TPNA01 - Stationary axisymmetric problem with radiation

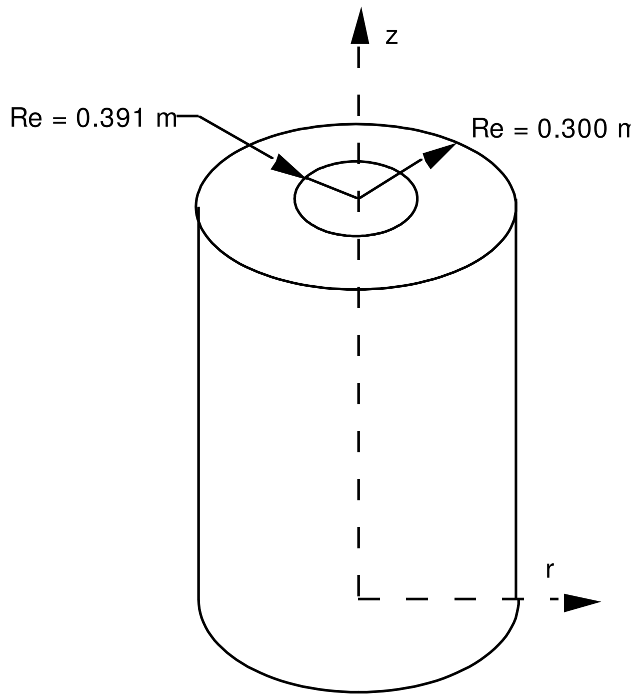
Summary:

This elementary test makes it possible to deal with an axisymmetric problem in stationary thermics with a boundary condition of type radiation. The solution is analytical. With the problem is dealt into axisymmetric and voluminal.

For modelings presented here, the variations of the results got by *Code_Aster* range between 1 and 2% of the analytically calculated reference.

1 Problem of reference

1.1 Geometry



The hollow roll is supposed infinitely long.

1.2 Material properties

Only the coefficient of conductivity intervenes. *Code_Aster* compulsory the supply of a function makes representing the given voluminal enthalpy starting from the voluminal coefficient of heat.

voluminal heat	$\rho\ C_P = 1.00\ J/\ m^3\ {}^\circ C$
thermal conductivity	$k = 40\ W\ /\ m^3\ {}^\circ C$

1.3 Boundary conditions and loadings

Condition of type radiation on surface interns cylinder, condition of type convection (exchange with the external medium) on external surface.

Pas de boundary condition on the ends of the cylinder (what amounts imposing a null flow).

Internal surface $k \frac{\partial T}{\partial n} = \varepsilon\,\sigma\left[\ (T+273.15)^4 - (T_{ext}^i + 273.15)^4\right]$

with $\varepsilon = 0.6$, $\sigma = 5.73\,10^{-8} W\ /\ m^2\ K^4$ and $T_{ext}^i = 500.\ {}^\circ C$, T into Centigrade

External surface $k \frac{\partial T}{\partial n} = h_e\left[T_{ext}^e - T\right]$

with $h_e = 142.\ W\ /\ m^2\ {}^\circ C$ and $T_{ext}^e = 20.\ {}^\circ C$

2 Reference solution

2.1 Method of calculating used for the reference solution

One in the case of lays out of an analytical solution a cylinder infinite length:

$$T(r) = \frac{T_e - T_i}{\log\left(\frac{R_e}{R_i}\right)} \log(r) + \frac{T_i \log(R_e) - T_e \log(R_i)}{\log(R_e) - \log(R_i)}$$

2.2 Results of reference

$r(m)$	$T(°C)$
.30000	105.55
.32275	99.21
.34550	93.30
.36825	87.76
.39100	82.56

Value of the temperature according to r

$r(m)$	$\phi(W/m^2)$
.300	11577.49
.391	8822.98

Value of flow according to r

2.3 Uncertainty on the solution

Exact solution.

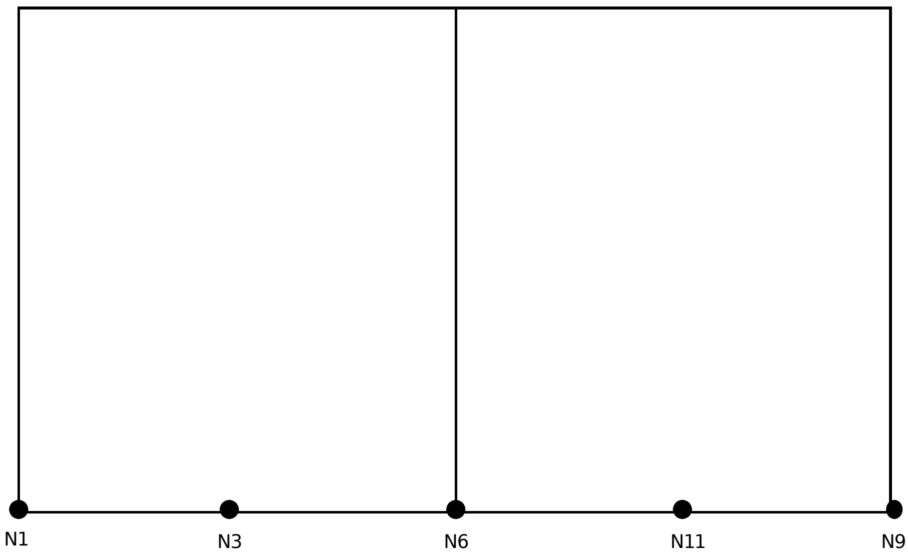
2.4 Bibliographical references

- Guide of validation of the software packages of structural analysis. French company of Mechanics AFNOR 1990 ISBN 2-12-486611-7

3 Modeling A

3.1 Characteristics of modeling

Modeling 2D:



3.2 Characteristics of the grid

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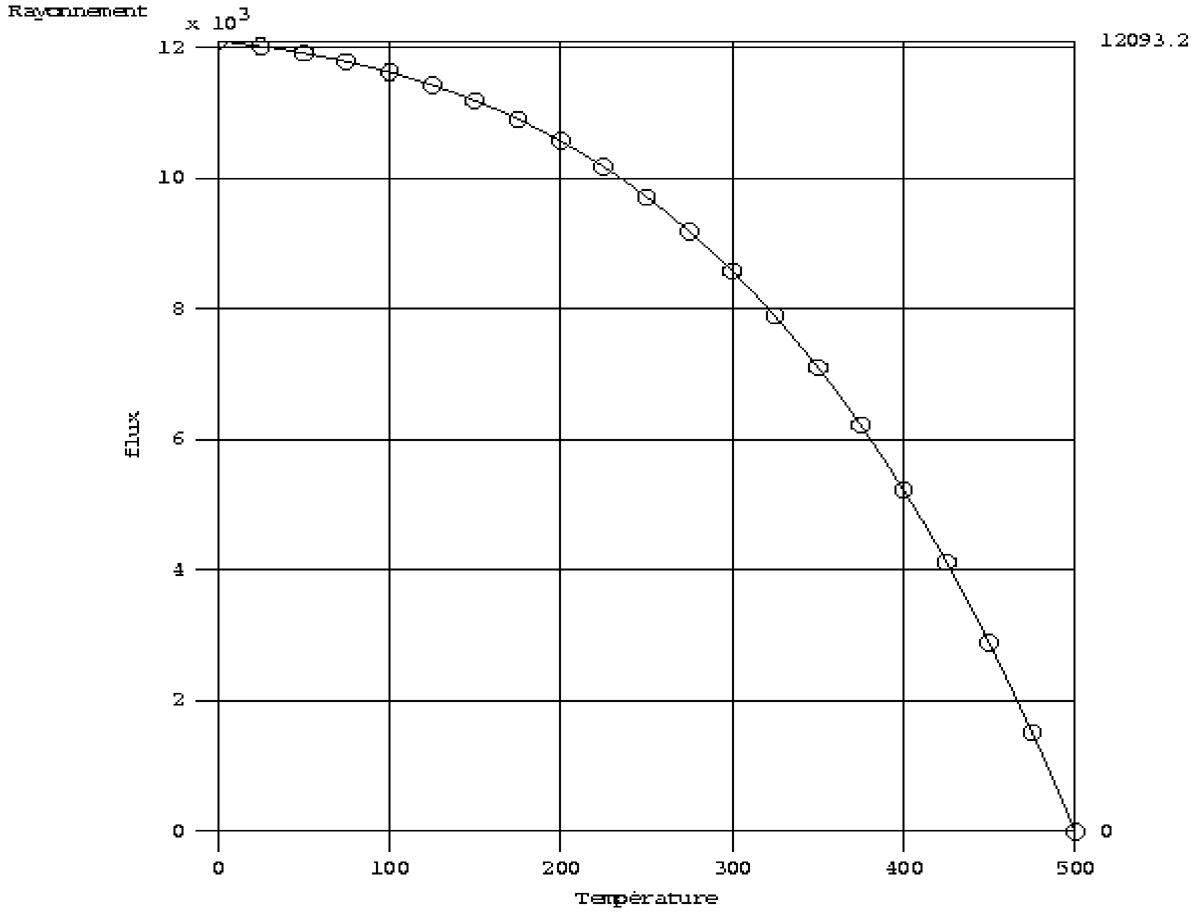
3.3 Values tested

The nodes observed have as a coordinate $z=0.0$

Identification temperature	Reference
$N1$ ($r=.30000$)	105.55
$N3$ ($r=.32275$)	99.21
$N6$ ($r=.34550$)	93.30
$N11$ ($r=.36825$)	87.76
$N9$ ($r=.39100$)	82.56

Identification flow	Reference
mesh $M1$ node $N1$	11577.49
mesh $M2$ node $N9$	8822.98

3.4 Remarks

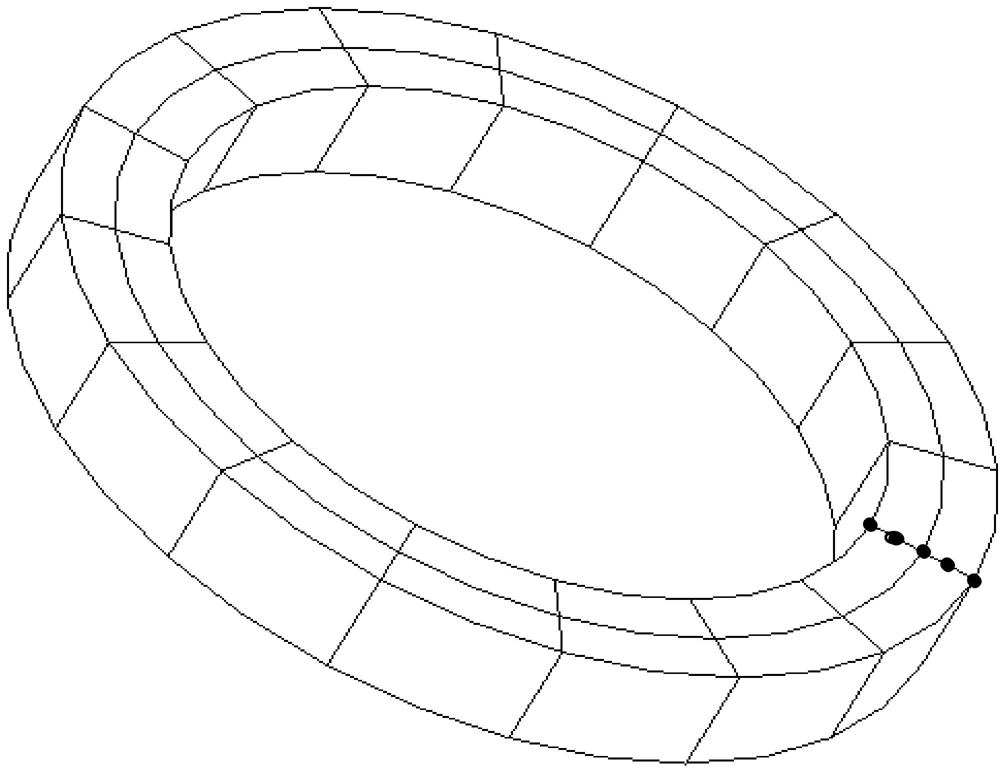


The boundary condition of type radiation is provided in the form of a function of the temperature interpolated linearly between each point (one discretized here the curve using 101 points).

4 Modeling B

4.1 Characteristics of modeling

Modeling 3D:



4.2 Characteristics of the grid

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4.3 Values tested

The nodes observed have as coordinates: $y = z = 0.0$

Identification temperature	Reference
NO106 (x=.30000)	105.55
NO105 (x=.32275)	99.21
NO115 (x=.34550)	93.30
NO125 (x=.36825)	87.76
NO123 (x=.39100)	82.56

Identification flow	Reference
mesh MA17 node NO106	11577.49
mesh MA16 node NO123	8822.98

4.4 Remarks

The function of flow used in modeling A is also used here.

5 Summaries of the results

The taking into account of the conditions of radiation is completely correct in this stationary case. Let us note that this test utilized a coefficient of thermal conductivity constant, only not the - linearity thus relates to the boundary conditions.

The errors are higher on the calculation of flow, which one can explain by the use of smoothings to the nodes, carried out starting from the computed values at the points of integration (points of GAUSS).