UMAT002 – Test of the Code_Aster-Umat *interface* in linear elasticity under multiaxial loading

Abstract:

One carries out, on a linear elastic problem, a comparison between *Code_Aster-Umat* and *Code-Aster* with behavior ELAS. This test implements a simulation of a way of loading in strains in a material point, i.e. on a model such as the stress states and of strains are homogeneous at any moment. The way of loading is multiaxial with an aim of checking the robustness and the reliability of numerical integration, its insensitivity compared to a change of units, 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 UMAT the model in $3D$.

1 Problem of reference

1.1 Geometry

It acts of a material point, representative of a stress state and strains homogeneous.

1.2 Properties of the materials

1.2.1 Given Umat

the coefficient of the Umat behavior are (cf [U4.43.01]):

$$C1=\lambda=\frac{E\nu}{(1+\nu)(1-2\nu)}$$

$$C2=\mu=\frac{E}{2(1+\nu)}$$

$$C3=\tilde{\lambda}=\frac{\lambda}{20}$$

$$C4=\tilde{\mu}=\frac{\mu}{20}$$

$$C5=\tilde{\nu}=0$$

1.3 Boundary conditions and loadings

the loading is identical to that of the tests COMP001, cf [V6.07.101].

1.3.1 Characteristics of the ways of loading

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

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

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:

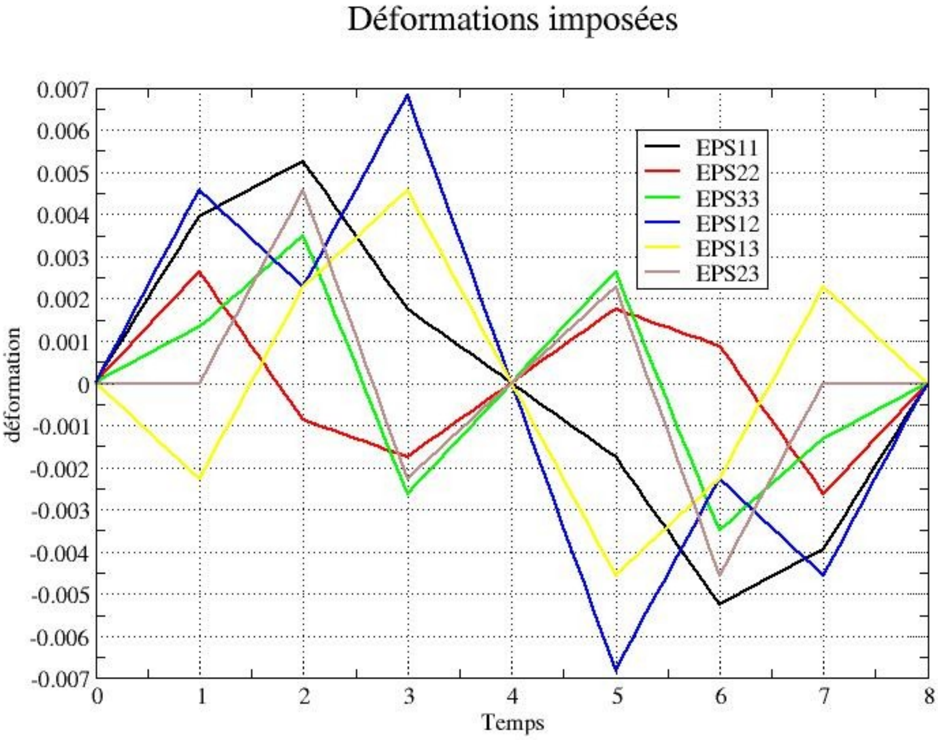
$$\bar{\varepsilon}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}=p\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}+d_1\begin{bmatrix}1 &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

1.3.3 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
$\varepsilon_{xx}*E$	787.5	1050	350	0	-350	-1050	-787.5	0
$\varepsilon_{yy}*E$	525.0	-175	-350	0.350.175			525	0
$\varepsilon_{zz}*E$	262.5	700	-525	0.525		-700	-262.5	0.700.350
$\varepsilon_{xy}*E/(1+\nu)$			1050	0	-1050	-350	-700	0
$\varepsilon_{xz}*E/(1+\nu)$	-350	350.700		0	-700	-350	700	0
$\varepsilon_{yz}*E/(1+\nu)$	0.700		-350	0.350		-700	0	0.525.525
P			-175	0.175		-525	-525	0
$d1$	262.5	525.525		0	-525	-525	-262.5	0
$d2$	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:

- study 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.

2.2 Study 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: ${}^t R \cdot \bar{\varepsilon} \cdot R$ where R is a matrix of rotation defined in part of the following arbitrary Eulerian angles: { $\Psi = 0.9\, radian$, $\theta = 0.7\, radian$ and $\varphi = 0.4\, radian$ }
- $Tsym$, way by imposing the tensor $\bar{\varepsilon}$ after a symmetry: permutation of x in y , y in z and z in x of $3\mathrm{D}$.

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.

3 Modelization A

3.1 Characteristic of the modelization

the coefficient chosen for behavior UMAT correspond to linear elasticity.

3.2 Quantities tested and Modelization

results 3D

Variations (%)	T_{Pa}	T_{sym}	T_{rot}	$N1$	$N5$	$N25$
$VMIS$	0	0	0	0		0
$TRACE$	0	0	0	0	0	0

tangent Matrix

Variations	$N25$
$Max(Ktgte-Kpert)$	1.1 E-11

4 Summary of the results

the results are satisfactory and validate the interface between *Code_Aster* and UMAT in small strains.

- 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.