COMP010 – thermomechanical Validation of the elastoviscoplastic models

Summarized

This test makes it possible to validate the taking into account of the temperature variation in the elastoviscoplastic constitutive laws. 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 the model `GRAN_IRRA_LOG`,
- Modelization b: this modelization makes it possible to validate LEMAITRE , Modelization
- the model C : this modelization makes it possible to validate LEMA_SEUIL , Modelization
- the model D : this modelization makes it possible to validate GATT_MONERIE , Modelization
- the model E : this modelization makes it possible to validate LEMAITRE_IRRA , Modelization
- the model F : this modelization makes it possible to validate VISC_IRRA_LOG , Modelization
- the model G : this modelization makes it possible to validate VISC_TAHERI , Modelization
- the model H : this modelization makes it possible to validate ROUSS_VISC , Modelization

- the model I : this modelization makes it possible to validate VISCOCHAB the model .
- Modelization J : this modelization makes it possible to validate META_LEMA_ANI the model .

1 Methodology

It acts of a double simulation, the first in thermomechanics, 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.

The first simulation (thermomechanical solution which one seeks to validate) consists in applying a temperature variation to a material point, with a strain imposed null according to the axis x : $\varepsilon_{xx}=0$. The imposed temperature is increasing linearly according to time . The temperature varies from $T_0=0\,°C$ with $T_{max}=500\,°C$. The transient consists of `NCAL` not. The reference temperature is of $T_{ref}=0\,°C$.

The second simulation (which must be equivalent to the first) consists in applying to the same material point a strain imposed according to x : $\varepsilon_{xx}=-\varepsilon^{th}=-\alpha(T)(T-T_{ref})$, in pure mechanics on `the urgent` NCAL of computations thermomechanics. 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, the stresses being corrected variation of the Young modulus

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 `SIMU_POINT_MAT/STAT_NON_LINE` .

2 Interpretation of the results

It acts to check with `TEST_TABLE` that result at every moment obtained mechanical transient thermo of the first simulation identical to is result obtained with the second simulation.

The validation is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand. The value of reference being the component of the field extracted to a time given i the first thermomechanical simulation carried out on `urgent` NCAL. The computed value is that obtained at the end of the mechanical computation $i+1$ of the loop on `the NCAL`.

3 Modelization A

3.1 Constitutive law and materials parameters

constitutive law tested "GRAN_IRRA_LOG", is documented in documentation [R5.03.09]. It is a constitutive law of creep and growth under irradiation for the fuel assemblies, similar to model "VISC_IRRA_LOG" for the viscoplastic strain, which integrates in more one strain of growth under irradiation. The elastic parameters are the following:

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

elastoplastic parameters are the following:

A B ω Φ Q a, b and s

Values of the parameters used:

Parameters	$T=0°C$	$T=500°C$
$E(T)$	$1.E5\,MPa$	$0.8E5\,MPa$
$\nu(T)$	0.	0.
$\alpha(T)$	$1.E-5\,K^{-1}$	$2.E-5\,K^{-1}$
A	$1.28E-1$	$1.28E-1$
B	0.01159	0.01159
ω	0.3540	0.3540
Φ	1.	1.
Q	5000.	5000.
a	$-1.51E-16$	$-1.51E-16$
b	$1.542E-13$	$1.542E-13$
s	0.396	0.396

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_19	VMIS (MPa)	AUTRE_ASTER	201.09766	0.10%
RESU_19	B TRACES (MPa	)	AUTRE_ASTER	-201.09766
0.10%	RESU_19	V1	AUTRE_ASTER	7.486279

4 0.10% Modelization

4.1 Constitutive law and materials parameters

constitutive law tested "LEMAITRE", is documented in documentation [R5.03.08]. It is about a nonlinear viscoplastic model of LEMAITRE without threshold. The elastic parameters are the following:

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

parameters elastoviscoplastic are the following:

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

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$1.\text{E}5\,MPa$	$2.\text{E}5\,MPa$
$\nu(T)$	0.	0.
$\alpha(T)$	$2.E-5\,K^{-1}$	$2.E-5\,K^{-1}$
$N(T)$	10.8	8.0
$1/K(T)$	$6.9\text{E}-4(MPa)^{-1}$	$4.0\text{E}-4(MPa)^{-1}$
$1/M(T)$	0.102	0.05

4.2 Quantities tested and results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	1037.97825	0.10%
RESU_19	C TRACES (MPa	)	AUTRE_ASTER	-1037.97825
0.10%	RESU_19	V1	AUTRE_ASTER	4.410109E-3

5 0.10% Modelization

5.1 Constitutive law and materials parameters

constitutive law tested "LEMA_SEUIL", is documented in documentation [R5.03.08]. It is about a viscoplastic model with threshold under irradiation for the fuel assemblies. The elastic parameters are the following:

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

parameters elastoviscoplastic are the following:

$A(T)$ and $S(T)$

Values of the parameters used:

Parameters	$T=0°C$	$T=500°C$
$E(T)$	$1.E5\,MPa$	$0.8E5\,MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$1.0E-4\,K^{-1}$	$2.0E-4\,K^{-1}$
$A(T)$	$1.0E-10$	$0.5E-10$
$S(T)$	$40.$	$20.$

5.2 Results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	499.998221	0.10%
RESU_19	D TRACES (MPa	)	AUTRE_ASTER	-499.998221
0.10%	RESU_19	V1	AUTRE_ASTER	3.557036E-8
0.10%	RESU_19	V2	AUTRE_ASTER	10.421848

6 0.10% Modelization

6.1 Constitutive law and materials parameters

constitutive law tested "GATT_MONERIE", is documented in documentation [R5.03.08]. This thermomechanical model of fuel makes it possible to simulate tests of indentation. It is about an isotropic elastoviscoplastic model without hardening. So that convergence is not too difficult one chooses here a maximum temperature of $400°C$ (instead of $500°C$). The elastic parameters are the following:

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

elastoplastic parameters are the following:

D_GRAIN, PORO_INIT, EPSI_01 and EPSI_01

Values of the parameters used:

Parameters	$T=20°C$	$T=400°C$
$E(T)$	$2.\text{E}5\, MPa$	$1.\text{E}5\, MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$1.0\text{E}-5\, K^{-1}$	$2.0\text{E}-5\, K^{-1}$
D_GRAIN	$6.\text{E}-6$	$6.\text{E}-6$
PORO_INIT	0.01	0.01
EPSI_01	$2.7252\text{E}-10$	$2.7252\text{E}-10$
EPSI_02	$9.1440\text{E}-41$	$9.1440\text{E}-41$

6.2 Results

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	800.	0.10%
RESU_19	E TRACES (MPa	)	AUTRE_ASTER -800	.
0.10%	RESU_19	V2	AUTRE_ASTER	0.01

7 0.10% Modelization

7.1 Simulation 1

It acts of a thermomechanical test with a strain imposed null according to the axis x. The test is carried out on a material point with command SIMU_POINT_MAT. The temperature varies from $T_0=20°C$ with $T_{max}=500°C$. The transient consists of NCAL not.
The reference temperature is of $T_{Ref}=20°C$.

7.2 Simulation 2

It acts to carry 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.

7.3 Constitutive law and materials parameters

the constitutive law tested, "LEMAITRE_IRRA ", is documented in documentation [R5.03.08]. It is about a constitutive law of creep and growth under irradiation for the fuel assemblies.

The elastic parameters are the following:

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

parameters elastoviscoplastic are the following:

N $1/M$ $1/K$ L ϕ_0 β Q/K a b, and S

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$2.E5\,MPa$	$1.E5\,MPa$
$\nu(T)$	0.0	0.0
$\alpha(T)$	$1.0E-5\,K^{-1}$	$2.0E-5\,K^{-1}$
$1/K$	$1.E-6\,MPa^{-1}$	$1.E-6\,MPa^{-1}$
$1/M$	0.207060772	0.207060772
N	2.3364	2.3364
L	0.	0.
ϕ_0	$4.240281E+21$	$4.240281E+21$
β	1.2	1.2
Q/K	3321.093	3321.093
a	$-1.51E-16$	$-1.51E-16$
b	$1.542E-13$	$1.542E-13$
S	0.396	0.396

7.4 Results

the validation is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand.

The command used is TEST_TABLE which tests the value of reference compared to the computed value.

The value of reference being the component of the field extracted to a time given i the first thermomechanical simulation carried out on urgent NCAL. The computed value is that obtained at the end of the mechanical computation $i+1$ of the loop on the NCAL.

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_19	VMIS (Pa)	AUTRE_ASTER	1000.	0.10%
RESU_19	F TRACES (Pa	)	AUTRE_ASTER -1000	.

8 0.10% Modelization

8.1 Simulation 1

It acts of a thermomechanical test with a strain imposed null according to the axis x. The test is carried out on a material point with command `SIMU_POINT_MAT`. The temperature varies from $T_0=0°C$ with $T_{max}=500°C$. The transient consists of `NCAL` not.
The reference temperature is of $T_{Ref}=0°C$.

8.2 Simulation 2

It acts to carry 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.

8.3 Constitutive law and materials parameters

constitutive law tested "`VISC_IRRA_LOG`", is documented in documentation [R5.03.09]. Creep model axial under irradiation of the fuel assemblies. It makes it possible to model primary education and secondary creep, parameterized by the neutron fluence.

The elastic parameters are the following:

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

parameters elastoviscoplastic are the following:

A B ϕ, ω and Q

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$195000.Mpa$	$180000.Mpa$
$\nu(T)$	0.	0.
$\alpha(T)$	$10^{-5}K^{-1}$	$2.\times10^{-5}K^{-1}$
A	0.128	0.128
B	0.01159	0.01159
ϕ	10^{-4}	10^{-4}
ω	0.3540	0.3540
Q	5000.	5000.

8.4 Results

the validation is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand.

The command used is TEST_TABLE which tests the value of reference compared to the computed value.
The value of reference being the component of the field extracted to a time given i the first thermomechanical simulation carried out on urgent NCAL. The computed value is that obtained at the end of the mechanical computation $i+1$ of the loop on the NCAL.

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	1799.49858	0.10%
RESU_19	G TRACES (MPa	)	AUTRE_ASTER	-1799.49858
0.10%	RESU_19	V1	AUTRE_ASTER	2.78565 E-6

9 0.10% Modelization

9.1 Simulation 1

It acts of a thermomechanical test with a strain imposed null according to the axis x. The test is carried out on a material point with command SIMU_POINT_MAT. The temperature varies from $T_0=20°C$ with $T_{max}=500°C$. The transient consists of NCAL not.
The reference temperature is of $T_{Ref}=20°C$.

9.2 Simulation 2

It acts to carry 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.

9.3 Constitutive law and materials parameters

constitutive law tested "VISC_TAHERI", is documented in documentation [R5.03.05]. It is about a constitutive law (visco) - plastic modelling the response of materials under cyclic plastic loading, and in particular making it possible to represent the effects of ratchet.

The elastic parameters are the following:

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

viscoplastic parameters are the following:

S C_∞ C_1 b m A, α and R_0

Values of the parameters used:

Parameters	$T=20°C$	$T=500°C$
$E(T)$	$200\,000.\,MPa$	$180\,000.\,MPa$
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$1.0E-5\,K^{-1}$	$2.0E-5\,K^{-1}$
S	$450.$	$400.$
C_∞	0.065	0.06
C_1	-0.012	-0.01
b	$30.$	$20.$
m	0.1	0.15
A	$312.$	$200.$
α	0.3	0.25
R_0	$72.$	$50.$

9.4 Results

the validation is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand.

The command used is TEST_TABLE which tests the value of reference compared to the computed value.
The value of reference being the component of the field extracted to a time given i the first thermomechanical simulation carried out on urgent NCAL. The computed value is that obtained at the end of the mechanical computation $i+1$ of the loop on the NCAL.

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_19	VMIS (MPa)	AUTRE_ASTER	117.329035	0.10%
RESU_19	H TRACES (MPa	)	AUTRE_ASTER	-117.329035
0.10%	RESU_19	V1	AUTRE_ASTER	8.948172E-3
0.10%	RESU_19	V2	AUTRE_ASTER	117.329035
0.10%	RESU_19	V9	AUTRE_ASTER	3.0

10 0.10% Modelization

10.1 Simulation 1

It acts of a thermomechanical test with a strain imposed null according to the axis x. The test is carried out on a material point with command SIMU_POINT_MAT. The temperature varies from $T_0=T_{ref}=20°C$ with $T_{max}=800°C$. The transient consists of NCAL=30 not.

10.2 Simulation 2

It acts to carry 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.

10.3 Constitutive law and materials parameters

constitutive law tested "ROUSS_VISC", is documented in documentation [R5.03.07]. It is about a elastoviscoplastic model behavior of Rousselier to model the ductility fracture.
The parameters of the behavior are the following:

Parameters	$T=20°C$	$T=800°C$
$E(T)$	$210000.\ MPa$	$100000.\ MPa$
$\nu(T)$	0.	0.
$\alpha(T)$	$10^{-5}K^{-1}$	$2.\times10^{-5}K^{-1}$
$\sigma_1(T)$	500.	450.
$\beta(T)$	1.	1.
$f_0(T)$	5.10^{-4}	3.10^{-4}
$D(T)$	1.5	2.5
$\sigma_0(T)$		800,800,2
$\varepsilon(T)$	1.10^{-2}	1.10^{-2}
m		2

as well as curves of tension:

$T=20°C$

ε	$\sigma(MPa)$
800/210000.	800
1.005	1600,

$T=800°C$

ε	$\sigma(MPa)$
600/100000.	600
1.005	1200

10.4 Results

the validation is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand.

The command used is TEST_TABLE which tests the value of reference compared to the computed value.
The value of reference being the component of the field extracted to a time given i the first thermomechanical simulation carried out on urgent NCAL. The computed value is that obtained at the end of the mechanical computation $i+1$ of the loop on the NCAL.

Result at the sequence number i	Name of the parameter tested	Standard of reference	Value of reference	tolerance
RESU_29	VMIS (MPa)	AUTRE_ASTER	709.6639	0.11%
RESU_29	I TRACES (MPa	)	AUTRE_ASTER	-709.66 39
0.11%	RESU_29	V1	AUTRE_ASTER	8.5046E -3
0.11%	RESU_29	V2	AUTRE_ASTER	4.9887E -4
0.11%	RESU_29	V3	AUTRE_ASTER	0.1229
0.11%	RESU_29	V5	AUTRE_ASTER	1

11 0.11% Modelization

11.1 Simulation 1

It acts of a thermomechanical test with a strain imposed null according to the axis x. The test is carried out on a material point with command `SIMU_POINT_MAT`. The temperature varies from $T_0=20°C$ with $T_{max}=200°C$. The transient consists of $NCAL=100$ step.
The reference temperature is of $T_{Ref}=20°C$.

11.2 Simulation 2

It acts to carry 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.

11.3 Constitutive law and materials parameters

constitutive law tested "`VISCOCHAB`", is documented in documentation [R5.03.12]. It is about a elastoviscoplastic constitutive law of J.L.Chaboche with 2 kinematical variables which gives an account of the cyclic behavior in elastoplasticity with 2 tensors of nonlinear kinematic hardening, a nonlinear isotropic hardening, an effect of hardening on the tensorial variables of recall, an effect of memory of greatest hardening, and effects of restoration. The elastic

parameters are the following: , and the

$E(T)$ parameters $\nu(T)$ $\alpha(T)$

elastoviscoplastic are the following:

$K(T)$ $\alpha_K(T)$ $\alpha_R(T)$ $K_0(T)$ $N(T)$ $\alpha(T)$ $B(T)$ $M_R(T)$ $G_R(T)$
$MU(T)$ $Q_0(T)$ $Q_M(T)$, $QR_0(T)$ $ETA(T)$ $C1(T)$ and $M_1(T)$ $D1(T)$ $G_{X1}(T)$
$G1_0(T)$ Values $C2(T)$ $M_2(T)$ $d2(T)$ $G\_X2(T)$ $G2\_0(T)$ of $a_\infty(T)$

the parameters used: Parameters

Parameters	$T=20°C$	$T=200°C$
$E(T)$	$150000.MPa$	$100000.MPa$
$\nu(T)$	0.	0.
$\alpha(T)$	$10^{-5}K^{-1}$	$2.\times10^{-5}K^{-1}$
$K(T)$	25.	40.
$\alpha_K(T)$	1.	1.
$\alpha_R(T)$	0.5	0.8
$K_0(T)$	60	80
$N(T)$	30	15
$\alpha(T)$	0.	0.
$B(T)$	15.	15.

Results	$T=20°C$	$T=200°C$
$M_R(T)$	2.	2.
$G_R(T)$	2.5×10^{-7}	1.5×10^{-7}
$MU(T)$	22	16
$Q_0(T)$	40	45
$Q_M(T)$	500	400
$QR_0(T)$	150	250
$ETA(T)$	0.06	0.03
$C1(T)$	1600	1600
$M_1(T)$	3	5
$D1(T)$	0.36×10^{-3}	0.42×10^{-3}
$G_{X1}(T)$	2.5×10^{-13}	1.5×10^{-13}
$G1_0(T)$	40	60
$C2(T)$	55000	55000
$M_2(T)$	5	3.5
$d2(T)$	0.05	0.06
$G\_X2(T)$	$0,8\times10^{-12}$	1.5×10^{-12}
$G2\_0(T)$	1500	1000
$a_\infty(T)$	0.41	0.56

11.4 the validation

is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand. The command

used is TEST_TABLE which tests the value of reference compared to the computed value. The value of reference
being the component of the field extracted to a time given the first i thermomechanical simulation carried out on urgent NCAL . The computed value is that obtained at the end of the mechanical computation of the loop $i+1$ on the NCAL. Result at the sequence number

Name of the parameter i	tested Standard of reference	Value of reference	tolerance	RESU_19 VMIS
(MPa)	AUTRE_ASTER	146.87158 0.0%	RESU_19	J
TRACES (MPa	)	AUTRE_ASTER	-146.87143 0.10%	RESU_19
V1		AUTRE_ASTER -2.14218	0.10%	RESU_19
V2		AUTRE_ASTER 1.0719	0.10%	RESU_19
V3		AUTRE_ASTER 1.0719	0.10%	

12 Modelization Simulation

12.1 1 It acts of

a thermomechanical test with a strain imposed null according to the axis formulates. x is carried out on an element HEXA8 with command STAT_NON_LINE . The temperature varies from formula with $T_0=700°C$. $T_{max}=1000°C$ consists of NCAL not . The reference temperature is of formula. Simulation $T_{Ref}=700°C$

12.2 2 It acts

to carry out a loop on NCAL mechanical computations . With each computation formulates, i loading is made up by the thermal strain formulates. $\varepsilon_{xx}=-\varepsilon_{th}=-\alpha(T)(T_i-T_{Ref})$ loading is made up by the strains, stresses and local variables of preceding mechanical computation. Constitutive law

12.3 and materials parameters the constitutive law

tested, "META_LEMA_ANI", is documented in documentation [R4.04.05]. It is about a constitutive law of creep of the sheath of the fuel pin with taking into account of the metallurgical transformations. The two metallurgical
phases are supposed here to have isotropic mechanical properties. The elastic

parameters are the following: , formula

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

elastoviscoplastic are the following: formulate,

a_1 , Q_1 , n_1 , m_1 , a_2 , Q_2 , n_2 , m_2 , a_3 , Q_3 , n_3 Values m_3

the parameters used: Parameters

formulates formula	$T=700°C$	$T=1000°C$
$E(T)$	$80000.MPa$	$40000.MPa$
$\nu(T)$	0.35	0.35
$\alpha(T)$	$10^{-5}K^{-1}$	$2.\times10^{-5}K^{-1}$

elastoviscoplastic quoted above are independent of the temperature: only the phase changes modify the properties of the material: : phase:

	$i=1$ phase: α	$i=2$ phase formulates $\alpha\beta$	$i=3$ formula β
a_i	$2.39MPa$	$0.22MPa$	$9.36MPa$
Q_i	$19922.8K$	$21023.7K$	$6219K$
n_i	4.39	2.96	6.11
m_i	0.	0.000077	0.000099

12.4 the validation

is done by the comparison between the computed fields with each step of the transient on the one hand and result of a mechanical computation on the other hand. The command

used is TEST_TABLE which tests the value of reference compared to the computed value. The value of reference

being the component of the field extracted to a time given formula i thermomechanical simulation carried out on urgent NCAL . The computed value is that obtained at the end of mechanical computation formulates $i+1$ on the NCAL. Result at the sequence number

formula Name i	tested Standard of reference	Value of reference	tolerance	RESU_19 SIYY
(MPa)	AUTRE_ASTER	-11.815 97	0.10% RESU_	19 V1
AUTRE_ASTER		0.0057046 0.10%	Synthesis	This

13 test makes it possible

to validate the taking into account of the variation in temperature in the élasto-viscoplastic constitutive laws. 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, For all

the constitutive laws tested in the present modelizations, these two criteria are well checked, because computations differences between thermomechanical computation and pure mechanical computation with interpolation is numerically null.