COMP007 – Vthermomechanical alidation of the non-linear elastic laws (BEHAVIOR)

Summary

This test makes it possible to validate the thermoelastic laws of behavior definite under BEHAVIOR. It makes it possible to check the 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.

The 4 laws of behaviors validated are the following ones:

- Modeling A : this modeling makes it possible to validate the model ELAS,
- Modeling B : this modeling makes it possible to validate the model ELAS_VMIS_LINE,
- Modeling C : this modeling makes it possible to validate the model ELAS_VMIS_PUIS,
- Modeling D : this modeling makes it possible to validate the model ELAS_VMIS_TRAC.

1 Methodology

It is about 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 (solution which one seeks to validate) consists in applying a temperature variation to a material point, by blocking for example the deformations according to x : $\varepsilon_{xx}=0$. The imposed temperature is increasing linearly according to time.

The second simulation (which must be equivalent to the first) consists in applying to the same material point a deformation imposed according to x : $\varepsilon_{xx}=-\varepsilon^{th}=-\alpha(T)(T-T_{ref})$, in pure mechanics. 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 with TEST_TABLE that at every moment got result of the mechanical transient thermo of the first simulation is identical to the result got with the second simulation.

3 Modeling A

3.1 Simulation 1

It is about a thermomechanical test with a worthless deformation imposed according to the axis x. The test is carried out on a material point with the order SIMU_POINT_MAT. The temperature varies $T_0=20°C$ with $T_{max}=500°C$. The material is elastic. The transient is made up of NCAL pas. La temperature of reference is of $T_{Ref}=20°C$.

3.2 Simulation 2

It is 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.

3.3 Law of behavior and parameters materials

The law of behavior tested is 'ELAS'documented in documentation [R4.01.02].

The elastic parameters are the following:

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

Values of the parameters used:

Parameter	$T=20°C$	$T=500°C$
$E(T)$	$200000.$ MPa	$100000.$ MPa
$\nu(T)$	$0.$	$0.$
$\alpha(T)$	$1.\times10^{-5}\ K^{-1}$	$2.\times10^{-5}\ K^{-1}$

3.4 Sizes tested and results

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

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

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

Result with the sequence number I	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_i	NOM_PARA		VALE_REF	SHEET
RESU_4	VMIS	NON_REGRESSION	960.	0.1%
RESU_4	TRACE	NON_REGRESSION	-960.	0.1%

4 Modeling B

4.1 Simulation 1

It is about a thermomechanical test with a worthless deformation imposed according to the axis x. The test is carried out on a material point with the order SIMU_POINT_MAT. The temperature varies $T_0=20°C$ with $T_{max}=500°C$. The transient is made up of NCAL pas. La temperature of reference is of $T_{Ref}=20°C$.

4.2 Simulation 2

It is 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.

4.3 Law of behavior and parameters materials

The law of behavior tested is 'ELAS_VMIS_LINE', is documented in documentation [R7.02.03].

It is a law of behavior élastiquE "nonlinear" (law of HENCKY) of VON MISES with linear isotropic work hardening.

The elastic parameters are the following:

$$E(T),\ \nu(T)\ ,\ \alpha(T),\ \sigma_y(T),\ E_T(T)$$

Values of the parameters used:

Parameter	$T=20°C$	$T=500°C$
$E(T)$	200000. MPa	100000. MPa
$\nu(T)$	0.	0.
$\alpha(T)$	$1.\times10^{-4}\ K^{-1}$	$2.\times10^{-4}\ K^{-1}$
$\sigma_y(T)$	1000. MPa	800. MPa
$E_T(T)$	2000. MPa	1000. MPa

4.4 Sizes tested and results

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

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

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

Result with the sequence number I	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_i	NOM_PARA		VALE_REF	SHEET
RESU_19	VMIS	NON_REGRESSION	888.	0.1%
RESU_19	TRACE	NON_REGRESSION	-888.	0.1%
RESU_19	V1	NON_REGRESSION	0.08712	0.1%

5 Modeling C

5.1 Simulation 1

It is about a thermomechanical test with a worthless deformation imposed according to the axis x. The test is carried out on a material point with the order SIMU_POINT_MAT. The temperature varies $T_0=20°C$ with $T_{max}=500°C$. The transient is made up of NCAL pas. La temperature of reference is of $T_{Ref}=20°C$.

5.2 Simulation 2

It is 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.

5.3 Law of behavior and parameters materials

The law of behavior tested is 'ELAS_VMIS_PUIS', is documented in documentation R5.03.02.

It is a law of behavior rubber band "nonlinear" (law of HENCKY) of VON MISES with nonlinear isotropic work hardening defined by a function power.

The elastic parameters are the following:

$E(T)$, $\nu(T)$, $\alpha(T)$, $\sigma_y(T)$, $a(T)$ and $n(T)$

Values of the parameters used:

Parameter	$T=20°C$	$T=500°C$
$E(T)$	200000. MPa	100000. MPa
$\nu(T)$	0.	0.
$\alpha(T)$	$1.\times10^{-4}$ K^{-1}	$2.\times10^{-4}$ K^{-1}
$\sigma_y(T)$	1000. MPa	800. MPa
$a(T)$	1.	0.8
$n(T)$	7.	6.

5.4 Sizes tested and results

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

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

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

Result with the sequence number I	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_i	NOM_PARA		VALE_REF	SHEET
RESU_19	VMIS	NON_REGRESSION	2008.142	0.1%
RESU_19	TRACE	NON_REGRESSION	-2008.142	0.1%
RESU_19	V1	NON_REGRESSION	0.0759186	0.1%

6 Modeling D

6.1 Simulation 1

It is about a thermomechanical test with a worthless deformation imposed according to the axis x. The test is carried out on a material point with the order SIMU_POINT_MAT. The temperature varies $T_0=20°C$ with $T_{max}=500°C$. The transient is made up of NCAL pas. La temperature of reference is of $T_{Ref}=20°C$

6.2 Simulation 2

It is 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.

6.3 Law of behavior and parameters materials

The law of behavior tested is 'ELAS_VMIS_TRAC', documented in documentation [R7.02.03].

It is a law of behavior "nonlinear" rubber band (law of HENCKY), of VON MISES with nonlinear isotropic work hardening.

The elastic parameters are the following:

$$E(T),\quad \nu(T)\ ,\ \alpha(T),\ \sigma(\varepsilon,T)$$

Values of the parameters used:

Parameter	$T=20°C$	$T=500°C$
$E(T)$	200000. MPa	100000. MPa
$\nu(T)$	0.	0.
$\alpha(T)$	$1.\times10^{-4}\ K^{-1}$	$2.\times10^{-4}\ K^{-1}$

Parameter	Temperature	$\varepsilon=0.005$	$\varepsilon=1.005$
$\sigma(\varepsilon,T)$	$20°C$	1000. MPa	3000. MPa
	$500°C$	800. MPa	2000. MPa

6.4 Sizes tested and results

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

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

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

Result with the sequence number I	Name of the parameter tested	Type of reference	Value of reference	tolerance
RESU_i	NOM_PARA		VALE_REF	SHEET
RESU_19	VMIS	NON_REGRESSION	905,918	0.1%
RESU_19	TRACE	NON_REGRESSION	-905,918	0.1%
RESU_19	V1	NON_REGRESSION	0.08694	0.1%

7 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.