

## SSNV301 - Cylindrical ring in rotation subjected to a thermal shock and an internal pressure – Von Mises (isotropic Work hardening)

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### Summary:

This test of non-linear quasi-static mechanics 3D relate to the modeling of a piece of ring cylindrical and checks the resumption of a field of deformation after a transitory linear thermal calculation (thermal shock: application of a heat flux inside the cylindrical ring). Then, calculation is taken again and one checks the transfer of the field of thermal deformation of origin and the use of a following loading (centrifugal force). Then, one takes again calculation once again by applying an internal pressure (change of the boundary conditions). One uses the criterion of Von Mises with isotropic work hardening defined by a function which depends on the temperature.

Comparison with the digital results of a modeling with the SAMCEF software V7.0 (module THERNL for the calculation of the field of temperature transitory and taken again with module MECANL for mechanical calculation not - linear geometrical and material).

Modeling with elements 3D HEXA20 and of the axisymmetric elements of meaxtr6 type. One uses a rather fine grid in order to check the robustness and the performances of *Code\_Aster*.

In two modelings A and B, the pressure applied is not following. The results got by the SAMCEF software are provided with and without following pressure.

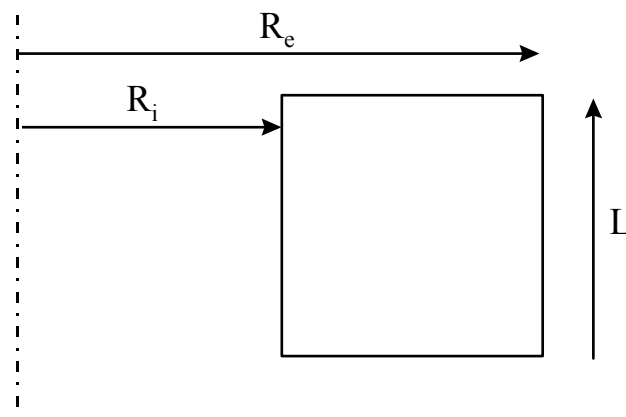
Moreover, one makes use of modeling A in order to validate the use of the indicator of error in residue in mechanics 'ERME\_ELEM' on a modeling 3D in the presence of rotations.

## 1 Problem of reference

### 1.1 Geometry

Cylinder with:

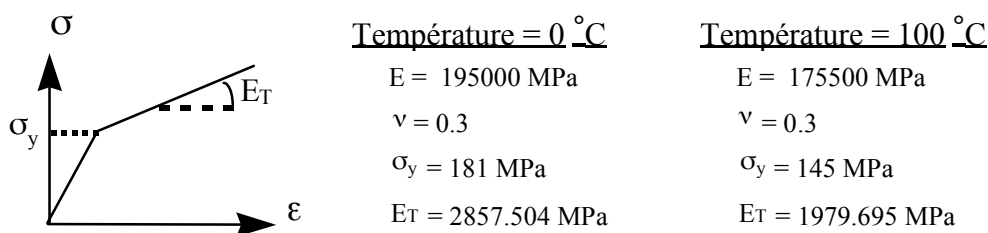
Interior ray	$R_i = 0.04 \text{ m}$
External ray	$R_e = 0.08 \text{ m}$
Height	$L = 0.04 \text{ m}$



### 1.2 Material properties

The material is homogeneous isotropic, thermoelastic linear. The material mechanical properties depend on the temperature. The properties vary linearly between the 2 extreme temperatures:  $0^\circ\text{C}$  and  $100^\circ\text{C}$ .

Law of behaviour to linear isotropic work hardening:



Thermal properties and density:

$$\lambda = 72 \frac{\text{J}}{\text{msK}}$$

$$\rho = 7860 \frac{\text{kg}}{\text{m}^3}$$

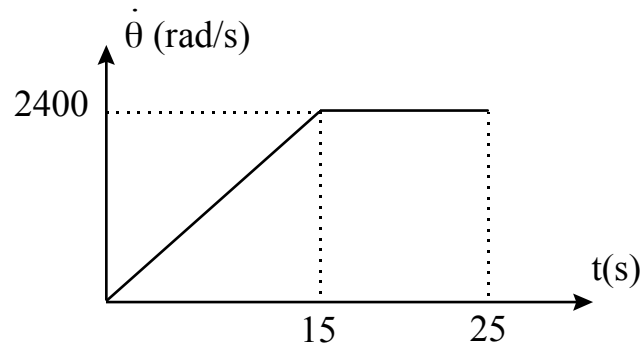
$$C_p = 452 \frac{\text{J}}{\text{kgK}}$$

$$\alpha = 12.E - 6 \frac{1}{\text{K}}$$

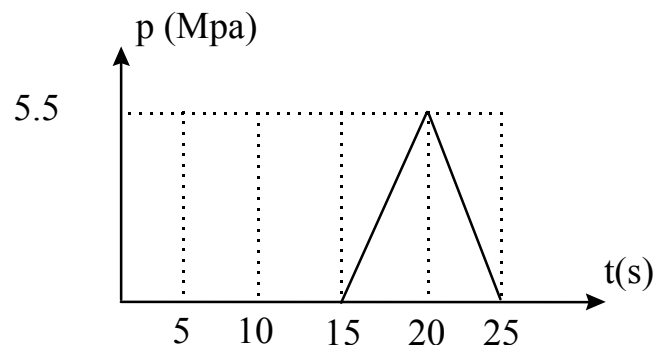
## 1.3 Boundary conditions and loadings

The thermal shock is modelled by a heat flux of  $300000 \text{ W/m}^2$  inside the cylinder. The structure has an initial temperature of  $0^\circ \text{C}$ .

At the same time a centrifugal force is applied: on an interval of  $15 \text{ s}$ , the number of revolutions is increased until  $2400 \text{ rad/s}$ , then kept constant.



Afterwards  $15 \text{ s}$ , an internal pressure is applied: the pressure increases linearly up to a value of  $5.5 \text{ MPa}$  who is reached with  $20 \text{ s}$ , then the pressure goes down to zero.



Thermal calculation and mechanical calculation are carried out with identical 50 pas de time.

A quarter of the cylinder is modelled by fixing the transverse components of displacements at the two cross sections of the cylinder. Moreover, the degree of translation according to the length of the cylinder is fixed on the interior ray of with dimensions inferior of the cylinder.

## 2 Reference solution

### 2.1 Method of calculating used for the reference solution

Comparison with the digital results of a voluminal modeling with the SAMCEF software V7.0 with 50 pas de time (module THERNL for the calculation of the field of temperature transitory and taken again with module MECANL for non-linear mechanical calculation).

An implicit scheme is used for the integration of the equation of heat.

Non-linear mechanical calculation was carried out with the SAMCEF software by using an axisymmetric modeling with 5 pas de time (nonlinear modeling geometrical) and a voluminal modeling (a quarter of cylinder) with 5 pas de time (geometrical nonlinear modeling).

### 2.2 Results of reference

**Evolution of the field of temperature according to the thickness on with dimensions lower of the cylinder**

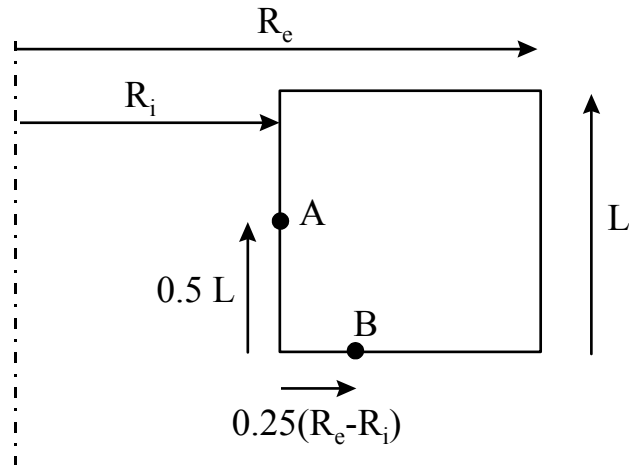
Axisymmetric calculation with 50 pas de time

Time = 0.5 dryness	Times = 25 dryness
1.25355E+01	8.64267E+01
5.71233E+00	7.65695E+01
2.44526E+00	6.77355E+01
1.12189E+00	5.98610E+01
4.83644E-01	5.28476E+01
2.22443E-01	4.66462E+01
9.62036E-02	4.11801E+01
4.43444E-02	3.64106E+01
1.92310E-02	3.22765E+01
8.87973E-03	2.87468E+01
3.85960E-03	2.57723E+01
1.78524E-03	2.33283E+01
7.78650E-04	2.13761E+01
3.63114E-04	1.98963E+01
1.64448E-04	1.88596E+01
8.80577E-05	1.82514E+01
6.54904E-05	1.80507E+01

Voluminal calculation with 50 pas de time

Time = 0.5 dryness	Times = 25 dryness
1.26658E+01	8.64175E+01
5.64556E+00	7.65753E+01
2.50690E+00	6.77332E+01
1.10448E+00	5.98571E+01
5.06396E-01	5.28510E+01
2.23330E-01	4.66453E+01
9.98984E-02	4.11819E+01
4.41255E-02	3.64095E+01
2.02976E-02	3.22781E+01
8.97177E-03	2.87460E+01
4.05352E-03	2.57736E+01
1.79338E-03	2.33275E+01
8.25938E-04	2.13766E+01
3.68531E-04	1.98979E+01
1.74367E-04	1.88647E+01
8.91805E-05	1.82450E+01
6.98548E-05	1.80607E+01

## Evolution of the longitudinal constraint $\sigma_T$



### Case where the pressure is nonfollowing

Geometrical nonlinear voluminal  
calculation with 5 pas de time

$t(s)$	$\sigma$	Not $A$	Not $B$
15.0	$\sigma_T$	1.21692E8	1.67285E8
20.0	$\sigma_T$	1.39804E8	1.65266E8
25.0	$\sigma_T$	1.28967E8	1.57980E8

Geometrical nonlinear axisymmetric  
calculation with 5 pas de time

$t(s)$	$\sigma$	Not $A$	Not $B$
15.0	$\sigma_T$	1.20472E8	1.66917E8
20.0	$\sigma_T$	1.39164E8	1.70412E8
25.0	$\sigma_T$	1.28421E8	1.63168E8

## Case where the pressure is following

Geometrical nonlinear voluminal  
calculation with 5 pas de time

$t (s)$	$\sigma$	Not A	Not B
15.0	$\sigma_T$	1.21692E8	1.67285E8
20.0	$\sigma_T$	1.39894E8	1.65313E8
25.0	$\sigma_T$	1.29032E8	1.58007E8

Geometrical nonlinear axisymmetric  
calculation with 5 pas de time

$t (s)$	$\sigma$	Not A	Not B
15.0	$\sigma_T$	1.20472E8	1.65934E8
20.0	$\sigma_T$	1.39252E8	1.64075E8
25.0	$\sigma_T$	1.28485E8	1.56886E8

## 2.3 Uncertainty on the solution

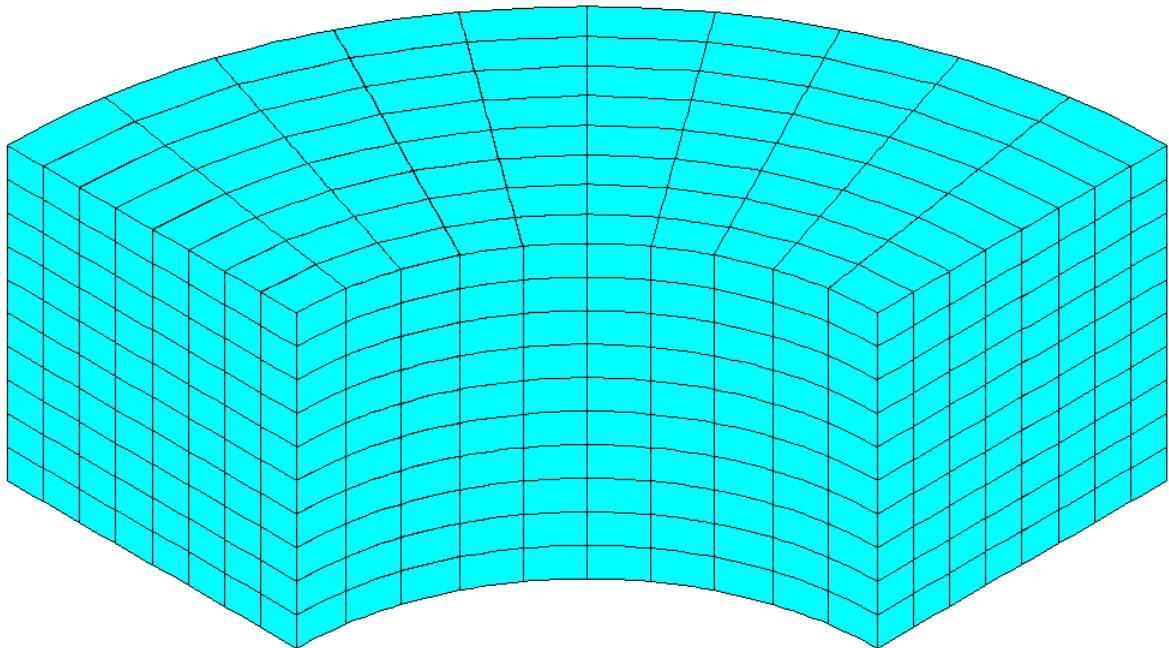
Uncertainty lower than 1 % for thermal calculation, uncertainty lower than 0.5 % for mechanical calculation.

## 3 Modeling A

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### 3.1 Characteristics of modeling A

A quarter of cylinder with a regular grid.



### 3.2 Characteristics of the grid

Many nodes:	4037
Many meshes and types:	800 <code>HEXA20</code> (8 meshes on the thickness, 10 meshes over the length and 10 meshes on the quadrant)

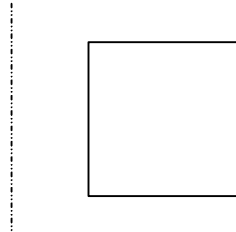
## 3.3 Sizes tested and results

Identification	Moment	Type of reference	Value of reference	Tolerance (%)
Temperature (N21)	0.5s	`SOURCE_EXTERNE`	1.266580E1	5.0
Temperature (N201)	0.5s	`SOURCE_EXTERNE`	5.645560E0	5.0
Temperature (N202)	0.5s	`SOURCE_EXTERNE`	2.506900E0	5.0
Temperature (N203)	0.5s	`SOURCE_EXTERNE`	1.104480E0	5.0
Temperature (N204)	0.5s	`SOURCE_EXTERNE`	5.063960E-1	5.0
Temperature (N205)	0.5s	`SOURCE_EXTERNE`	2.233300E-1	5.0
Temperature (N206)	0.5s	`SOURCE_EXTERNE`	9.989840E-2	5.0
Temperature (N207)	0.5s	`SOURCE_EXTERNE`	4.412550E-2	5.0
Temperature (N208)	0.5s	`SOURCE_EXTERNE`	2.029760E-2	5.0
Temperature (N209)	0.5s	`SOURCE_EXTERNE`	8.971770E-3	5.0
Temperature (N210)	0.5s	`SOURCE_EXTERNE`	4.053520E-3	5.0
Temperature (N211)	0.5s	`SOURCE_EXTERNE`	1.793380E-3	5.0
Temperature (N212)	0.5s	`SOURCE_EXTERNE`	8.259380E-4	5.0
Temperature (N213)	0.5s	`SOURCE_EXTERNE`	3.685310E-4	5.0
Temperature (N214)	0.5s	`SOURCE_EXTERNE`	1.743670E-4	5.0
Temperature (N215)	0.5s	`SOURCE_EXTERNE`	8.918050E-5	5.0
Temperature (N28)	0.5s	`SOURCE_EXTERNE`	6.985480E-5	5.0
Temperature (N21)	25s	`SOURCE_EXTERNE`	8.641750E1	5.0
Temperature (N201)	25s	`SOURCE_EXTERNE`	7.657530E1	5.0
Temperature (N202)	25s	`SOURCE_EXTERNE`	6.773320E1	5.0
Temperature (N203)	25s	`SOURCE_EXTERNE`	5.985710E1	5.0
Temperature (N204)	25s	`SOURCE_EXTERNE`	5.285100E1	5.0
Temperature (N205)	25s	`SOURCE_EXTERNE`	4.664530E1	5.0
Temperature (N206)	25s	`SOURCE_EXTERNE`	4.118190E1	5.0
Temperature (N207)	25s	`SOURCE_EXTERNE`	3.640950E1	5.0
Temperature (N208)	25s	`SOURCE_EXTERNE`	3.227810E1	5.0
Temperature (N209)	25s	`SOURCE_EXTERNE`	2.874600E1	5.0
Temperature (N210)	25s	`SOURCE_EXTERNE`	2.577360E1	5.0
Temperature (N211)	25s	`SOURCE_EXTERNE`	2.332750E1	5.0
Temperature (N212)	25s	`SOURCE_EXTERNE`	2.137660E1	5.0
Temperature (N213)	25s	`SOURCE_EXTERNE`	1.989790E1	5.0
Temperature (N214)	25s	`SOURCE_EXTERNE`	1.886470E1	5.0
Temperature (N215)	25s	`SOURCE_EXTERNE`	1.824500E1	5.0
Temperature (N28)	25s	`SOURCE_EXTERNE`	1.806070E1	5.0
SIYY (M473, N2931)	15s	`SOURCE_EXTERNE`	1.216920E8	5.0
SIYY (M74 , N204 )	15s	`SOURCE_EXTERNE`	1.672850E8	5.0
SIYY (M473, N2931)	20s	`SOURCE_EXTERNE`	1.398040E8	5.0
SIYY (M74 , N204 )	20s	`SOURCE_EXTERNE`	1.652660E8	5.0
SIYY (M473, N2931)	25s	`SOURCE_EXTERNE`	1.289670E8	5.0
SIYY (M74 , N204 )	25s	`SOURCE_EXTERNE`	1.579800E8	5.0
Indicator of error ERME_ELEM	25s	`NON_REGRESSION`	-	-



## 4 Modeling B

### 4.1 Characteristics of modeling B



### 4.2 Characteristics of the grid

Many nodes: 357  
Many meshes and types: 160 TRIA6  
(8 meshes on the thickness, 10 meshes over the length)

### 4.3 Sizes tested and results

Identification	Moment	Type of reference	Value of reference	Tolerance (%)
Temperature (N1)	0.5s	'SOURCE EXTERNE'	1.25355E1	0,031
Temperature (N161)	0.5s	'SOURCE EXTERNE'	5.712330E0	- 0,034
Temperature (N162)	0.5s	'SOURCE EXTERNE'	2.445260E0	0,058
Temperature (N163)	0.5s	'SOURCE EXTERNE'	1.121890E0	- 0,009
Temperature (N164)	0.5s	'SOURCE EXTERNE'	4.836440E-1	0,064
Temperature (N165)	0.5s	'SOURCE EXTERNE'	2.224430E-1	0,004
Temperature (N166)	0.5s	'SOURCE EXTERNE'	9.620360E-2	0,068
Temperature (N167)	0.5s	'SOURCE EXTERNE'	4.434440E-2	0,012
Temperature (N168)	0.5s	'SOURCE EXTERNE'	1.923100E-2	0,070
Temperature (N169)	0.5s	'SOURCE EXTERNE'	8.879760E-3	0,019
Temperature (N170)	0.5s	'SOURCE EXTERNE'	3.859600E-3	0,072
Temperature (N171)	0.5s	'SOURCE EXTERNE'	1.785240E-3	0,024
Temperature (N172)	0.5s	'SOURCE EXTERNE'	7.786500E-4	0,072
Temperature (N173)	0.5s	'SOURCE EXTERNE'	3.631140E-4	0,028
Temperature (N174)	0.5s	'SOURCE EXTERNE'	1.644480E-4	0,073
Temperature (N175)	0.5s	'SOURCE EXTERNE'	8.805770E-5	0,030
Temperature (N14)	0.5s	'SOURCE EXTERNE'	6.549040E-5	0,069
Temperature (N1)	25s	'SOURCE EXTERNE'	8.642670E1	0,001
Temperature (N161)	25s	'SOURCE EXTERNE'	7.656950E1	- 0.01
Temperature (N162)	25s	'SOURCE EXTERNE'	6.773550E1	0,001
Temperature (N163)	25s	'SOURCE EXTERNE'	5.986100E1	- 0,001
Temperature (N164)	25s	'SOURCE EXTERNE'	5.284760E1	0,001
Temperature (N165)	25s	'SOURCE EXTERNE'	4.664620E1	- 0,001
Temperature (N166)	25s	'SOURCE EXTERNE'	4.118010E1	0,001
Temperature (N167)	25s	'SOURCE EXTERNE'	3.641060E1	- 0,001

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Temperature (N168)	25s	`SOURCE_EXTERNE'	3.227650E1	0,001
Temperature (N169)	25s	`SOURCE_EXTERNE'	2.874680E1	- 0,001
Temperature (N170)	25s	`SOURCE_EXTERNE'	2.577230E1	0,001
Temperature (N171)	25s	`SOURCE_EXTERNE'	2.332830E1	- 0,001
Temperature (N172)	25s	`SOURCE_EXTERNE'	2.137660E1	0,001
Temperature (N173)	25s	`SOURCE_EXTERNE'	1.989790E1	0.
Temperature (N174)	25s	`SOURCE_EXTERNE'	1.886470E1	0,001
Temperature (N175)	25s	`SOURCE_EXTERNE'	1.824500E1	0.
Temperature (N14)	25s	`SOURCE_EXTERNE'	1.806070E1	0,001
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SIYY (M90, N222)	15s	`SOURCE_EXTERNE'	1.204720E8	- 0,347
SIYY (M101, N164 )	15s	`SOURCE_EXTERNE'	1.659340E8	0,151
SIYY (M90 , N222)	20s	`SOURCE_EXTERNE'	1.391640E8	- 0,558
SIYY (M101, N164 )	20s	`SOURCE_EXTERNE'	1.640310E8	0,174
SIYY (M90, N222)	25s	`SOURCE_EXTERNE'	1.284210E8	- 0,652
SIYY (M101, N204 )	25s	`SOURCE_EXTERNE'	1.568610E8	- 0,138

## 5 Summary of the results

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It was checked that one gets the same results with or without recovery, with or without modification of the boundary conditions.

It should be noted that the nodal efforts that one provides to Aster are divided by  $2\pi$  compared to those which one provides to the SAMCEF software into axisymmetric.

The indicator of error in residue in mechanics ``ERME_ELEM'` function correctly for modelings 3D in rotation.