAL	0.0	1.0E-5
ER_TRACE_N30	ANALYTICAL	0.0	1.0E-5
ER_TRACE_N60	ANALYTICAL	0.0	1.0E-10

15 Synthesis

For the whole of the behaviors visco-élasto-plastics tested, the results are satisfactory:

- the results are valid during a physical change of unit of the problem (Pa in MPa), or following a rotation or a symmetry of the loading
- the results converge correctly with the step of time, and the diagrams of integration are robust, since they make it possible to use great steps of time. Let us announce however for these models implementing a viscosity a greater sensitivity to the step of time than for the elastoplastic models.
- the tangent matrices are correct because similar to the tangent matrices calculated by disturbance.