
TPNV01 - Hollow sphere: convection, Summarized

radiation:

This test is resulting from the validation independent of version 3 in nonlinear steady thermal.

It is about a voluminal problem represented by two modelizations, one 3D, the other axisymmetric one.

The features tested are the following ones:

- thermal element 3D,
- axisymmetric thermal element,
- limiting conditions of convection and radiation.

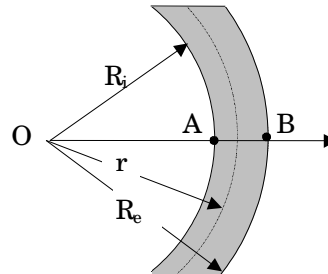
The interest of the test lies in the taking into account of the radiation.

The results are compared with an analytical solution on a test VPCS.

1 Problem of reference

1.1 Geometry

Rayon intérieur $R_i = 0.300$ m
Rayon extérieur $R_e = 0.392$ m



1.2 Properties of the thermal

$\lambda = 40$ W/m°C material Conductivity
 $\rho C = 1$ J/m³°C voluminal Heat

1.3 Boundary conditions and loadings

- Surfaces intern: radiation, $\varepsilon = 0.6$ (coefficient of gray body) $T_i^e = 500.0$ °C ,
- Surfaces external: convection $h_e = 133.5$ W/m²°C $T_e^e = 20.0$ °C .

1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating used for the reference solution

$$T(r) = \frac{T_e - T_i}{\frac{1}{R_e} - \frac{1}{R_i}} \frac{1}{r} + \frac{\frac{T_i}{R_e} - \frac{T_e}{R_i}}{\frac{1}{R_e} - \frac{1}{R_i}}$$

$$\phi_e = h_e (T_e - T_e^e), \quad \phi = 4 \pi R_e^2 h_e (T_e - T_e^e) \quad \text{éq 2.1-1}$$

$$\phi_i = \sigma \varepsilon [(T_i^e + 273.15)^4 - (T_i + 273.15)^4] \quad \text{éq 2.1-2}$$

$$\phi = 4 \pi R_i^2 \sigma \varepsilon [(T_i^e + 273.15)^4 - (T_i + 273.15)^4]$$

$$\phi = 4 \pi r^2 \varphi = \text{constante} \quad \phi = 4 \pi \lambda \frac{T_e - T_i}{1/R_e - 1/R_i} \quad \text{éq 2.1-3}$$

$\sigma = 5.73 \cdot 10^{-8} \text{ W/m}^2 \text{ K}^4$ (constant of Stefan) with T in $^{\circ}\text{C}$
the reference temperatures is obtained by numerically solving by the method of Newton an equation of the 4th degree in T_i obtained starting from the equations [éq 2.1-1] [éq 2.1-2] and [éq 2.1-3].

2.2 Results of reference

	in A :	in B :
Temperatures	$T_i = 91.77^{\circ}\text{C}$	$T_e = 71.22^{\circ}\text{C}$
Densities flux	$\phi_i = 11675. \text{ W/m}^2$	$\phi_e = 6838. \text{ W/m}^2$

2.3 Uncertainty on the analytical solution Solution.

2.4 Bibliographical references

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

3 Modelization A

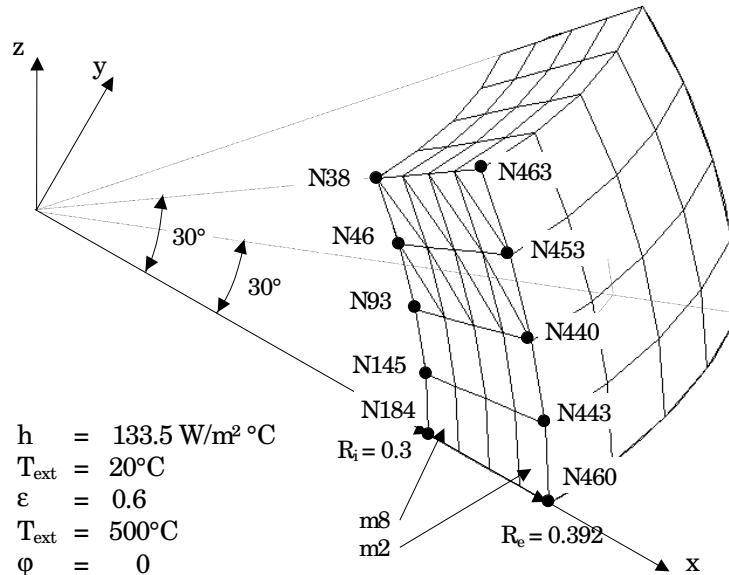
3.1 Characteristic of the modelization

3D (HEXA20, PENTA15, QUAD8)

Conditions limites:

- face externe
- face interne
- autre faces

$$\begin{aligned}
 h &= 133.5 \text{ W/m}^2 \text{ }^\circ\text{C} \\
 T_{\text{ext}} &= 20^\circ\text{C} \\
 \varepsilon &= 0.6 \\
 T_{\text{ext}} &= 500^\circ\text{C} \\
 \varphi &= 0
 \end{aligned}$$



3.2 Characteristic of the mesh

Many nodes: 465
Number of meshes and types: 96 (32 HEXA20, 64 PENTA15)

4 Results of the modelization A

4.1 Values tested

Identification	Reference	tolerance
Temperature (°C)		
N184	91.77	1%
N145	91.77	1%
N93	91.77	1%
N46	91.77	1%
N38	91.77	1%
N460	71.22	1%
N443	71.22	1%
N440	71.22	1%
N453	71.22	1%
N463	71.22	1%
Density flux (W/m^2)		
Nets $m8$, $N184$	11675.	2%
Mesh $m2$, $N460$	6838.	2%

4.2 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 the curve in 101 points).

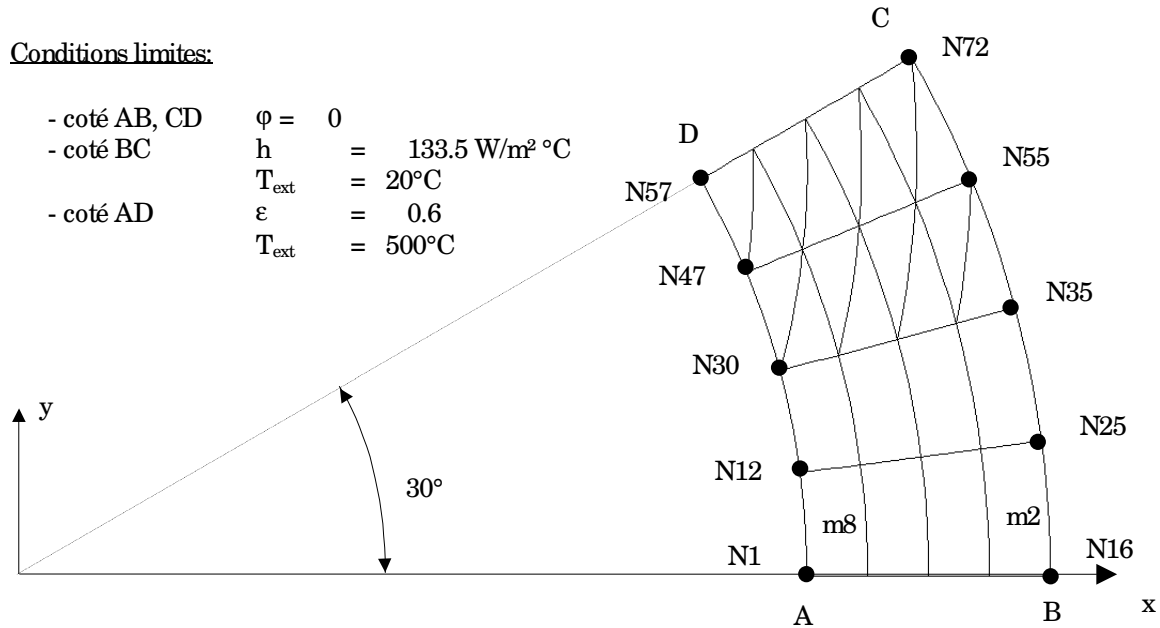
5 Modelization B

5.1 Characteristic of modelization

AXIS (TRIA6, QUAD8, SEG3)

Conditions limites:

- coté AB, CD $\varphi = 0$
- coté BC $h = 133.5 \text{ W/m}^2 \text{ }^\circ\text{C}$
- $T_{\text{ext}} = 20^\circ\text{C}$
- coté AD $\varepsilon = 0.6$
- $T_{\text{ext}} = 500^\circ\text{C}$



5.2 Characteristic of the mesh

Many nodes: 73
Number of meshes and types: 24: (16 TRIA6, 8 QUAD8)

6 Results of the modelization B

6.1 Values tested

Identification	Reference	tolerance
Temperature (°C)		
N1	91.77	1%
N12	91.77	1%
N30	91.77	1%
N47	91.77	1%
N57	91.77	1%
N16	71.22	1%
N25	71.22	1%
N35	71.22	1%
N55	71.22	1%
N72	71.22	1%
Density flux (W/m^2)		
Nets $m8$, NI	11675.	2%
Mesh $m2$, $NI6$	6838.	2%

6.2 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 the curve in 101 points).

7 Summary of the results

the results of reference provided by VPCS are incorrect. New results of reference were given from an analytical approach.

The got results are satisfactory. The maximum change is of:

- modelization A (3D : HEXA20, PENTA15): 0.026% for the temperature and of 0.076% for flux,
- modelization B (AXIS : QUAD4, TRIA3): 0.022% for the temperature and of 0.16% for flux.

The limiting condition of radiation was imposed via a nonlinear flux loading (flux function of the temperature). In this test the taking into account of the radiation is completely correct.

This test with license to test the command `AFPE_CHAR_THER_F` (associate with operand `FLUX_NL` which makes it possible to affect a flux non_linéaire) in the cases of modelization AXIS and 3D.