TPNV01 - Hollow sphere: convection, radiation

Summary:

This test is resulting from the validation independent of version 3 in nonlinear stationary thermics.

It is about a voluminal problem represented by two modelings, 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.

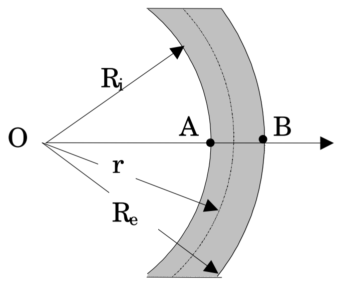
The interest of the test lies in the taking into account of the radiation.

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 material

$\lambda = 40\ W/m\ °C$ Thermal conductivity

$\rho C = 1\ J/m^3\ °C$ Voluminal heat

1.3 Boundary conditions and loadings

- Internal surface: radiation, $\varepsilon = 0.6$ (coefficient of gray body), $T_i^e = 500.0\ °C$,
- External surface: convection, $h_e = 133.5\ W/m^2\ °C$, $T_e^e = 20.0\ °C$.

1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating used for the reference solution

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

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

$$\varphi_i=\sigma\,\varepsilon\left[(T_i^e+273.15)^4-(T_i+273.15)^4\right]$$
$$\phi=4\pi R_i^2\sigma\,\varepsilon\left[(T_i^e+273.15)^4-(T_i+273.15)^4\right]$$ **éq 2.1-2**

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

$\sigma=5.73\,.10^{-8}\,W/m^2K^4$ (constant of Stefan) with T in $°C$

The temperatures of reference are obtained by numerically solving by the method of Newton an equation of the 4ème 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	$T_i=91.77\,°C$	$T_e=71.22\,°C$
Densities flux	$\phi_i=11675.\,W/m^2$	$\phi_e=6838.\,W/m^2$

2.3 Uncertainty on the solution

Analytical solution.

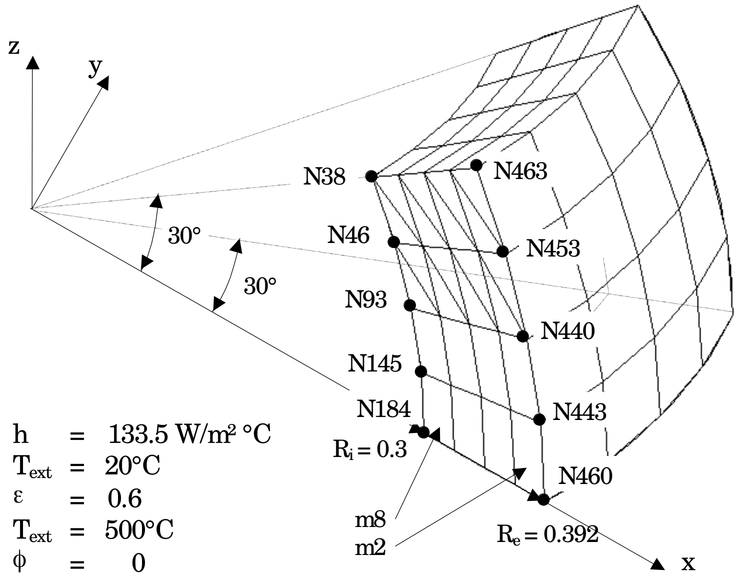
2.4 Bibliographical references

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

3 Modeling A

3.1 Characteristics of modeling

3D (HEXA20, PENTA15, QUAD8)



Conditions limites:

- face externe: $h = 133.5$ W/m² °C, $T_{ext} = 20°C$
- face interne: $\varepsilon = 0.6$, $T_{ext} = 500°C$
- autre faces: $\phi = 0$

3.2 Characteristics of the grid

Many nodes:	465
Many meshs and types:	96 (32 HEXA20, 64 PENTA15)

4 Results of modeling 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)		
Mesh $m8$, $N184$	11675.	2%
Mesh $m2$, $N460$	6838.	2%

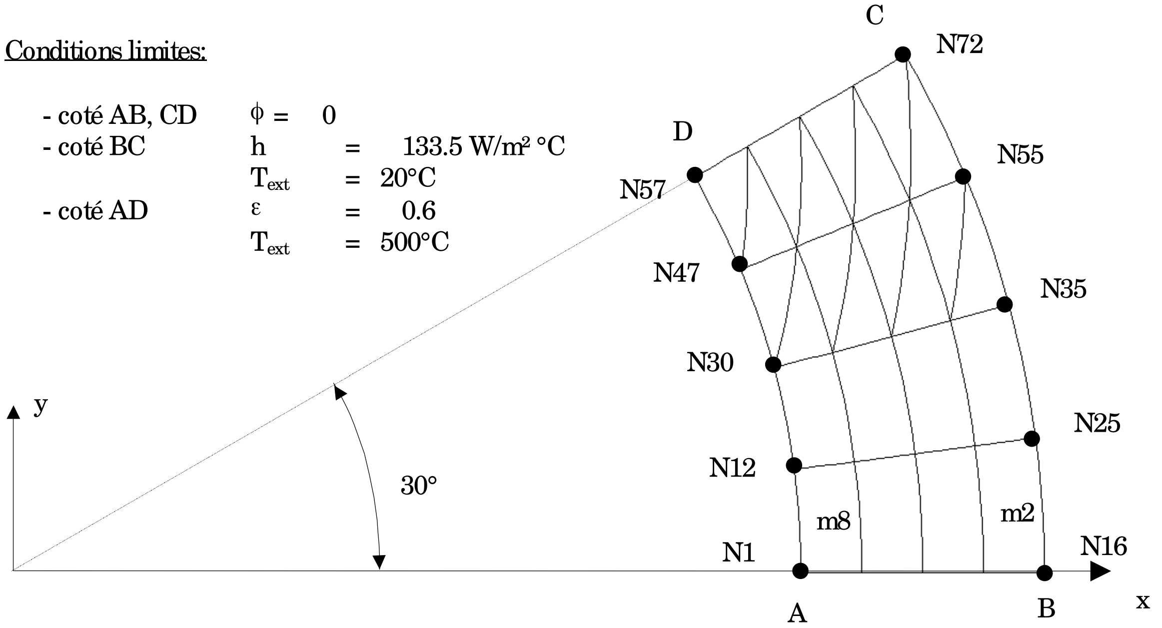
4.2 Remarks

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 Modeling B

5.1 Characteristics of modeling

AXIS (TRIA6, QUAD8, SEG3)



5.2 Characteristics of the grid

Many nodes:	73
Many meshs and types:	24: (16 TRIA6, 8 QUAD8)

6 Results of modeling 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)		
Mesh $m8$, $N1$	11675.	2%
Mesh $m2$, $N16$	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

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

The got results are satisfactory. The maximum change is of:
- modeling A (3D : HEXA20, PENTA15): 0,026% for the temperature and of 0,076% for flows,
- modeling B (AXIS : QUAD4, TRIA3): 0,022% for the temperature and of 0.16% for flows.

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

This test with licence to test the order AFFE_CHAR_THER_F (associate with the operand FLUX_NL who allows to affect a flow non_linéaire) in the cases of modeling AXIS and 3D.