SSNV172 – Single-crystal viscoplastic behaviors

Abstract:

This test makes it possible to validate the single-crystal behaviors in a uniaxial situation. The treated geometry is a cube, the stress state and strains is homogeneous. In order to test the constitutive laws as well as possible, independently of the definition of sliding systems, here a system of particular sliding, nonphysical is used, which represents a sliding in only one direction. This makes it possible to compare two of the single-crystal viscoplastic behaviors, (with kinematic hardening defined by a variable of recall) with the macroscopic viscoplastic behavior of Chaboche.

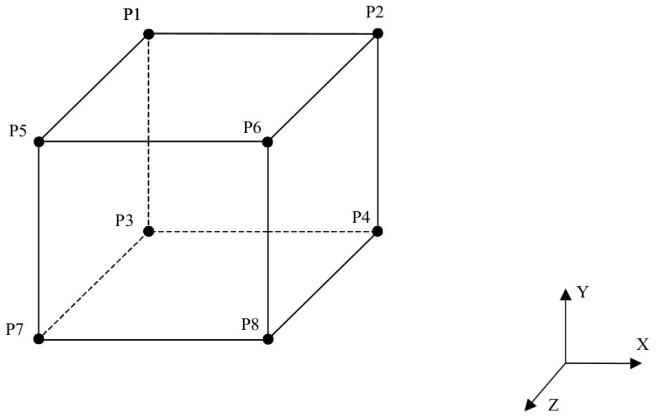
For other behaviors (in particular KOCKS_RAUCH) one checks only non regression results.

All these tests are carried out in the modelization A (3D).

The modelization B allows to validate, always by intercomparison with the model of Chaboche, the single-crystal behaviors in 2D (C_PLAN).

1 Problem of reference

1.1 Geometry



One A defines a material point, represented in the modelization (3D) by a volume element $MA1$, containing the nodes $P1$ $P2$ $P3$ $P4$ $P5$ $P6$, $P7$ and $P8$.

1.2 Material properties

Behavior elastic with: Young modulus : $E=145200\ MPa$
Poisson's ratio: $\nu=0.3$

1.2.1 Computation of reference : behavior VISC_CIN1_CHAB

It acts of the reference solution used in the modelizations A and B. the material parameters are:

```
CIN1_CHAB=_F (R_0=75.5 MPa
              R_I=85.27 MPa
              B=19.34,
              C_I=10.0 MPa
              K=1.0,
              W=0.0,
              G_0=36.68,
              A_I=1.0,),
LEMAITRE=_F (N=10.0,
             UN_SUR_K=0.025 Mpa-1
             UN_SUR_M=0.0,),
```

1.2.2 Behavior single-crystal of type 1, with system of sliding UNIAXIAL

the parameters used here, into uniaxial, correspond to those used for VISC_CIN1_CHAB, by noticing simply that $Q=R_I-R_0$. One must thus get the same results as VISC_CIN1_CHAB.

These behaviors are tested in $3D$ (in the modelization A) and $2D$ plane stresses (in the modelization B).

•Type of flow: **MONO_VISC1** whose parameters are:

$$c=10\ MPa \quad n=10\ , \quad K=40\ MPa$$

•isotropic Type of hardening: **MONO_ISOT1** whose parameters are:

$$R_0=75.5\ MPa \quad b=19.34 \quad Q=9.77\ MPa \quad h=0$$

•Type of kinematic hardening: **MONO_CINE1** whose parameters are:

$$d = 36.68$$

The family of sliding systems is: **UNIAXIAL**

Two computations are carried out: one with implicit local integration, the other with explicit local integration. It is checked that these two computations provide identical results (with the temporal discretization near).

1.2.3 Behavior single-crystal of type 2, comparable to type 1, with system of sliding UNIAXIAL

the behavior of the monocrystal is defined in such way that one is reduced to the behavior of type 1. The results must thus correspond. The parameters are:

•Type of flow: **MONO_VISC2** whose parameters are:

$$n = 10 \quad k = 40\,MPa \quad c = 10\,MPa \quad d = 0\,,\ a = 0$$

•isotropic Type of hardening: **MONO_ISOT2** whose parameters are:

$$R_0 = 75.5 \quad b_1 = 19.34 \quad b_2 = 0 \quad Q_1 = 9.77\,MPa \quad Q_2 = 0$$

•Type of kinematic hardening: **MONO_CINE2** whose parameters are:

$$d = 36.68 \quad M = 0 \quad m = 0 \quad c = 0$$

The family of sliding systems is: **UNIAXIAL**

Two computations are carried out: one with implicit local integration, the other with explicit local integration. It is checked that these two computations of type 1. provide results identical to those of the single-crystal behavior

1.2.4 Behavior single-crystal of type 2, complete test

the parameters of the behavior of the monocrystal of the type 2 are all non-zero:

•Type of flow: **MONO_VISC2** whose parameters are:

$$n = 10 \quad k = 40\,MPa \quad c = 10\,MPa \quad d = 0.1\,,\ a = 0.5$$

•isotropic Type of hardening: **MONO_ISOT2** whose parameters are:

$$R_0 = 75.5 \quad b_1 = 19.34 \quad b_2 = 10 \quad Q_1 = 9.77\,MPa \quad Q_2 = 10$$

•Type of kinematic hardening: **MONO_CINE2** whose parameters are:

$$d = 36.68 \quad M = 10 \quad m = 0{,}1 \quad c = 10$$

The family of sliding systems is: **UNIAXIAL.** The tests are of non regression.

1.2.5 Computation with the behavior monocrystal of the type 1 and one orthotropic elasticity

the parameters of the orthotropy correspond in fact to the isotropy:

```
ELAS_ORTH=_F (  E_L = 145200.0,
                E_T = 145200.0,
                E_N = 145200.0,
                NU_LT = 0. ,
                NU_LN = 0. ,
                NU_TN = 0. ,
                G_LT = 72600. ,
                G_LN = 72600. ,
                G_TN = 72600),
```

the results must thus correspond to the computation of reference. Two computations are carried out: one with implicit local integration, the other with explicit integration.

1.2.6 Computation with the behavior monocrystal of the type 1 and the sliding systems of ZIRCONIUM

Five computations are carried out with this family of sliding systems:
1.a computation of non regression with the family defined in the code
2.a comparative computation in the first, by providing an array containing the matrix of interaction
3.a comparative computation to the precedents, with a polycrystal comprising only one grain,
4.a comparative computation with the precedents, by providing five families defined from an array containing sliding systems. The set of these systems corresponds to the Zirconium family. This tests the possibility of defining different coefficients material according to sliding systems considered,
5.a computation identical to the precedent, with a polycrystal comprising only one grain.

1.2.7 Behavior Kocks-Rauch: single-crystal, with system of sliding BCC24

the behavior of the monocrystal is defined by flow: **MONO_DD_KR** whose parameters are:

```
K      = 8.62E-5,
TAUR   = 498. ,
TAU0   = 132. ,
GAMMA0 = 1.E6,
DELTAG0= 0.768,
BSD    = 2.514E-5,
GCB    = 31.822,
KDCS   = 22.9,
P      = 0.335,
Q      = 1.12,
H1     = 0.25,
H2     = 0.25,
H3     = 0.25,
H4     = 0.25
```

Three computations are carried out with this behavior:
1) An implicit computation MONOCRISTAL
2) a computation MONOCRISTAL clarifies
3) a computation POLYCRISTAL clarifies, with only one phase
These three computations must lead to the same results.

1.3 Boundary conditions and loadings

The node is outside the field of definition with a right profile of the EXCLU type node: $P4$	$DX=DY=0$
The node is outside the field of definition with a right profile of the EXCLU type node: $P8$	$DX=DY=DZ=0$
Nodes $P2$ and $P6$	: $DX=0$
Nodes $P1$ $P3$, $P5$ and $P7$	: either $FX=25$, or $DX=0.001$

the loading in imposed force is increasing of $FX=0$ with $FX=25\times 0.755\,N$, in an increment, which leads to a uniaxial stress state of $75.5\,MPa$ (limit of linearity)
the loading believes then until $FX=25\times 0.955\,N$ in n increments. The computation from reference is obtained with $n=100$. Single-crystal computations are carried out with $n=20$.

With regard to behaviors MONO_VISC2 and MONO_DD_KR, the loading is a varying imposed displacement of 0, at initial time, 0.001 at time 2, in m increments.

For the implicit resolutions $m=20$, and the explicit resolutions $m=100$.

For the modelization B the loading is a varying imposed displacement of 0, at initial time, 0.001 at time 3, in 20 increments.

2 Reference solution

2.1 Méthode de calcul

In 3D , (modelization A), the first computation (behavior VISC_CIN1_CHAB) is used as reference. The values obtained with the last increment are (in any point of the mesh):

Stress	*SIXX*	-9.55E+01
total Deflection	*EPXX*	-6.76443E-04
Plastic strain	*EPXX*	-1.87292E-05

computations with MONO_ISOT1 or the first computations with MONO_ISOT2 is validated by comparison with this result or intercomparison.

On the other hand, other computations (behaviors MONO_VISC2, MONO_DD_KR) do not have a value of reference. The tests are thus of NON-regression. Moreover, five computations corresponding to Zirconium do not have a reference solution but must give only one and even solution.

In 2D , (modelization B), the first computation (behavior VISC_CIN1_CHAB) is used as reference. The values obtained with the last increment are (in any point of the mesh, because one imposes a uniform strain):

Stress	*SIXX*	95.999316

the second and the third computations (behavior MONOCRISTAL with system of sliding UNIAXIAL) are validated by comparison with this result.

The third computation uses an explicit integration (RUNGE_KUTTA), whereas the second computation uses an implicit integration.

3 Modelization A

3.1 Characteristic of the mesh

Many nodes: 8. Modelization 3D : 1 quadratic volume element: **HEXA8**.
The structure contains only one grain, the stress state and of strains is homogeneous.

3.2 Quantities tested and results

3.2.1 Behavior of type 1: MONO_VISC1 , MONO_ISOT1 , MONO_CINE1

Integration	Identification	Reference	% Tolerance
implicit	ε_{xx} of EPSI_ELGA	-6.764427E-04	0.10
implicit	ε_{xx} of EPSP_ELGA	-1.87292E-05	2.0
Behavior	ε_{xx} clarifies	EPSI_ELGA	-6.764427E-04
0.2	ε_{xx} explicit of	EPSP_ELGA	-1.87292E-05

3.2.2 4.0 of type 2: MONO_VISC2 , MONO_ISOT2 , MONO_CINE2

Comparison between MONO_VISC2 , MONO_ISOT2 , MONO_CINE2 and MONO_VISC1, MONO_ISOT1, MONO_CINE1

Integration	Identification	Reference	% Tolerance
implicit	ε_{xx} of EPSI_ELGA	-6.76241E-04	0.10
implicit	ε_{xx} of EPSP_ELGA	-1.85279E-05	0.10
Behavior	ε_{xx} clarifies	EPSI_ELGA	-6.757537E-04
0.10	ε_{xx} explicit of	EPSP_ELGA	-1.804038E-05

3.2.3 0.10 of type 2: MONO_VISC2 , MONO_ISOT2 , Non regression

MONO_CINE2 for MONO_VISC2 , MONO_ISOT2 , MONO_CINE2

Integration	Identification	Reference	% Tolerance
implicit	σ_{xx} of EPSI_ELGA	-95.9311	0.10
implicit	ε_{xx} of EPSP_ELGA	-1.3393175E-03	0.10

3.2.4 Behavior of type 1 with ELAS_ORTH

Comparison between MONO_VISC1 , MONO_ISOT1 , MONO_CINE1, with ELAS and ELAS_ORTH

Integration	Identification	Reference	% Tolerance
implicit	ε_{xx} of EPSI_ELGA	-6.76241E-04	0.10
Behavior	ε_{xx} clarifies	EPSI_ELGA	-6.75754E-04

3.2.5 0.10 of type 1: MONO_VISC1 , MONO_ISOT1 , MONO_CINE1 for ZIRCONIUM

the First computation: sliding systems stamp interaction (matrix identity h=0) and defined in Code_Aster:

Integration	Identification	Reference	% Tolerance
Implicit	σ_{xx} of SIEF_ELGA	-212.31	0.1
implicit	ε_{xx} of EPSP_ELGA	-5.3785E-04	0.1
implicit	v_{92} of VARI_ELGA	5.2868E-04	the 0.1

Second computation: sliding systems defined in Code_Aster, matrix of interaction defined by the user (matrix identity, provided in data in an array). Comparison with the first computation.

Integration	Identification	Reference	% Tolerance
Implicit	σ_{xx} of SIEF_ELGA	-212.3	0.1
implicit	ε_{xx} of EPSP_ELGA	-5.3785E-04	0.1
implicit	v_{92} of VARI_ELGA	5.2868E-04	the 0.1

Third computation: sliding systems defined in Code_Aster, matrix of interaction defined by the user (matrix identity, provided in data in an array), and behavior POLYCRISTAL :

Integration	Identification	Reference	% Tolerance
Polycrystal	σ_{xx} of SIEF_ELGA	-212.3	0.1
Polycrystal	ε_{xx} of EPSP_ELGA	-5.3785E-04	0.1
Polycrystal	v_{99} of VARI_ELGA	5.2868E-04	the 0.1

Fourth computation: sliding systems and interaction stamps defined by the user:

Integration	Identification	Reference	% Tolerance
Implicit	σ_{xx} of SIEF_ELGA	-212.3	0.1
implicit	ε_{xx} of EPSP_ELGA	-5.3785E-04	0.1
implicit	v_{92} of VARI_ELGA	5.2868E-04	the 0.1

Fifth computation: sliding systems and interaction stamps defined by the user, and behavior POLYCRISTAL (only one phase, to allow the comparison with preceding computations):

Integration	Identification	Reference	% Tolerance
Polycrystal	σ_{xx} of SIEF_ELGA	-212.3	0.1
Polycrystal	ε_{xx} of EPSP_ELGA	-5.3785E-04	0.3
Polycrystal	v_{99} of VARI_ELGA	5.2868E-04	0.8

3.2.6 Behavior: MONO_DD_KR

Integration	Identification	Reference	% Tolerance
implicit	σ_{xx} of SIEF_ELGA	-324.37	0.40
implicit	ε_{xx} of EPSP_ELGA	-8.1822E-04	0.20
clarifies	σ_{xx} SIEF_ELGA	-324.37	0.40
explicit	ε_{xx} of EPSP_ELGA	-8.1822E-04	0.05
Polycrystal	σ_{xx} of SIEF_ELGA	-324.37	0.40
Polycrystal	ε_{xx} of EPSP_ELGA	-8.1822E-04	0.05

4 Modelization B

4.1 Characteristic of the mesh

Many nodes: 4.
1 mesh **QUAD4**.
Modelization C_PLAN (by method DEBORST).

4.2 Quantities tested and results

the Second computation (implicit, MONO_VISC1, MONO_ISOT1, MONO_CINE1)

Identification	Reference	% Tolerance
σ_{xx} of SIEF_ELGA	-95.9993	the 0.10

Third computation (clarifies, MONO_VISC1, MONO_ISOT1, MONO_CINE1)

Identification	Reference	% Tolerance
σ_{xx} of SIEF_ELGA	-95.9993	0.10

5 Summary of the results

the got results are in concord with the reference solution. The noted difference ($3,6\%$ to the maximum) comes from the different numerical diagrams, sensitive to the temporal discretization.