HSNA105 - Expansion of an infinite hollow roll with taking into account of thermal dissipations due to the mechanical strains

Abstract:

The purpose of this test is to validate the installation of a thermomechanical coupling with taking into account of thermal dissipations due to the mechanical strains like heat source in the equation of the thermal. The coupling is carried out via the classical method of the literature known as of isothermal staged diagram.

This case test comprises two modelizations which correspond to two distinct physical transients described in the literature [2]:
- thermo-elastic modelization a: Case where the expansion of a cylinder causes its cooling;
- thermoelastoplastic modelization b: Case where the effect of plastic dissipation compensates for the preceding effect and involves the total warming of the cylinder.

The got results are in strong correlation.

1 Problem of reference

1.1 Geometry

One considers an infinite hollow roll.

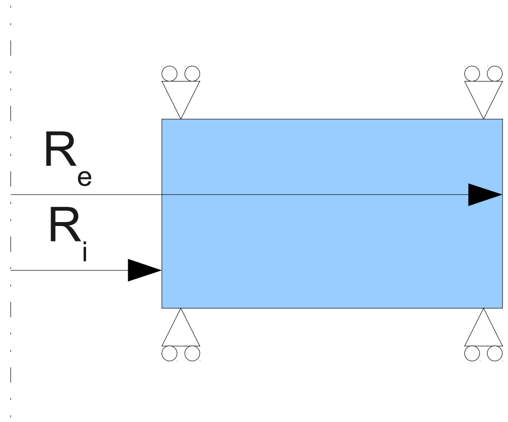


Figure 1 : Geometry of the hollow roll

Modelization a:

the geometrical properties are:

- Internal radius $R_i = 10\,mm$
- external Radius $R_e = 20\,mm$

Modelization b:

the geometrical properties are:

- Internal radius $R_i = 100\,mm$
- external Radius $R_e = 200\,mm$

1.2 Properties of the material

the materials used in computations use constitutive law `VMIS_JOHN_COOK`. Its function of hardening is written in the following way [1]:

$$R(p, \dot{p}, T) = (A + B\,p^n)\left(1 + C \ln\left(\frac{\dot{p}}{\dot{p}_0}\right)\right)\left(1 - \left(\frac{T - T_{room}}{T_{melt} - T_{room}}\right)\right)$$

We will not use the terms related to the dependence with the temperature and the plastic strainrate. One will work then with:

$$R(p) = A + B\,p^n$$

Modelization a:

One models an elastic constitutive law. One uses the mechanical and thermal parameters following:

- Young modulus $E=206\,900\,MPa$
- Poisson's ratio $\nu=0.29$
- Elastic limit $A=5.10^{100}\,Pa$
- Slope post-elastic $B=2.10^{10}\,Pa$
- Power post-elastic $n=1$
- Density $\rho=7800\,kg/m^3$
- Coefficient of thermal expansion $\alpha=1{,}5.10^{-5}\,K^{-1}$
- Conductivity $\lambda=45\,W/(m.K)$
- Heat capacity $C_p=460\,J/(kg.K)$
- Reference temperature $T_{ref}=293\,K$

Modelization b:

One models elastoplastic constitutive law equivalent to a model VMIS_ISOT_LINE . One uses the mechanical and thermal parameters following:

- Young modulus $E=70\,000\,MPa$
- Poisson's ratio $\nu=0.3$
- Elastic limit according to the temperature $A(T)=A(T_{ref})(1-w(T-T_{ref}))$
- Elastic limit with the reference temperature $A(T_{ref})=70\,MPa$
- linear Coefficient of softening $w=3.10^{-4}\,K^{-1}$
- Slope post-elastic $B=210\,MPa$
- Power post-elastic $n=1$
- Density $\rho=2700\,kg/m^3$
- Coefficient of thermal expansion $\alpha=2{,}38.10^{-5}\,K^{-1}$
- Conductivity $\lambda=150\,W/(m.K)$
- Heat capacity $C_p=900\,J/(kg.K)$
- Reference temperature $T_{ref}=293\,K$

1.3 Boundary conditions and loadings

Modelization a:

One imposes a radial displacement of $20\,mm$ on the inner face of the cylinder at the speed of $1\mathrm{mm}/s$. The temperature of the external face is imposed on T_{ref} . The other sides of the cylinder are regarded as thermically isolated. The behavior is thermo-elastic and the expansion of a cylinder thus causes its cooling.

Modelization b:

the surface of the cylinder is regarded as thermically isolated. The displacement of the inner face of the cylinder of $130\,mm$ is applied in $1{,}3\,s$. The behavior is thermoelastoplastic and the effect of plastic dissipation compensates for the preceding effect of thermoelastic cooling to involve the total warming of the cylinder.

1.4 Initial conditions

the temperature of the cylinder is equal to T_{ref} .

2 Reference solution

2.1 Méthode de calcul

the reference solutions for each of the two problems result from the curves presented in the thesis of L. ADAM. These results were got using software METAFOR, develop by the University of Liege.

2.2 Bibliographical references

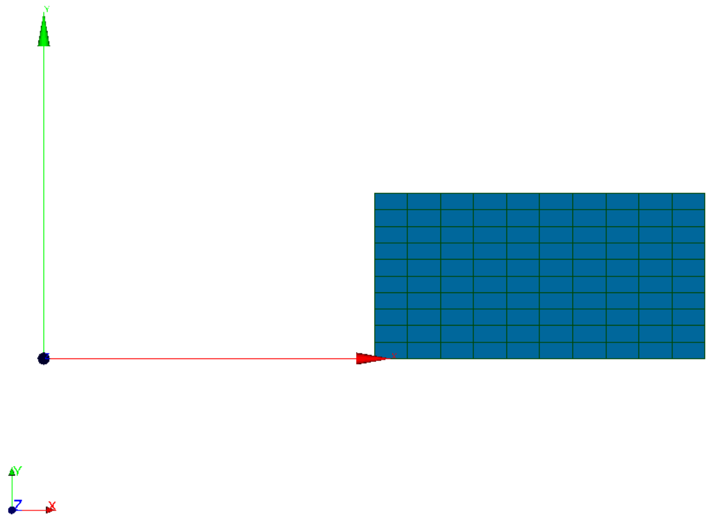
[1] U4.43.01 Document, Operator DEFI_MATERIAU , instruction manual of *Code_Aster*.

[2] L. ADAM, “Modelization of the thermo-élasto-viscoplastic behavior of the metals subjected to large deformations. Application to superplastic forming. ”, Doctorate, University of Liege, 2003.

3 Modelization A

3.1 Characteristic of the modelization

One uses a modelization AXIS_DIAG for the thermal and a modelization AXIS_SI for the mechanics. The introducing test of large deformations, one uses formalism GDEF_LOG.



3.2 Characteristics of the meshes

two meshes are used (for each phenomenon).
For the thermal, one uses a mesh of elements with linear interpolation:

- 100 elements of the type QUAD4 .
- 121 nodes.

For the mechanics, one uses a mesh of elements with quadratic interpolation:

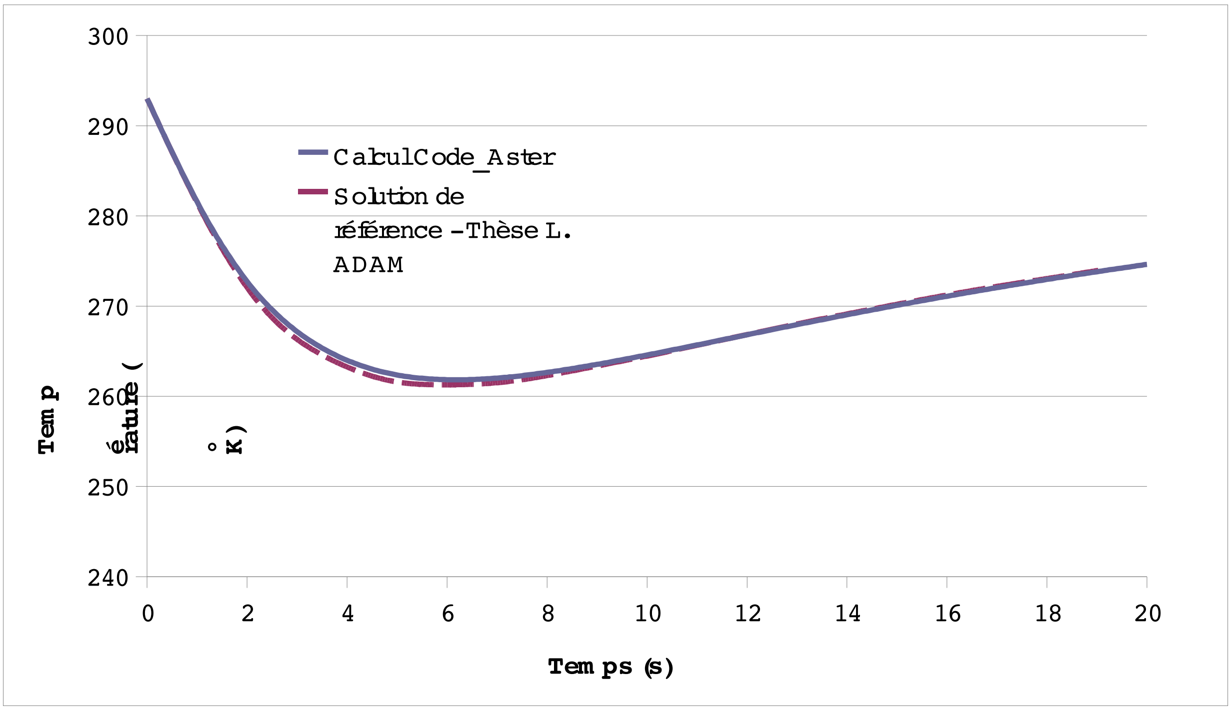
- 100 elements of the type QUAD 8 .
- 341 nodes.

3.3 Quantities tested and results

One tests the temperature on the internal wall of the cylinder at the time $t=6\text{s}$, which corresponds to the peak of cooling of the cylinder.

Standard	identification of reference	Value of reference	Tolerance
Temperature out of internal wall	"SOURCE_EXTERNE"	$261,5$	0,2%

We traced the change of the temperature of the internal face of the cylinder during computation and result let us have we it compared to L. ADAM. One can see that we find the same results.



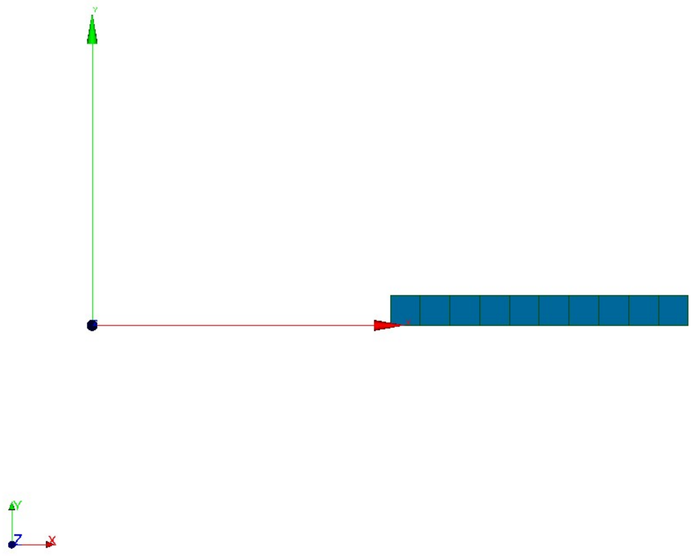
3.4 _remark

The result obtained with the coupling introduce in Code_Aster give some good performance.

4 Modelization B

4.1 Characteristic of the modelization

One uses a modelization AXIS_DIAG for the thermal and a modelization AXIS_SI for the mechanics. The introducing test of large deformations, one uses formalism GDEF_LOG.



4.2 Characteristics of the meshes

two meshes are used (for each phenomenon).
For the thermal, one uses a mesh of elements with linear interpolation:

- 22 elements of the type QUAD4 .
- 22 nodes.

For the mechanics, one uses a mesh of elements with quadratic interpolation:

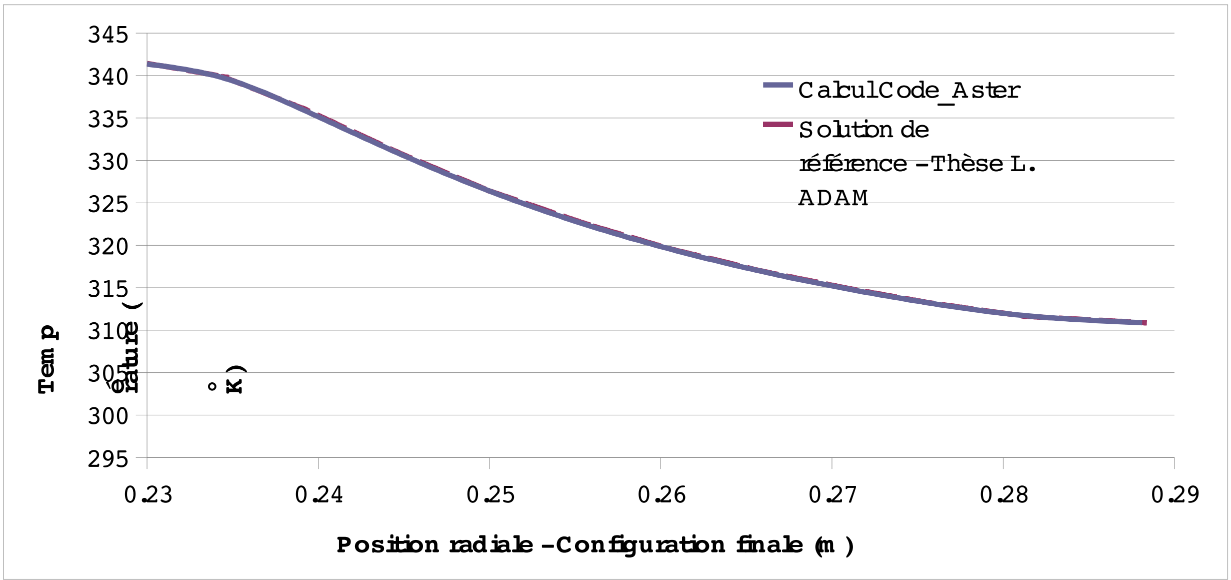
- 22 elements of the type QUAD 8 .
- 53 nodes.

4.3 Quantities tested and results

One tests the temperature on the internal wall of the cylinder at the end of the transient.

Standard	identification of reference	Value of reference	Tolerance
Temperature out of internal wall	"SOURCE_EXTERNE"	341,44	0,1%

We have the temperature in the thickness of the cylinder at the end of the computation and result let us have we it compared to L. ADAM. One can see that we find the same results.



4.4 _remark

The result obtained with the coupling introduce in Code_Aster give some good performance.

5 Summary of the results

the method of coupling thermomechanical established in the cases tests of *Code_Aster* makes it possible to find coherent results with those of the literature. The approach developed in these cases tests is sufficiently generic to be applied to any situation.