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

Summary:

One carries out, on a linear elastic problem, a comparison enters *Code_Aster*-Umat and *Code-aster* with the behavior ELAS. This test implements a simulation of a way of loading in deformations in a material point, i.e. on a model such as the stress and strain states are homogeneous at any moment. The way of loading is multiaxial with an aim of checking the robustness and the reliability of digital 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.

Modeling a: this modeling makes it possible to validate the model UMAT in $3D$.

1 Problem of reference

1.1 Geometry

It is about a material point, representative of a stress and strain state homogeneous.

1.2 Properties of materials

1.2.1 Umat data

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

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

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

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

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

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

One will use: `DEFI_MATERIAU/UMAT=_F (LISTE_COEF= (C1, C2, C3, C4, C5)),`

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 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:

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

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

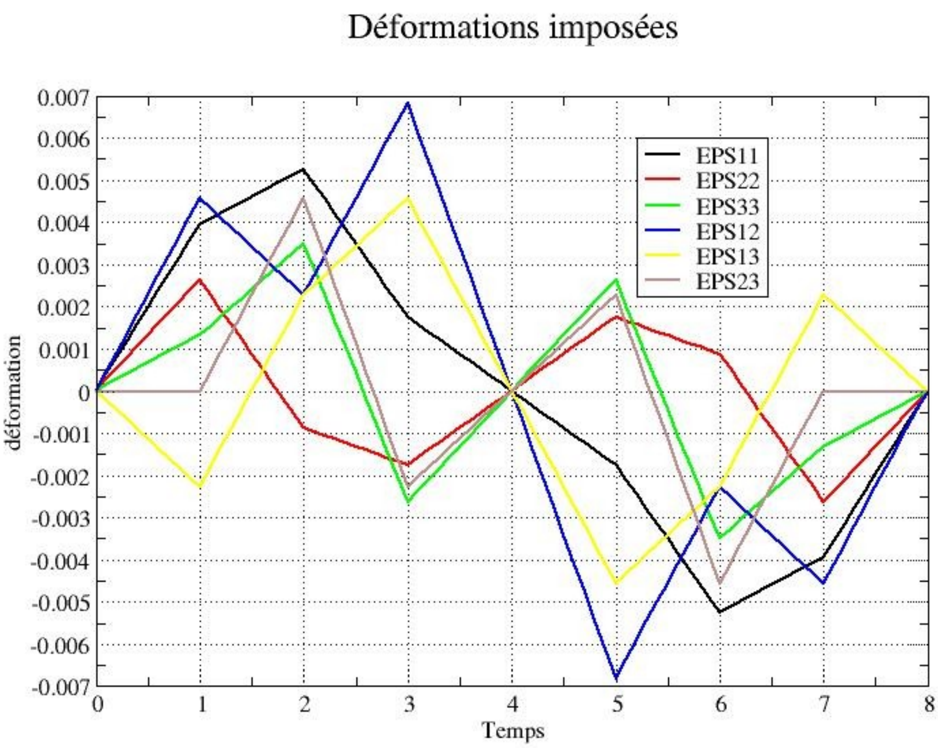
$$\bar{\varepsilon}=\begin{bmatrix}\varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz}\\ \varepsilon_{xy} & \varepsilon_{yy} & \varepsilon_{yz}\\ \varepsilon_{xz} & \varepsilon_{yz} & \varepsilon_{zz}\end{bmatrix}=p\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}+d_1\begin{bmatrix}1 &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

1.3.3 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
$\varepsilon_{xx}*E$	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
$\varepsilon_{xy}*E/(1+\nu)$	700	350	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
P	525	525	-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 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:

- study 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.

2.2 Study 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: ${}^{t}R\cdot\bar{\varepsilon}\cdot R$ where R is a matrix of rotation defined in part of the following arbitrary angles of Euler: $\{\Psi=0.9\,radian$, $\theta=0.7\,radian$ 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 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.

3 Modeling A

3.1 Characteristics of modeling

The coefficient chosen for behavior UMAT correspond to linear elasticity.

3.2 Sizes tested and results

Modeling 3D

Variations (%)	T_{Pa}	T_{sym}	T_{rot}	$N1$	$N5$	$N25$
$VMIS$	0	0	0	0	0.1	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 enters *Code_Aster* and UMAT in small deformations.

- the results are valid during a physical change of unit of the problem (Pa in Mpa), either 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.