# TTLA203 - Roll with temperatures imposed with adiabatic crack

**Abstract**

This test aims to validate the thermal elements axisymmetric X-FEMs in transitory linear thermal.

One considers a full cylinder, fissured on the level of the section located at middle height. The crack is a contour of interior radius the half radius of the cylinder, and of radius external the radius of the cylinder. The loading is transitory and consists of a variation in temperature imposed by the application of conditions of Dirichlet at the two ends of the cylinder. One makes the assumption of an adiabatic crack (null flux on the lips of crack and discontinuous temperature through crack)

Four modelizations are considered:

- modelization $A$ : $\text{FEM AXIS}$ (crack with a grid)
- modelization $B$ : $\text{X-FEM AXIS}$ , crack in the middle of the elements
- modelization $C$ : $\text{FEM 3D}$ (crack with a grid)
- modelization $D$ : $\text{X-FEM3D}$ , crack in the middle of the elements

# 1 Problem of reference

## 1.1 Geometry

the structure, represented to the Figure, is a cylinder of radius $R=1\,m$ and height $H=2\,m$ comprising a plane crack on the section located at middle height. (included in the plane of equation $y=H/2$ ). The crack is emerging, and has as a geometrical support the contour of interior radius $R/2$ and of external radius $R$ (contour filled in red on Figure 1.1-1).

One calls "disc the lower" disc included in the plane of equation $y=0$ , and "disc the higher" disc included in the plane of equation $y=H$ .

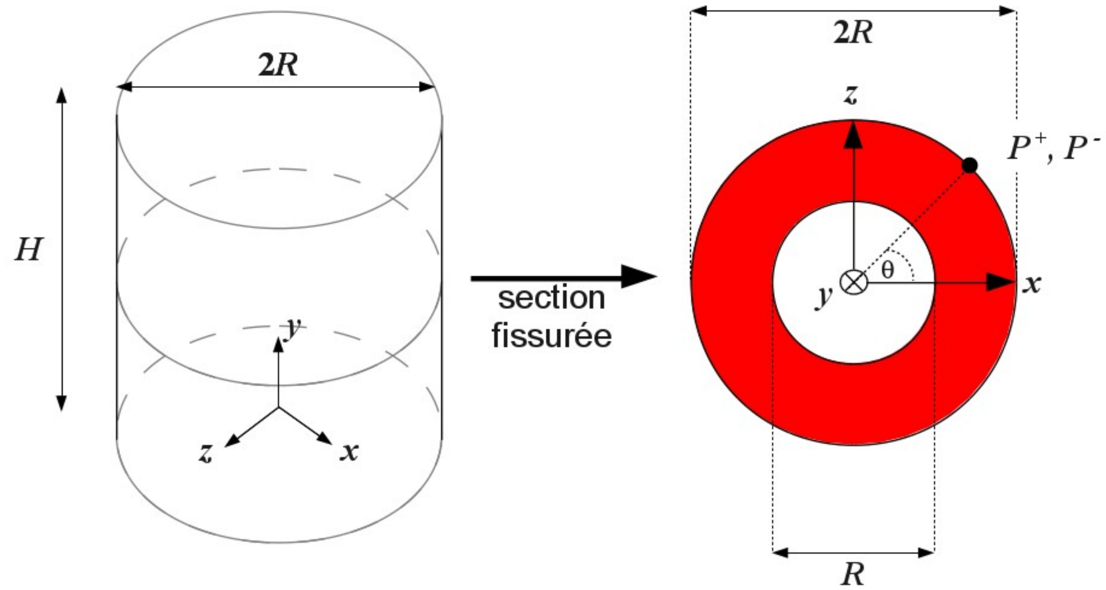


**Figure 1.1-1: Geometry of the problem**

Lastly, one notes $P^+(\theta)$ the point of coordinates $(R\cos\theta, H^+/2, R\sin\theta)$ (located on the upper lip), and $P^-(\theta)$ the point of coordinates $(R\cos\theta, H^-/2, R\sin\theta)$ (located on the lower lip)

## 1.2 Properties of the thermal

material Conductivity: $\lambda=1\,W.m^{-1}.K^{-1}$
Voluminal heat capacity: $\rho C_p=2\,J.m-3.\mathrm{K}^{-1}$

## 1.3 Boundary conditions and loadings

One solves the problem on the time interval $[0.s, 1.s]$ discretized in 5 time step equal (of period $\Delta t=0.2\,s$ ). One takes the value by default in THER_LINEAIRE of the parameter of the theta-diagram: $\theta=0.57$ .

On the nodes of the lower disc (*cf* paragraph 2) one imposes the slope of following temperature:

with $t=0.s$ , $\bar{T}^{AB}=10°C$ ; with $t=1.s$ , $\bar{T}^{\sup}=20°C$

On the nodes of the higher disc (*cf* paragraph 2) one imposes the slope of following temperature:

with $t=0.s$ , $\bar{T}^{\inf}=20°C$ ; with $t=1.s$ , $\bar{T}^{\inf}=40°C$

## 1.4 Initial conditions

the initial state is given by solving the steady problem with $t=0.s$ (with the boundary conditions given to paragraph 2)

# 2 Reference solution

## 2.1 Méthode de calcul

the reference solution is obtained by refining the mesh of the modelization A (axisymmetric classical elements with crack with a grid): regular mesh composed of $1000\times2000$ QUAD8 (instead of $100\times200$ QUAD8 for the mesh A)

## 2.2 Quantities and results of reference

One time step tests the temperature at the end of the last ( $t=1.s$ ) at the points $P^{+}(\theta)$ and $P^{-}(\theta)$ (see Figure 1.1-1).

| Standard | identification of reference | Value of reference |
|---|---|---|
| Not $P^{+}(\theta)$ - $TEMP$ | "AUTRE_ASTER" | $23{,}559884847913\,°C$ |
| Not $P^{+}(\theta)$ - $TEMP$ | "AUTRE_ASTER" | $15{,}592470476233\,°C$ |

the problem being axisymmetric, the values tested cannot vary with $\theta$ . One tests these values then with:

- $\theta=0$ for the modelizations A and B (respectively $\mathrm{FEM\ AXIS}$ and $\mathrm{X\text{-}FEM\ AXIS}$ )
- $\theta=\pi/4$ for the modelizations C and D (respectively $\mathrm{FEM\ 3D}$ and $\mathrm{X\text{-}FEM\ 3D}$ )

# 3 Modelization A

In this modelization, the classical finite element method is used, the crack is with a grid.

## 3.1 Characteristics of the modelization

One uses modelization AXIS of the THERMAL phenomenon.

## 3.2 Characteristics of the mesh

the structure is modelled by a mesh $2D$ regular made up of $100\times200$ QUAD4, respectively along the axes $x$ and $y$. The crack is with a grid.

## 3.3 Quantities tested and results

One time step tests the temperature at the end of the last ( $t=1.s$ ) with the nodes $P^{+}(0)$ formulates $P^{-}(0)$ formulates (see 1.1-1 1.1-1

| ) | Standard Identification of | reference Value of reference | |
|---|---|---|---|
| Tolerance $P^{+}(0)$ Not $TEMP$ | - "AUTRE_ASTER | $23,559884847913\,°C$ | ” |
| 0.1% $P^{-}(0)$ Point $TEMP$ | - "AUTRE_ASTER | $15,592470476233\,°C$ | ” |

# 4 0.1% Modelization

In this modelization, the wide finite element method (X-FEM) is used.

## 4.1 Characteristics of the modelization

One uses modelization AXIS of the THERMAL phenomenon.

## 4.2 Characteristics of the mesh

the structure is modelled by a mesh 2D regular made up of $101\times 201$ QUAD4, respectively along the axes $x$ and $y$. The crack is not with a grid.

## 4.3 Quantities tested and results

One time step tests the temperature at the end of the last ( $t=1.s$ ) with the nodes $P^+(0)$ and $P^-(0)$ (see Figure 1.1-1). For that one tests the field of temperature after call to operators POST_MAIL_XFEM and POST_CHAM_XFEM.

| Standard | identification of reference | Value of reference | Tolerance |
|---|---|---|---|
| Not $P^+(0)$ - $TEMP$ | "AUTRE_ASTER" | $23,559884847913\,°C$ | 0.1% |
| Point $P^-(0)$ - $TEMP$ | "AUTRE_ASTER" | $15,592470476233\,°C$ | 0.1% |

# 5 Modelization C

In this modelization, the classical finite element method is used, the crack is with a grid.

## 5.1 Characteristics of the modelization

One uses the modelization 3D THERMAL phenomenon.

## 5.2 Characteristics of the mesh

the structure is modelled by a mesh $3D$ made up of $30720$ HEXA8.

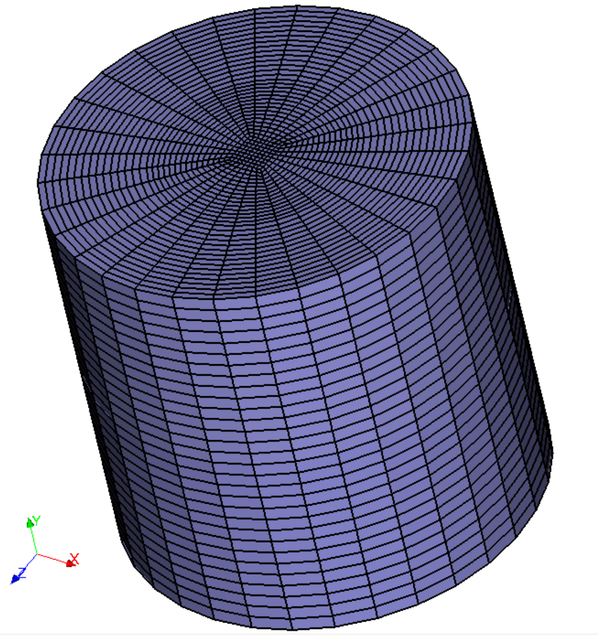


**Figure 5.2-1: Mesh C**

## 5.3 Quantities tested and results

One time step tests the temperature at the end of the last ( $t=1.s$ ) with the nodes $P^+(\pi/4)$ and $P^-(\pi/4)$ (see Figure 1.1-1)

| Standard | Identification of reference | Value of reference | Tolerance |
|---|---|---|---|
| Not $P^+(\pi/4)$ - $TEMP$ | "AUTRE_ASTER" | $23{,}559884847913\,°C$ | 1.% |
| Point $P^-(\pi/4)$ - $TEMP$ | "AUTRE_ASTER" | $15{,}592470476233\,°C$ | 1.% |

# 6 Modelization D

In this modelization, the wide finite element method (X-FEM) is used.

## 6.1 Characteristics of the modelization

One uses the modelization 3D THERMAL phenomenon.

## 6.2 Characteristics of the mesh

the structure is modelled by a mesh $3D$ made up of $31744$ HEXA8. The crack is not with a grid.

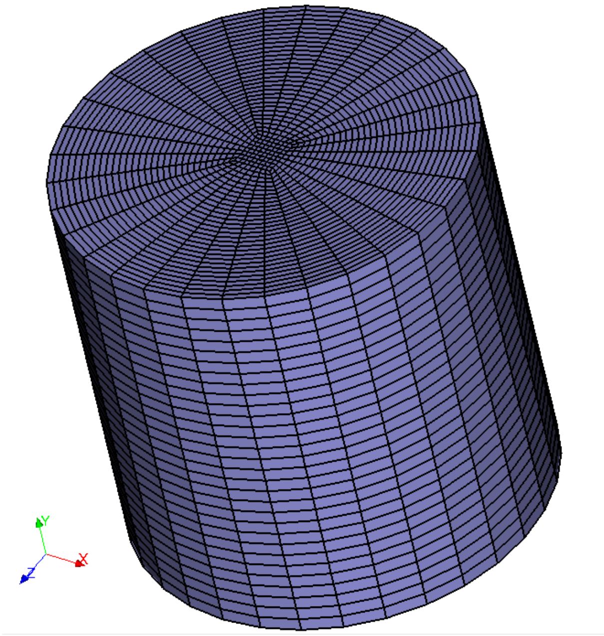


**Figure 6.2-1: Mesh D**

## 6.3 Quantities tested and results

One time step tests the temperature at the end of the last ( $t=1.s$ ) with the nodes $P^+(0)$ and $P^-(\pi/4)$ (see Figure 1.1-1). For that one tests the field of temperature after call to operators POST_MAIL_XFEM and POST_CHAM_XFEM.

| Standard | identification of reference | Value of reference | Tolerance |
|---|---|---|---|
| Not $P^+(\pi/4)$ - $TEMP$ | "AUTRE_ASTER" | $23,559884847913°C$ | 1.% |
| Point $P^-(\pi/4)$ - $TEMP$ | "AUTRE_ASTER" | $15,592470476233°C$ | 1.% |

# 7 Summaries of the results

the purpose of this test is reached: to validate on a simple case the axisymmetric thermal elements $\mathrm{X\text{-}FEM}$ in transitory linear thermal.