COMP008 – Thermomechanical validation of the elastoplastic laws

Summary

This test makes it possible to validate the taking into account of the temperature variation in the laws of elastoplastic behavior. These tests make it possible to check the two following points:

- Thermal dilation is well calculated (with taking into account of the variation of thermal dilation with the temperature)
- The variation of the coefficients material with the temperature is correct, in particular in the incremental resolution of the behavior,

The laws of behaviors validated are the following ones:

- Modeling A : this modeling makes it possible to validate the model ELAS with an isotropic material
- Modeling B : this modeling makes it possible to validate the model ELAS with an orthotropic material,
- Modeling C : this modeling makes it possible to validate the model VMIS_ISOT_LINE,
- Modeling D : this modeling makes it possible to validate the model VMIS_CINE_LINE,
- Modeling E : this modeling makes it possible to validate the model VENDOCHAB,
- Modeling F : this modeling makes it possible to validate the model VMIS_ECMI_LINE,
- Modeling G : this modeling makes it possible to validate the model VMIS_CIN1_CHAB,
- Modeling H : this modeling makes it possible to validate the model VMIS_CIN2_CHAB,
- Modeling I : this modeling makes it possible to validate the model VMIS_CIN2_MEMO,
- Modeling J : this modeling makes it possible to validate the model VISC_CIN1_CHAB,
- Modeling K : this modeling makes it possible to validate the model VISC_CIN2_CHAB,
- Modeling L : this modeling makes it possible to validate the model VISC_CIN2_MEMO,
- Modeling M : this modeling makes it possible to validate elasticity isotropic transverse,
- Modeling N : this modeling makes it possible to validate the model ROUSS_PR.

- Modeling O : this modeling makes it possible to validate the model VMIS_JOHN_COOK.

1 Methodology

It is about a double simulation, the first into thermomechanical, the second in pure mechanics. The first will be validated in comparison with the second, by supposing of course that the behavior tested provides a correct solution in pure mechanics.

1.1 Simulation 1

The first simulation (solution which one seeks to validate) consists in applying a temperature variation to a material point, by blocking the deformations according to x : $\varepsilon_{xx}=0$. The imposed temperature is increasing linearly according to time.
Except contrary mention, Ltemperature has varies $T_0=20°C$ with $T_{max}=500°C$. The parameters material are selected so that part of the transient is in the nonlinear field of the law of behavior, except in elasticity. The transient is made up of `NCAL` pas. La temperature of reference is of $T_{Ref}=T_0$.

1.2 Simulation 2

The second simulation (which must be equivalent to the first) consists in applying, in pure mechanics, without thermics, and at every moment, a deformation imposed according to x equivalent to the thermal deformation of the first simulation: It is thus a question of carrying out a loop on `NCAL` mechanical calculations. With each calculation i, the imposed loading is made up by the thermal deformation $\varepsilon_{xx}=-\varepsilon_{th}=-\alpha(T)(T_i-T_{Ref})$. The initial loading is made up by the strains, stresses and internal variables of preceding mechanical calculation.

Indeed, for any behavior (while supposing the additive decomposition of the deformations):

$$\sigma_{xx}=E(T)(\varepsilon_{xx}-\varepsilon^{th}-\varepsilon^{p}_{xx})$$

in the first case, $\sigma_{xx}=E(T)(0-\varepsilon^{th}-\varepsilon^{p}_{xx})$, and in the second: $\sigma_{xx}=E(T)(\varepsilon-\varepsilon^{p}_{xx})$.

It is thus enough, at every moment to apply, for mechanical calculation, $\varepsilon_{xx}=-\varepsilon^{th}=-\alpha(T)(T-T_{ref})$.

Moreover, to get the same results in both cases, it is necessary, with each step of time of the second simulation, to carry out pure mechanical calculation with coefficients whose values are interpolated according to the temperature at the current moment. This interpolation is carried out in the command file of the test, in a loop in time external with `STAT_NON_LINE` .

2 Interpretation of the results

It is a question of checking that the result obtained at every moment mechanical transient thermo of the first simulation is identical to the result got with the second simulation:

- Lhas value to test is the component of the field extracted at a given moment i the first thermomechanical simulation carried out on `NCAL` moments.
- the value of reference is that obtained for mechanical calculation

3 Modeling A

3.1 Characteristics of modeling

The law of behavior tested is ' ELAS '. This elastic law is associated with an isotropic material.
The temperature varies here $T_0=51.7°C$ with $T_{max}=101.7°C$. The elastic parameters are the following:

Parameters	$T=51.7°C$	$T=76.7°C$	$T=101.7°C$
$E(T)$	$1.0\ MPa$	$1.1\ MPa$	$1.2\ MPa$
$\nu(T)$	0.0	0.0	0.0
$\alpha(T)$	$1.\times10^{-5}\ K^{-1}$	$1.5\times10^{-5}\ K^{-1}$	$2.\times10^{-5}\ K^{-1}$

3.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_4	VMIS	AUTRE_ASTER	1.2E-3	0.10%
RESU_4	TRACE	AUTRE_ASTER	-1.2E-3	0.10%

4 Modeling B

4.1 Characteristics of modeling

The temperature varies $T_0=51.7°C$ with $T_{max}=101.7°C$. The law of behavior tested is 'ELAS'. Cette elastic law is associated an orthotropic material, whose elastic parameters are the following:

Parameters	$T=51.7°C$	$T=76.7°C$	$T=101.7°C$
$E_L(T)=E_N(T)=E_T(T)$	$1.0\ MPa$	$1.1\ MPa$	$1.2\ MPa$
$\nu_{LN}(T)=\nu_{LT}(T)=\nu_{TN}(T)$	0.0	0.0	0.0
$G_{LN}(T)=G_{LT}(T)=G_{TN}(T)$	$0.5\ MPa$	$0.55\ MPa$	$0.6\ MPa$
$\alpha_L(T)=\alpha_N(T)=\alpha_T(T)$	$1.\times10^{-5}\ K^{-1}$	$1.5\times10^{-5}\ K^{-1}$	$2.\times10^{-5}\ K^{-1}$

4.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_4	VMIS	AUTRE_ASTER	1.2E-3	0.10%
RESU_4	TRACE	AUTRE_ASTER	-1.2E-3	0.10%

5 Modeling C

5.1 Characteristics of modeling

The law of behavior tested is 'VMIS_ISOT_LINE'documented in Doc. [R5.03.02]. It is a law of Von Mises with linear isotropic work hardening. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

Parameters elastoplastic are the following:

$\sigma_y(T)$, $E_T(T)$

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$\sigma_y(T)$	100. MPa	50. MPa
$E_T(T)$	10000. MPa	5000. MPa

5.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACE	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	9.025E-03	0.10%

6 Modeling D

6.1 Characteristics of modeling

The law of behavior tested is 'VMIS_CINE_LINE'documented in Doc. [R5.03.02]. This law is with linear kinematic work hardening (law of Prager). The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$\sigma_y(T)$, $E_T(T)$

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$\sigma_y(T)$	100. MPa	50. MPa
$E_T(T)$	10000. MPa	5000. MPa

6.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACE	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	-30.3333	0.10%

7 Modeling E

7.1 Characteristics of modeling

The law of behavior tested is 'VENDOCHAB' . It is a viscoplastic law of behavior coupled with the isotropic damage of Lemaitre-Chaboche [R5.03.15]. The elastic parameters are the following:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$150000\ MPa$	$100000\ MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$1.\times10^{-5}\ K^{-1}$	$2.\times10^{-5}\ K^{-1}$

The parameters of the viscoplastic law are the following:

$S(T)$, $\alpha_D(T)$, $\beta_D(T)$, $1/K(T)$, $A_D(T)$, $R_D(T)$ and $K_D(T)$

$N(T)$, $1/K(T)$ and $1/M(T)$

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$S(T)$	$0.\ MPa$	$900.\ MPa$
$\alpha_D(T)$	$0.$	$1.$
$\beta_D(T)$	$0.$	$1.$
$A_D(T)$	$3.\times10^3\ MPa$	$3.5\times10^3\ MPa$
$R_D(T)$	6	7
$K_D(T)$	15	10

Parameters	$T=20°C$	$T=500°C$
$N(T)$	12	15
$1/K(T)$	$5.\times10^{-3}(Mpa)^{-1}$	$1.\times10^{-3}(Mpa)^{-1}$
$1/M(T)$	$0.$	0.1111

7.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS (MPa)	AUTRE_ASTER	959.9793	0.10%
RESU_9	TRACE (MPa)	AUTRE_ASTER	-959.9802	0.10%
RESU_9	V1	AUTRE_ASTER	-9.8381E-08	0.10%

8 Modeling F

8.1 Characteristics of modeling

The law of behavior tested is 'VMIS_ECMI_LINE'documented in Doc. [R5.03.16]. It is a law of Von Mises with a linear kinematic work hardening and a linear isotropic work hardening. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

Parameters elastoplastic are the following:

$\sigma_y(T)$, $E_T(T)$ and $C(T)$.

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$\sigma_y(T)$	100. MPa	50. MPa
$E_T(T)$	10000. MPa	5000. MPa
$C(T)$	2000. MPa	500. MPa

8.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS (MPa)	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACE (MPa)	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	9.025E-03	0.10%

9 Modeling G

9.1 Characteristics of modeling

The law of behavior tested is 'VMIS_CIN1_CHAB'documented in Doc. [R5.03.04]. It is about a law of Chaboche with nonlinear kinematic work hardening. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$R_I(T)$, $R_0(T)$, $B(T)$, $C_I(T)$, $G_0(T)$, K, W, A_I

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$R_I(T)$	300. MPa	150. MPa
$R_0(T)$	100. MPa	50. MPa
$B(T)$	12.	5.
$C_I(T)$	2000. MPa	500. MPa
$G_0(T)$	45.	75.
K	1.	1.
W	0.	0.
A_I	1.	1.

9.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS (MPa)	AUTRE_ASTER	57.9707	0.10%
RESU_9	TRACE (MPa)	AUTRE_ASTER	-57.9707	0.10%
RESU_9	V1	AUTRE_ASTER	9.4202E-03	0.10%

10 Modeling H

10.1 Characteristics of modeling

The law of behavior tested is 'VMIS_CIN2_CHAB'documented in Doc. [R5.03.04]. It is a law of Chaboche with two work hardenings nonlinear kinematics.

The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$R_I(T)$, $R_0(T)$, $B(T)$, $C1_I(T)$, $C2_I(T)$, $G1_0(T)$, $G2_0(T)$, K, W, A_I

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$R_I(T)$	300. MPa	150. MPa
$R_0(T)$	100. MPa	50. MPa
$B(T)$	12.	5.
$C1_I(T)$	2000. MPa	500. MPa
$C1_I(T)$	2000. MPa	500. MPa
$G1_0(T)$	45.	75.
$G2_0(T)$	45.	75.
K	1.	1.
W	0.	0.
A_I	1.	1.

10.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	61.3071	0.10%
RESU_9	TRACE	AUTRE_ASTER	-61.3071	0.10%
RESU_9	V1	AUTRE_ASTER	9.3869E-03	0.10%

11 Modeling I

11.1 Characteristics of modeling

The law of behavior tested is ‘VMIS_CIN2_MEMO‘documented in Doc. [R5.03.04]. It is about a law of Chaboche comprising two variables of nonlinear kinematic work hardening and modeling the effect of memory. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$R_I(T)$, $R_0(T)$, $B(T)$, $C1_I(T)$, $C2_I(T)$, $G1_0(T)$, $G2_0(T)$, K, W, A_I, $MU(T)$, $Q\_M(T)$, $Q\_0(T)$ and ETA.

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E-5 K^{-1}	2.E-5 K^{-1}
$R_I(T)$	300. MPa	150. MPa
$R_0(T)$	100. MPa	50. MPa
$B(T)$	12.	5.
$C1_I(T)$	2000. MPa	500. MPa
$C1_I(T)$	2000. MPa	500. MPa
$G1_0(T)$	45.	75.
$G2_0(T)$	45.	75.
$K(T)$	1.	1.
$W(T)$	0.	0.
$A_I(T)$	1.	1.
$MU(T)$	17.	19.
$Q\_M(T)$	340. MPa	460. MPa
$Q\_0(T)$	140. MPa	100. MPa
ETA	0.5	0.5

11.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	66.0797	0.10%
RESU_9	TRACE	AUTRE_ASTER	-66.0798	0.10%

RESU_9	V1	AUTRE_ASTER	9.3392E-03	0.10%

12 Modeling J

12.1 Characteristics of modeling

The law of behavior tested is 'VISC_CIN1_CHAB'documented in Doc. [R5.03.04]. It is a viscoplastic law of Chaboche with a kinematic work hardening nonlinear, similar to the law of modeling G, with viscosity moreover. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$R_I(T)$, $R_0(T)$, $B(T)$, $C1_I(T)$, $G1_0(T)$, K, W, A_I.
The parameters of viscosity are the following:

N, $1/K(T)$ and $1/M(T)$.

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$R_I(T)$	300. MPa	150. MPa
$R_0(T)$	100. MPa	50. MPa
$B(T)$	12.	5.
$C_I(T)$	2000. MPa	500. MPa
$G_0(T)$	45.	75.
K	1.	1.
W	0.	0.
A_I	1.	1.
N	24.	16.
$1/K$	1/100. MPa^{-1}	1/150. MPa^{-1}
$1/M$	0.	0.

12.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	171.5016	0.10%
RESU_9	TRACE	AUTRE_ASTER	-171.5016	0.10%

RESU_9	V1	AUTRE_ASTER	8.28498E-03	0.10%

13 Modeling K

13.1 Characteristics of modeling

The law of behavior tested is 'VISC_CIN2_CHAB'documented in Doc. [R5.03.04]. It is a viscoplastic law of Chaboche with two variables of kinematic work hardening nonlinear, similar to the law of modeling H, with viscosity moreover. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

The elastoplastic parameters are the following:

$R_I(T)$, $R_0(T)$, $B(T)$, $C1_I(T)$, $C2_I(T)$, $G1_0(T)$, $G2_0(T)$, K, W, A_I.

The parameters of viscosity are the following: N, $1/K(T)$ and $1/M(T)$.

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$R_I(T)$	300. MPa	150. MPa
$R_0(T)$	100. MPa	50. MPa
$B(T)$	12.	5.
$C1_I(T)$	2000. MPa	500. MPa
$C2_I(T)$	2000. MPa	500. MPa
$G1_0(T)$	45.	75.
$G2_0(T)$	45.	75.
K	1.	1.
W	0.	0.
A_I	1.	1.
N	24.	16.
$1/K$	1/100. MPa^{-1}	1/150. MPa^{-1}
$1/M$	0.	0.

13.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Value of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	174.5461	0.10%
RESU_9	TRACE	AUTRE_ASTER	-174.5470	0.10%
RESU_9	V1	AUTRE_ASTER	8.2545E-03	0.10%

14 Modeling L

14.1 Characteristics of modeling

The law of behavior tested is 'VISC_CIN2_MEMO'[R5.03.04]. It is about a law of Chaboche comprising two variables of nonlinear kinematic work hardening and modeling the effect of memory. (cf modeling I, with besides the parameters of viscosity: N, $1/K(T)$ and $1/M(T)$.

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$R_I(T)$	300. MPa	150. MPa
$R_0(T)$	100. MPa	50. MPa
$B(T)$	12.	5.
$C1_I(T)$	2000. MPa	500. MPa
$C2_I(T)$	2000. MPa	500. MPa
$G1_0(T)$	45.	75.
$G2_0(T)$	45.	75.
K	1.	1.
W	0.	0.
A_I	1.	1.
$MU(T)$	17.	19.
$Q\_M(T)$	340. MPa	460. MPa
$Q\_0(T)$	140. MPa	100. MPa
ETA	0.5	0.5
N	24.	16.
$1/K$	1/100. MPa^{-1}	1/150. MPa^{-1}
$1/M$	0.	0.

14.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	toleranc e
RESU_9	VMIS	AUTRE_ASTER	178.3386	0.10%
RESU_9	TRACE	AUTRE_ASTER	-178.3386	0.10%
RESU_9	V1	AUTRE_ASTER	8.2166E-03	0.10%

15 Modeling M

15.1 Characteristics of modeling

The temperature varies here $T_0=51.7°C$ with $T_{max}=101.7°C$. Llaw of behavior tested has is 'ELAS'. Cette elastic law is associated with a transverse isotropic material. The elastic parameters are the following:

$E_L(T)$, $E_N(T)$, $\nu_{LN}(T)$, $\nu_{LT}(T)$, $G_{LN}(T)$, $\alpha_L(T)$ and $\alpha_N(T)$

Values of the parameters used:

Parameters	$T=51.7°C$	$T=76.7°C$	$T=101.7°C$
$E_L(T)$	1.0 MPa	1.1 MPa	1.2 MPa
$E_N(T)$	1.0 MPa	1.1 MPa	1.2 MPa
$\nu_{LN}(T)$	0.0	0.0	0.0
$\nu_{LT}(T)$	0.0	0.0	0.0
$G_{LN}(T)$	0.5 MPa	0.55 MPa	0.6 MPa
$\alpha_L(T)$	$1.\times10^{-5}$ K^{-1}	1.5×10^{-5} K^{-1}	$2.\times10^{-5}$ K^{-1}
$\alpha_N(T)$	$1.\times10^{-5}$ K^{-1}	1.5×10^{-5} K^{-1}	$2.\times10^{-5}$ K^{-1}

15.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_4	VMIS	AUTRE_ASTER	1.2E-3	0.10%
RESU_4	TRACE	AUTRE_ASTER	-1.2E-3	0.10%

16 Modeling NR

16.1 Characteristics of modeling

Llaw of behavior tested has is ‘ROUSS_PR‘. It is an elastoplastic law modelling the damage due to the growth of cavities, used in the modeling of the ductile rupture of metals. The temperature varies here $T_0=20°C$ with $T_{max}=800°C$

Values of the parameters used:

Parameters	$T=20°C$	$T=800°C$
$E(T)$	2.1E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
$D(T)$	1,5	1,5
$BETA$	1	1
PORO_INIT	5.10^{-4}	5.10^{-4}
S_1(T)	500. MPa	500. MPa
Traction diagrams	$\varepsilon;\sigma(MPa)$	$\varepsilon;\sigma(MPa)$
First point	$\frac{800}{2.1\,10^5};800.0$	$\frac{600}{1.0\,10^5};600.0$
Second point	1,005; 1600,	1,005; 1200,

16.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	Tolerance
RESU_29 (t=1, T=800°C)	VMIS	AUTRE_ASTER	605.5	0.10%
RESU_29 (t=1, T=800°C)	TRACE	AUTRE_ASTER	−605.5	0.10%
RESU_29 (t=1, T=800°C)	V1	AUTRE_ASTER	9.546E−03	0.10%
RESU_29 (t=1, T=800°C)	V2	AUTRE_ASTER	5.046E−04	0.10%

17 Modeling O

17.1 Characteristics of modeling

The law of behavior tested is 'VMIS_JOHN_COOK'documented in Doc. [R5.03.02]. It is a law of Von Mises with isotropic work hardening of Johnson-Cook. The elastic parameters are the following:

$E(T)$, $\nu(T)$ and $\alpha(T)$

Parameters elastoplastic are the following:

A, B, C, N_{PUISS}, M_{PUISS}, $EPSP0$, $TROOM$ and $TMELT$

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	2.E5 MPa	1.E5 MPa
$\nu(T)$	0.	0.
$\alpha(T)$	1.E−5 K^{-1}	2.E−5 K^{-1}
A	90. MPa	
B	292. MPa	
C	0.025	
N_{PUISS}	0.31	
M_{PUISS}	1.09	
$EPSP0$	10000 s^{-1}	
$TROOM$	298 $°K$	
$TMELT$	1083 $°K$	

17.2 Sizes tested and results

Result with the sequence number i	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACE	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	9.025E-03	0.10%

18 General synthesis of the results

For each studied law of behavior, the results of the mechanical transient thermo of the first simulation are compared with those obtained with the second simulation in pure mechanics. The results are concordant, which show the good taking into account of thermal dilation by these laws of behavior, as well as the good dependence of the parameters materials at the temperature.