COMP007 – Thermomechanical validation of the nonlinear elastic models (COMP_ELAS)

Summarized

This test makes it possible to validate the thermoelastic constitutive laws definite under COMP_ELAS. It makes it possible to check the 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.

The 4 validated constitutive laws are the following ones:

- Modelization A : this modelization makes it possible to validate ELAS , Modelization
- the model B : this modelization makes it possible to validate ELAS_VMIS_LINE , Modelization
- the model C : this modelization makes it possible to validate ELAS_VMIS_PUIS , Modelization
- the model D : this modelization makes it possible to validate ELAS_VMIS_TRAC 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 (solution which one seeks to validate) consists in applying a temperature variation to a material point, by blocking for example the strains 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 strain 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 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 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.

3 Modelization A

3.1 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 material is elastic. The transient consists of NCAL not. The reference temperature is of $T_{Ref}=20°C$.

3.2 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.

3.3 Constitutive law and materials parameters

the constitutive law 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 Quantities 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 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_i	NOM_PARA		VALE_REF	TOLE
RESU_4	VMIS	NON_REGRESSION	960.	0.1%
RESU_4	B	TRACES	NON_REGRESSION	.

			−960	

4 0.1% Modelization

4.1 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 $T_{Ref}=20°C$.

4.2 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.

4.3 Constitutive law and materials parameters

the constitutive law tested is "ELAS_VMIS_LINE", is documented in documentation [R7.02.03].

It is an elastic constitutive law "nonlinear" (model of HENCKY) of Von Mises with linear isotropic hardening.

The elastic parameters are the following:

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

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 Quantities 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 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_i	NOM_PARA		VALE_REF	TOLE
RESU_19	VMIS	NON_REGRESSION	888.	0.1%
RESU_19	C	TRACES	NON_REGRESSION -888	.
0.1%	RESU_19	V1	NON_REGRESSION	0.08712

5 0.1% Modelization

5.1 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 $T_{Ref}=20°C$.

5.2 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.

5.3 Constitutive law and materials parameters

the constitutive law tested is "ELAS_VMIS_PUIS", is documented in R5.03.02 documentation.

It is an elastic constitutive law "nonlinear" (model of HENCKY) of Von Mises with nonlinear isotropic hardening defined by a function power.

The elastic parameters are the following:

$$E(T) \quad \nu(T) \quad \alpha(T) \quad \sigma_y(T), \; a(T) \text{ and } n(T)$$

Values of the parameters used:

Parameter	$T=20°C$	$T=500°C$
$E(T)$	200000. MPa	100000. MPa
$\nu(T)$	0.	0.
$\alpha(T)$	$1.\times 10^{-4}\ K^{-1}$	$2.\times 10^{-4}\ K^{-1}$
$\sigma_y(T)$	1000. MPa	800. MPa
$a(T)$	1.	0.8
$n(T)$	7.	6.

5.4 Quantities 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 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_i	NOM_PARA		VALE_REF	TOLE
RESU_19	VMIS	NON_REGRESSION	2008.142	0.1%
RESU_19	D	TRACES	NON_REGRESSION	-2008.142
0.1%	RESU_19	V1	NON_REGRESSION	0.0759186

6 0.1% Modelization

6.1 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 $T_{Ref}=20°C$

6.2 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.

6.3 Constitutive law and materials parameters

the constitutive law tested is "`ELAS_VMIS_TRAC`", documented in documentation [`R7.02.03`].

It is an elastic constitutive law "nonlinear" (model of `HENCKY`), of `Von Mises` with nonlinear isotropic hardening.

The elastic parameters are the following:

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

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 Quantities 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 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_i	NOM_PARA		VALE_REF	TOLE
RESU_19	VMIS	NON_REGRESSION	905.918	0.1%
RESU_19	TRACES	NON_REGRESSION	-905.918	0.1%
RESU_19	V1	NON_REGRESSION	0.08694	0.1%

7 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.