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

Summary:

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

This case test comprises two modelings which correspond to two distinct physical transients described in the literature [2]:

- thermoelastic modeling a: Case where the expansion of a cylinder causes its cooling;
- thermoelastoplastic modeling b: Case where the effect of dissipation plastic 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

An infinite hollow roll is considered.

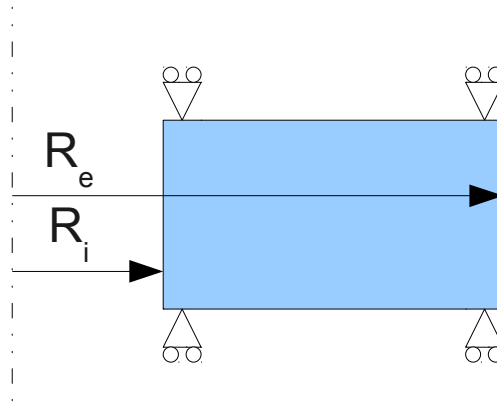


Figure 1 : Geometry of the hollow roll

Modeling a:

The geometrical properties are:

- Internal ray $R_i = 10 \text{ mm}$
- External ray $R_e = 20 \text{ mm}$

Modeling b:

The geometrical properties are:

- Internal ray $R_i = 100 \text{ mm}$
- External ray $R_e = 200 \text{ mm}$

1.2 Properties of material

The materials used in calculations use the law of behavior VMIS_JOHN_COOK. Its function of work 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 at the temperature and the speed of plastic deformation. One will work then with:

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

Modeling a:

An elastic law of behavior is modelled. One uses the mechanical and thermal parameters following:

- Young modulus $E = 206\,900\text{ MPa}$
- Poisson's ratio $\nu = 0.29$
- Elastic limit $A = 5 \cdot 10^{100}\text{ Pa}$
- Slope post-rubber band $B = 2 \cdot 10^{10}\text{ Pa}$
- Power post-rubber band $n = 1$
- Density $\rho = 7800\text{ kg/m}^3$
- Dilation coefficient $\alpha = 1,5 \cdot 10^{-5}\text{ K}^{-1}$
- Conductivity $\lambda = 45\text{ W/(m.K)}$
- Heat-storage capacity $C_p = 460\text{ J/(kg.K)}$
- Temperature of reference $T_{ref} = 293\text{ K}$

Modeling b:

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

- Young modulus $E = 70\,000\text{ MPa}$
- Poisson's ratio $\nu = 0.3$
- Elastic limit according to the temperature $A(T) = A(T_{ref})(1 - w(T - T_{ref}))$
- Limit elastic at the temperature of reference $A(T_{ref}) = 70\text{ MPa}$
- Linear coefficient of softening $w = 3 \cdot 10^{-4}\text{ K}^{-1}$
- Slope post-rubber band $B = 210\text{ MPa}$
- Power post-rubber band $n = 1$
- Density $\rho = 2700\text{ kg/m}^3$
- Dilation coefficient $\alpha = 2,38 \cdot 10^{-5}\text{ K}^{-1}$
- Conductivity $\lambda = 150\text{ W/(m.K)}$
- Heat-storage capacity $C_p = 900\text{ J/(kg.K)}$
- Temperature of reference $T_{ref} = 293\text{ K}$

1.3 Boundary conditions and loadings

Modeling a:

One imposes a radial displacement of 20 mm with the inner face of the cylinder at the speed of 1 mm/s . The temperature of the external face is imposed on T_{ref} . The others faces of the cylinder are regarded as thermally isolated. The behavior is thermoelastic and the expansion of a cylinder thus causes its cooling.

Modeling b:

The surface of the cylinder is regarded as thermally isolated. The displacement of the inner face of the cylinder is of 130 mm applied in $1,3\text{ s}$. The behavior is thermoelastoplastic and the effect of dissipation plastic 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 Method of calculating

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.

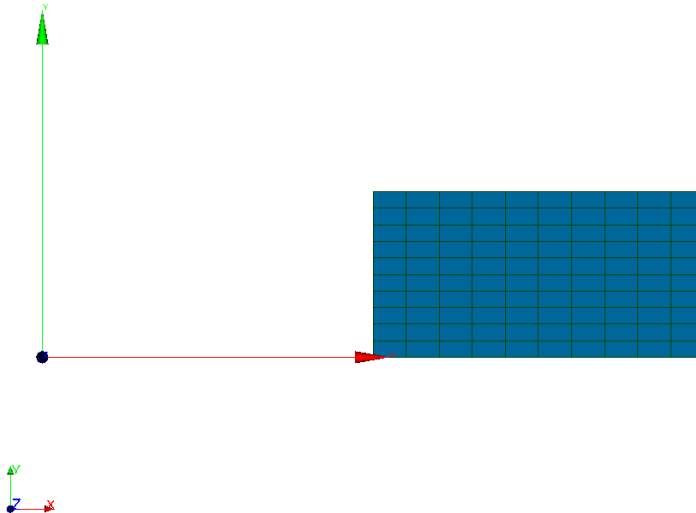
2.2 Bibliographical references

- [1] U4.43.01 document, Operator `DEFI_MATERIAU` , instruction manual of *Code_Aster*.
- [2] L. ADAM, "Modeling of the thermo-élasto-viscoplastic behavior of the metals subjected to great deformations. Application to superplastic forming. ", Doctorate, University of Liege, 2003.

3 Modeling A

3.1 Characteristics of modeling

A modeling is used `AXIS_DIAG` for thermics and a modeling `AXIS_SI` for mechanics. The introducing test of great deformations, one uses the formalism `GDEF_LOG`.



3.2 Characteristics of the grids

Two grids are used (for each phenomenon).

For thermics, one uses a grid of elements with linear interpolation:

- 100 elements of the type `QUAD 4` .
- 121 nodes.

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

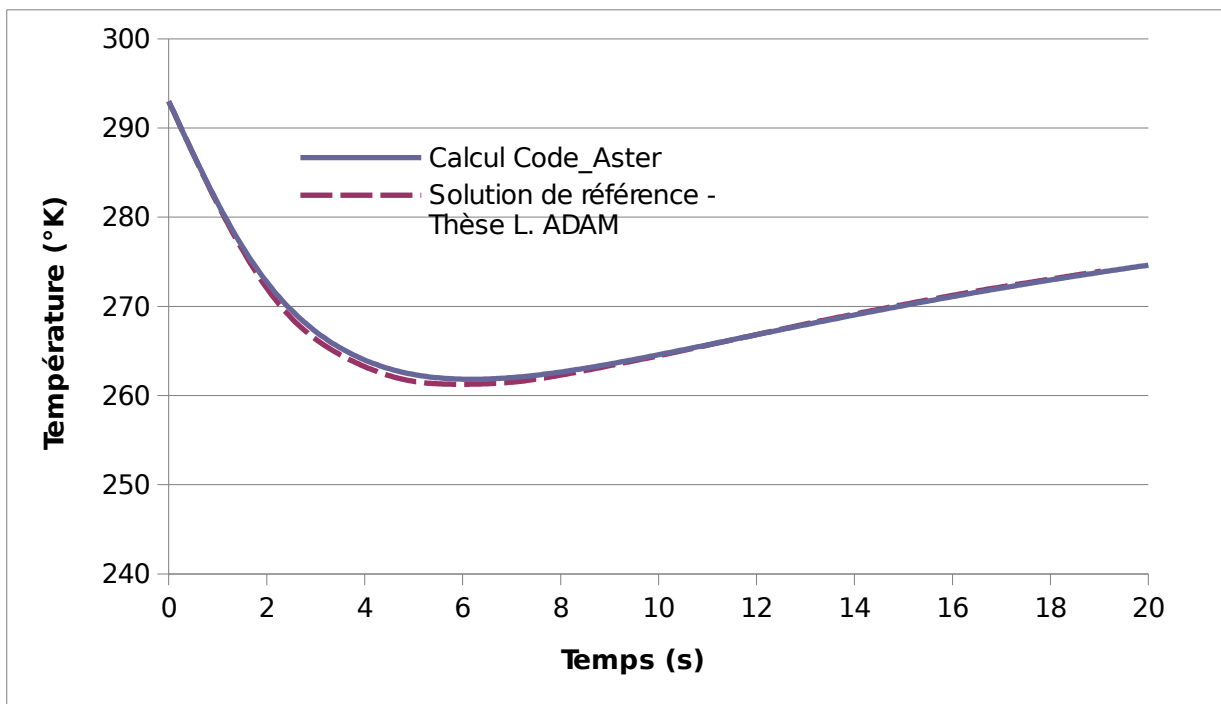
- 100 elements of the type `QUAD 8` .
- 341 nodes.

3.3 Sizes tested and results

One tests the temperature on the internal wall of the cylinder at the moment $t=6s$, which corresponds to the peak of cooling of the cylinder.

Identification	Type of reference	Value of reference	Tolerance
Temperature in internal wall	'SOURCE_EXTERNE'	261,5	0.2%

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



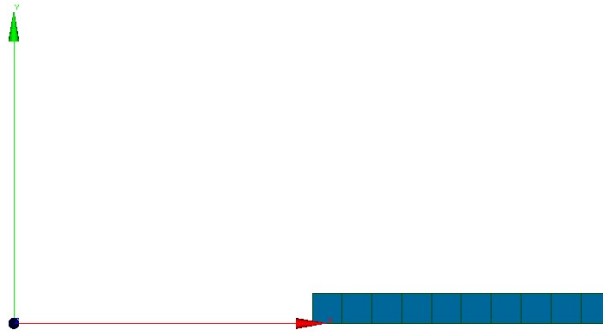
3.4 Remarks

The results got with the coupling introduced into Code_Aster gives good performances.

4 Modeling B

4.1 Characteristics of modeling

A modeling is used `AXIS_DIAG` for thermics and a modeling `AXIS_SI` for mechanics. The introducing test of great deformations, one uses the formalism `GDEF_LOG`.



4.2 Characteristics of the grids

Two grids are used (for each phenomenon).

For thermics, one uses a grid of elements with linear interpolation:

- 22 elements of the type `QUAD 4` .
- 22 nodes.

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

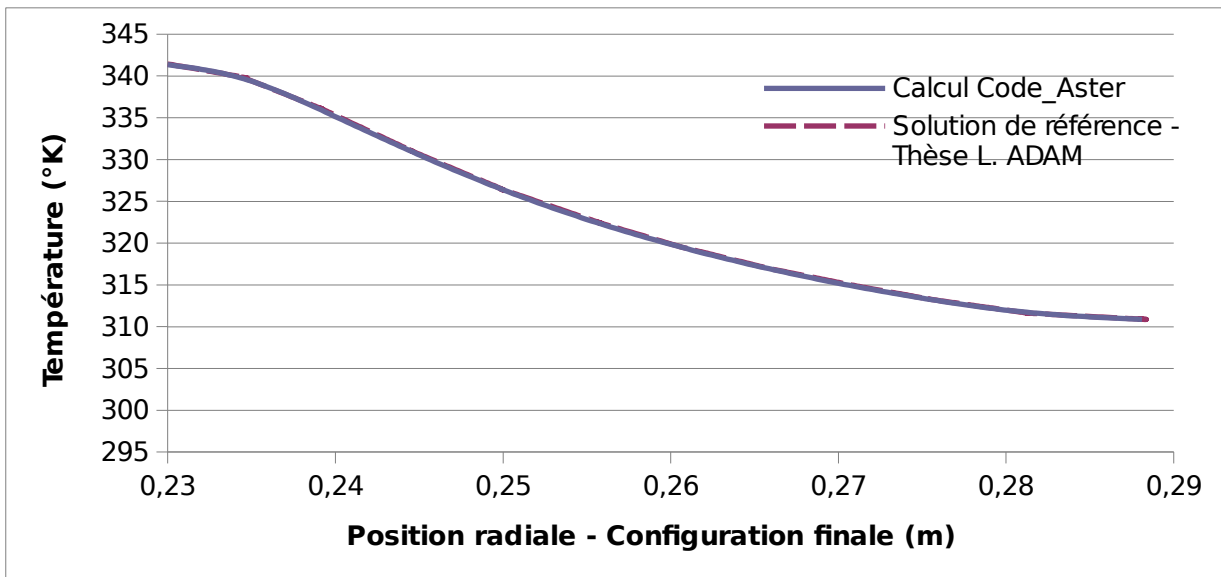
- 22 elements of the type `QUAD 8` .
- 53 nodes.

4.3 Sizes tested and results

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

Identification	Type of reference	Value of reference	Tolerance
Temperature in internal wall	'SOURCE_EXTERNE'	341,44	0.1%

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



4.4 Remarks

The results got with the coupling introduced into Code_Aster gives good performances.

5 Summary of the results

Method of coupling thermomechanical established in the cases tests of *Code_Aster* allows 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.