COMP008 – Thermomechanical validation of the elastoplastic models

Summarized

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

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

the validated constitutive laws are the following ones:

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

- Modelization O : this modelization makes it possible to validate VMIS_JOHN_COOK the model.

1 Methodology

It acts of 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 strains according to x : $\varepsilon_{xx}=0$. The imposed temperature is increasing linearly according to time.
Except contrary mention, the temperature varies from $T_0=20°C$ with $T_{max}=500°C$. The material parameters are selected so that part of the transient is in the nonlinear field of the constitutive law , except in elasticity. The transient consists of `NCAL` not. The reference temperature 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 thermal, and at every moment, a strain imposed according to x equivalent to the thermal strain of the first simulation: It is thus a question of carrying out a loop on `NCAL` mechanical computations. A each computation i , the imposed loading is made up by the thermal strain $\varepsilon_{xx}=-\varepsilon_{th}=-\alpha(T)(T_i-T_{Ref})$. The initial loading is made up by the strains, stresses and local variables of preceding mechanical computation.

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

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

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

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

Moreover, to get the same results in both cases, it is necessary, with each time step of the second simulation, to carry out pure mechanical computation with coefficients whose values are interpolated according to the temperature at current time. 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 acts to check that result at every moment obtained mechanical transient thermo of the first simulation identical to is result obtained with the second simulation:

- the value to be tested is the component of the field extracted at a time given i the first thermomechanical simulation carried out on `urgent` NCAL.
- the value of reference is that obtained for mechanical computation

3 Modelization A

3.1 Characteristic of the modelization

the constitutive law tested is " ELAS ". This elastic model 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
$\alpha(T)$	$1.\times 10^{-5}\ K^{-1}$	$1.5\times 10^{-5}\ K^{-1}$	$2.\times 10^{-5}\ K^{-1}$

3.2 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_4	VMIS	AUTRE_ASTER	1.2E-3	0.10%
RESU_4	TRACES	AUTRE_ASTER	-1.2E-3	0.10%

4 Modelization B

4.1 Characteristic of the modelization

the temperature varies from $T_0=51.7°C$ with $T_{max}=101.7°C$. The constitutive law tested is "ELAS". This elastic model 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 Grandeurs tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_4	VMIS	AUTRE_ASTER	1.2E-3	0.10%
RESU_4	TRACES	AUTRE_ASTER	-1.2E-3	0.10%

5 Modelization C

5.1 Characteristic of the modelization

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

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

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

5.2 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACES	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	9.025E-03	0.10%

6 Modelization D

6.1 Characteristic of the modelization

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

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

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 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACES	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	-30.3333	0.10%

7 Modelization E

7.1 Characteristic of the modelization

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

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$150000 \quad MPa$	$100000 \quad MPa$
$\nu(T)$	0.	0.
$\alpha(T)$	$1.\times 10^{-5} \quad K^{-1}$	$2.\times 10^{-5} \quad K^{-1}$

the parameters of the viscoplastic model 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	$T=20°C$	$T=500°C$
$S(T)$	$0. \quad MPa$	$900. \quad MPa$
$\alpha_D(T)$	0.	1.
$\beta_D(T)$	0.	1.
$A_D(T)$	$3.\times 10^3 \quad MPa$	$3.5\times 10^3 \quad MPa$
$R_D(T)$	6	7
$K_D(T)$	15	10

Parameters	$T=20°C$	$T=500°C$
$N(T)$	12	15
$1/K(T)$	$5.\times 10^{-3}(Mpa)^{-1}$	$1.\times 10^{-3}(Mpa)^{-1}$
$1/M(T)$	0.	0.1111

7.2 Quantities tested and results

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

8 Modelization F

8.1 Characteristic of the modelization

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

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

elastoplastic parameters 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 Quantities tested and results

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

9 Modelization G

9.1 Characteristic of the modelization

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

$E(T)$, $\nu(T)$ and the $\alpha(T)$
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 Quantities tested and results

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

10 Modelization H

10.1 Characteristic of the modelization

the constitutive law tested is "`VMIS_CIN2_CHAB`" documented in Doc. [`R5.03.04`]. It is a model of Chaboche with two nonlinear kinematic hardenings.

The elastic parameters are the following:

$E(T)$, $\nu(T)$ and the $\alpha(T)$
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 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	61.3071	0.10%
RESU_9	TRACES	AUTRE_ASTER	-61.3071	0.10%
RESU_9	V1	AUTRE_ASTER	9.3869E-03	0.10%

11 Modelization I

11.1 Characteristic of the modelization

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

$E(T)$, $\nu(T)$ and the $\alpha(T)$
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 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	66.0797	0.10%
RESU_9	TRACES	AUTRE_ASTER	-66.0798	0.10%

RESU_9	V1	AUTRE_ASTER	9.3392E-03	0.10%

12 Modelization J

12.1 Characteristic of the modelization

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

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

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 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	171.5016	0.10%
RESU_9	TRACES	AUTRE_ASTER	-171.5016	0.10%

RESU_9	V1	AUTRE_ASTER	8.28498E-03	0.10%

13 Modelization K

13.1 Characteristic of the modelization

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

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

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 Quantities tested and results

Result at 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	TRACES	AUTRE_ASTER	-174.5470	0.10%
RESU_9	V1	AUTRE_ASTER	8.2545E-03	0.10%

14 Modelization L

14.1 Characteristic of the modelization

the constitutive law tested is "VISC_CIN2_MEMO" [R5.03.04]. It is about a model of Chaboche comprising two variables of nonlinear kinematic hardening and modelization the effect of memory. (cf modelization 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 Quantities tested and results

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

15 Modelization M

15.1 Characteristic of the modelization

the temperature varies here $T_0=51.7°C$ with $T_{max}=101.7°C$. The constitutive law tested is "ELAS". This elastic model 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
$\alpha_L(T)$	$1.\times 10^{-5}$ K^{-1}	1.5×10^{-5} K^{-1}	$2.\times 10^{-5}$ K^{-1}
$\alpha_N(T)$	$1.\times 10^{-5}$ K^{-1}	1.5×10^{-5} K^{-1}	$2.\times 10^{-5}$ K^{-1}

15.2 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	Tolerance
RESU_4	VMIS	AUTRE_ASTER	1.2E-3	0.10%
RESU_4	TRACES	AUTRE_ASTER	-1.2E-3	0.10%

16 Modelization N

16.1 Characteristic of the modelization

the constitutive law tested is "ROUSS_PR". It is an elastoplastic model modelling the damage due to the growth of cavities, used in the modelization of the ductility fracture 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
Curves of tension	$\varepsilon;\sigma(MPa)$	$\varepsilon;\sigma(MPa)$
First not	$\frac{800}{2.1\,10^5};800.0$	$\frac{600}{1.0\,10^5};600.0$
Second point	1,005 ; 1600,	1,005 ; 1200,

16.2 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard 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 Modelization O

17.1 Characteristic of the modelization

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

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

elastoplastic parameters 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 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_9	VMIS	AUTRE_ASTER	97.5	0.10%
RESU_9	TRACES	AUTRE_ASTER	-97.5	0.10%
RESU_9	V1	AUTRE_ASTER	9.025E-03	0.10%

18 Synopsis general of the results

For each studied constitutive law, 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 thermal expansion by these constitutive laws, as well as the good dependence of materials parameters with the temperature.