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

material point:

This test implements a simulation of a way of loading in stresses or strains in a material point, i.e. on a model such as the stress states and of strains 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 numerical integration, their insensitivity compared to a change of units, the good taking into account of the command variables whose the coefficients depend on the model, invariance compared to a total rotation applied to the problem, the accuracy of the tangent matrix.

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

1 Problem of reference

1.1 Geometry

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

1.2 Properties of the material

the characteristics of the materials are defined for each behavior via command 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 models were selected starting from the benchmarks of Code_Aster. The two following tables summarize all the models of Code_Aster considered and the associated parameters

Model.	viscoplastic models of ASTER	parameters selected	test retained for the choice of parameters
A	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	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 Hardening given 16MND5 parameters ssnv101c kinematical 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 part VISC_SINH Material characteristics 16MND5 for hardening
G	VISC_ISOT_TRAC	curve of tension with 100°C of 16 MND5 SIGM_0=6176. EPSI_0=3.31131121483e13 M=6.76	Test ssnl129 for part VISC_SINH Material characteristics 16MND5 for 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	Choices kinematical 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	Hardening: different data 16MND5 parameters ssnv101c kinematical Choice X1+X2= X of VMIS_CIN1_CHAB Effect of memory.
J	viscoplastic	MONOCRISTAL models of ASTER	plastic Parameters resulting from ssnv171. Orthotropic parameters resulting from SSLV120
K	VMIS_JOHN_COOK	YOUNG = 124000.e6; POISSON = 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. ; POISSON = 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 Characteristic of the ways of loading

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

- cumulated, p of 4 with on 5% the increase dede, a plastic strain group
- of the way 1% plastic strain cumulated p during a portion of the way,
- in the presence of viscosity, a velocity of request in strain respectively of 10-3, 10-4 and $10^{-5}\mathrm{s}^{-1}$. Those were evaluated in an approximate way by considering an equivalent strain of 5% on the group of the way: maybe of times of ways of 50,500 and 5000 seconds respectively for $\mathrm{v1}$, $\mathrm{v2}$ and $\mathrm{v3}$. The restored tests correspond at a velocity of $10^{-5}\mathrm{s}^{-1}$.

This calibration was carried out on model VMIS_ISOT_LINE, then deferred on the other models.

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

Schematically, it follows a path 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 symmetric 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 means of macro-command SIMU_POINT_MAT [U4.51.12]) by requesting a homogeneous element of way while imposing:

- in $3D$, 6 components of the strain tensor:

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

- into $2D$ the 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 strains imposed will be broken up into a hydrostatic and deviatoric part on bases of shears:

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

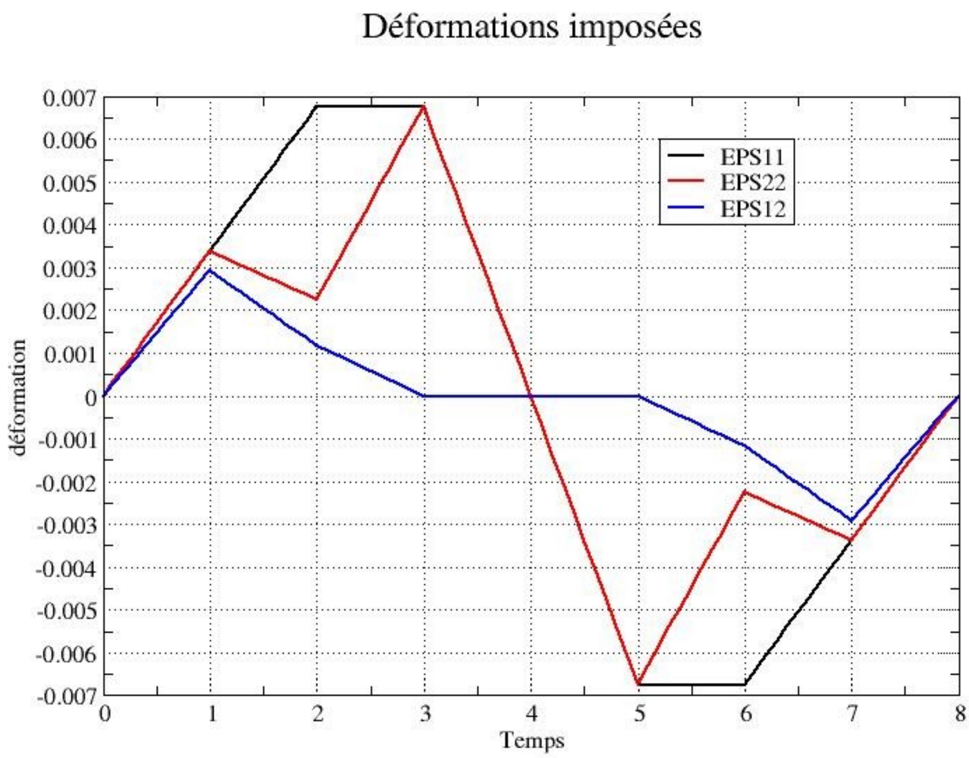
$$\bar{\boldsymbol{\varepsilon}}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}=p\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}+d_1\begin{bmatrix}1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

1.3.3 Description of the way of strain imposed in 2D

the way applied is described in the table below, the values of strains are gauged with respect to the elastic modulus:

times	1	2	3	4	5	6	7	8
Point of loading	A	B	C	O	C'	B'	A'	O
$E.\varepsilon_{xx}$	675	1350	1350	0	-1350	-1350	-675	0.675.450
$E.\varepsilon_{yy}$			1350	0	-1350	-450	-675	0.450.180
$\frac{E}{(1+\nu)}\varepsilon_{xy}$			0	0	0	-180	-450	0.675.900
p			1350		-1350	-900	-675	0
d	0	0.450		0	0	-450	0	0

This way is illustrated by the following graph:

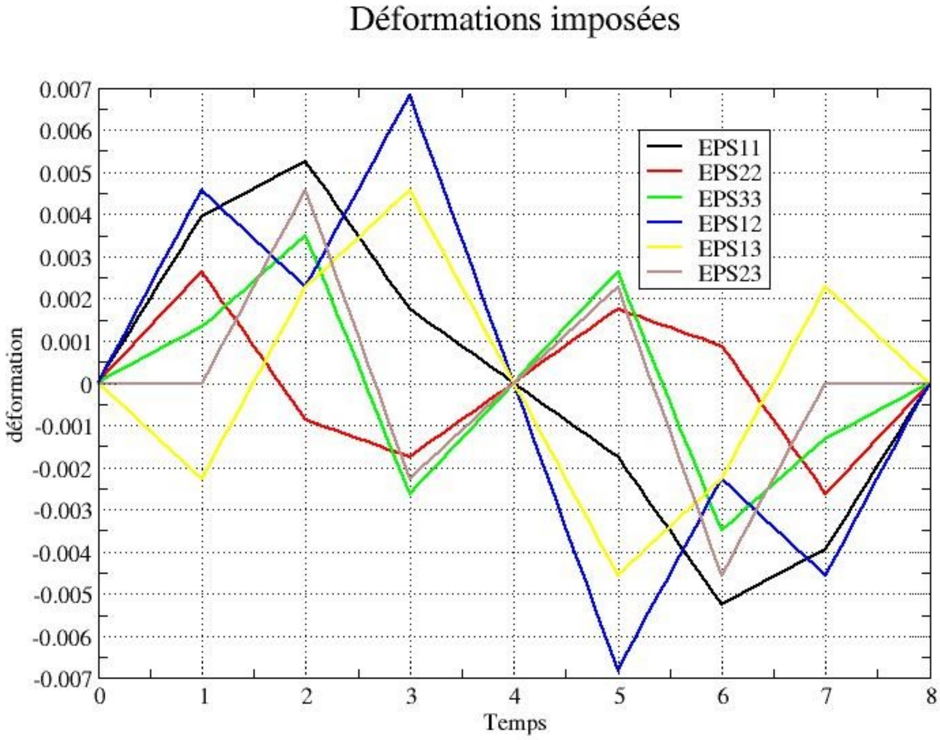


1.3.4 Description of the way of strain imposed in 3D

the way applied is described in the table below, the values of strains applied are gauged with respect to the elastic modulus:

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	0.700.350
$\frac{E}{(1+\nu)}\varepsilon_{xy}$			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	0.525.525
p			-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 Forced

initial conditions and null strains.

2 Reference solution

This test proceeds, for each modelization, with an intercomparison between the reference solution (obtained with one time step very fine), the solution with a fairly coarse discretization, the solution with effect of the temperature (or another command variable), the solution by changing the system of units (Pa into 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 constitutive laws:

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

For each one of them, one studies the evolution the relative differences between several computations using the same model but presenting parameters or different computation options. The operating relates to the invariants of the tensor of the stresses: trace tensor, stress of Von-Put and the local 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:

- computation of the tangent matrix of prediction to each converged increment (REAC_INC=1)
- computation 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 time step for each segment of the way, the solution obtained for each model is compared with 3 strictly equivalent problems for the state of the material point:

- Tpa , even way with a change of unit, one substitutes to them Pa for MPa in the data materials and the possible parameters of the model,
- Trot, way by imposing the same tensor $\bar{\varepsilon}$ after a rotation: $R\,\bar{\varepsilon}\,R^T$ where R is a matrix of rotation. For the case $2D$, the swing angle will be $\alpha=0.9$ radian, for the configuration $3D$, one chose the Eulerian angles 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 $2D$, permutation of x in y , y z and z x of 3D.

For each one of these problems, the solution (invariants of the stresses, cumulated equivalent plastic strain) 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 machine accuracy 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 time step

One studies the behavior of the integration of the models according to the discretization. For the same modelization, 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 period 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 group of way	40.200	
Computation	T1	Tréf reference solution

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

2.4.1 Model 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
TRAC	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 Model 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
TRAC	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 Model 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
TRAC	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 Model 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

TRAC	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	bibliographical
0.00e+00	SIYZ	2.43e-01	5.68e-01	3.11e-01	7.77e-02	1.38e-02

2.5 0.00e+00 References

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

3 Modelization A

3.1 Characteristic of the modelization

the behavior tested is LEMAITRE , in 3D.

3.2 Quantities tested and Modelization

results 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

Matrix tangent, $Theta=1$

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

Modelization 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

Matrix tangent, $Theta=0.5$

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

4 Modelization B

4.1 Characteristic of the modelization

the behavior tested is VISC_CIN1_CHAB , in 3D.

4.2 Quantities tested and Modelization

results 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
$\mathrm{Max}(\mathrm{Ktgte}-\mathrm{Kpert})$	2.2E-4

5 Modelization C

5.1 Characteristic of the modelization

the behavior tested is VISC_CIN2_CHAB , in 3D.

5.2 Quantities tested and Modelization

results 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 Modelization D

6.1 Characteristic of the modelization

the behavior tested is VENDOCHAB , in 3D.

6.2 Quantities tested and Modelization

results 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:

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

7 Modelization E

7.1 Characteristic of the modelization

the behavior tested is VISC_TAHERI , in 3D.

7.2 Quantities tested and Modelization

results 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 Modelization F

8.1 Characteristic of the modelization

the behavior tested is VISC_ISOT_LINE , in 3D.

8.2 Quantities tested and Modelization

results 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 Modelization G

9.1 Characteristic of the modelization

the behavior tested is VISC_ISOT_TRAC , in 3D.

9.2 Quantities tested and Modelization

results 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 Modelization H

10.1 Characteristic of the modelization

the behavior tested is VISC_CIN2_MEMO , in 3D.

10.2 Quantities tested and Modelization

results 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 Modelization I

11.1 Characteristic of the modelization

the behavior tested is VISCOCHAB , in 3D.

11.2 Quantities tested and Modelization

results 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
$\text{Max}(\text{Ktgte}-\text{Kpert})$	$1.69\ 10^{-4}$

Note::

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

12 Modelization J

12.1 Characteristic of the modelization

the behavior tested is MONOCRISTAL , in C_PLAN and 3D.

12.2 Quantities tested and results

Modelization 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

Modelization 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:

The accuracy in case C_PLAN is less good than in 3D case for the loading case " 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 the TEMPS CPU of this test, the iterations (and stopping criteria) 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 the large ones time step).

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

13 Modelization K

13.1 Characteristic of the modelization

the behavior tested is VMIS_JOHN_COOK , in 3D.

13.2 Quantities tested and Standard

Identification	results of reference	Reference	Tolerance
ER_V1_Pa_1	ANALYTIQUE		0.0.1.0E-10
ER_V1_Th_1	ANALYTIQUE		0.0.1.0E-10
ER_V1_sym_1	ANALYTIQUE		0.0.1.0E-10
ER_V1_rot_1	ANALYTIQUE		0.0.1.0E-10
ER_V1_N1	ANALYTIQUE	0.0.0.1	
ER_V1_N5	ANALYTIQUE	0.0	0.01
ER_V1_N25	ANALYTIQUE	0.0	0.01
ER_VMIS_Pa_1	ANALYTIQUE		0.0.1.6E-15
ER_VMIS_Th_1	ANALYTIQUE		0.0.1.0E-10
ER_VMIS_sym_1	ANALYTIQUE		0.0.1.0E-10
ER_VMIS_rot_1	ANALYTIQUE		0.0.1.0E-10
ER_VMIS_N1	ANALYTIQUE		0.0.1.1E-15
ER_VMIS_N5	ANALYTIQUE		0.0.1.1E-15
ER_VMIS_N25	ANALYTIQUE	0.0	0.01
ER_TRACE_Pa_1	ANALYTIQUE		0.0.1.0E-10
ER_TRACE_Th_1	ANALYTIQUE		0.0.1.0E-10
ER_TRACE_sym_1	ANALYTIQUE		0.0.1.0E-10
ER_TRACE_rot_1	ANALYTIQUE		0.0.1.0E-10
ER_TRACE_N1	ANALYTIQUE		0.0.1.8E-15
ER_TRACE_N5	ANALYTIQUE		0.0.1.2E-15
ER_TRACE_N25	ANALYTIQUE	0.0	0.010
MAT_DIFF	ANALYTIQUE		0.0.3.3E-10

14 Modelization L

14.1 Characteristic of the modelization

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

14.2 Quantities tested and Standard

Identification	results of reference	Reference	Tolerance
ER_V7_Pa_1	ANALYTIQUE		0.0.1.0E-5
ER_V7_Th_1	ANALYTIQUE		0.0.1.0E-5
ER_V7_sym_1	ANALYTIQUE		0.0.1.0E-5
ER_V7_rot_1	ANALYTIQUE		0.0.1.0E-5
ER_V7_N10	ANALYTIQUE		0.0.1.0E-5
ER_V7_N30	ANALYTIQUE		0.0.1.0E-5
ER_V7_N60	ANALYTIQUE		0.0.1.0E-10
ER_VMIS_Pa_1	ANALYTIQUE		0.0.1.0E-5
ER_VMIS_Th_1	ANALYTIQUE		0.0.1.0E-5
ER_VMIS_sym_1	ANALYTIQUE		0.0.1.0E-5
ER_VMIS_rot_1	ANALYTIQUE		0.0.1.0E-5
ER_VMIS_N10	ANALYTIQUE		0.0.1.0E-5
ER_VMIS_N30	ANALYTIQUE		0.0.1.0E-5
ER_VMIS_N60	ANALYTIQUE		0.0.1.0E-10
ER_TRACE_Pa_1	ANALYTIQUE		0.0.1.0E-5
ER_TRACE_Th_1	ANALYTIQUE		0.0.1.0E-5
ER_TRACE_sym_1	ANALYTIQUE		0.0.1.0E-5
ER_TRACE_rot_1	ANALYTIQUE		0.0.1.0E-5
ER_TRACE_N10	ANALYTIQUE		0.0.1.0E-5
ER_TRACE_N30	ANALYTIQUE		0.0.1.0E-5
ER_TRACE_N60	ANALYTIQUE		0.0.1.0E-10

15 Synthesis

For all 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 time step, and the diagrams of integration are robust, since they make it possible to use the large ones time step. Let us announce however for these models implementing a viscosity a greater sensitivity to time step than for the elastoplastic models.
- the tangent matrixes are correct because similar to the tangent matrixes calculated by disturbance.