TPLA07 - Orthotropic hollow roll

Summary:

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

It is about an axisymmetric problem 2D represented by two modelings, the first three-dimensional one, the axisymmetric second 2D.

The interest of this case test is to test an orthotropic material subjected to various boundary conditions (imposed flow, convection, linear variation of the outside temperatures).

The results resulting from this case test are compared with those provided by VPCS.

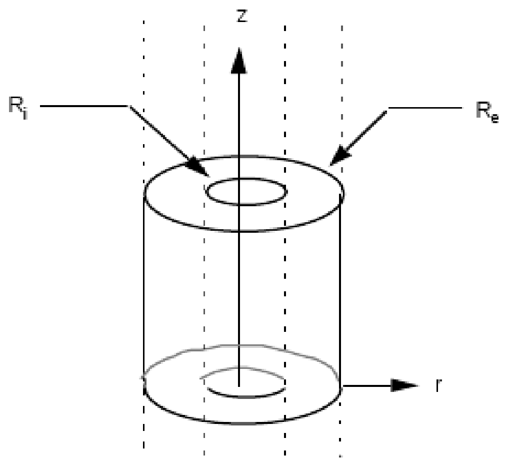
Moreover, this test validates the calculation of thermal energy for an orthotropic material on the elements 2D. For that two calculations are done besides that with orthotropic material:

– a calculation with isotropic material (keyword THER of DEFI_MATERIAU) being used as reference
– a calculation with isotropic material but using the keyword THER_ORTH of DEFI_MATERIAU validated by the first calculation.

For really orthotropic calculation one will use a reference NON_REGRESSION .

1 Problem of reference

1.1 Geometry



Interior ray	$R_i = 0.03\,m$
External ray	$R_e = 0.05\,m$
Height	$l = 0.40\,m$

1.2 Properties of material

$\lambda_t = 2.89\,W/m\,°C$	thermal conductivity along the axis r
$\lambda_z = 40.0\,W/m\,°C$	thermal conductivity along the axis z
λ circumferential:	unspecified

1.3 Boundary conditions and loadings

- density flux $\varphi = -500\,W/m^2$ through surface $z=0$ (outgoing flow),
- density flux $\varphi = +500\,W/m^2$ through surface $z=0.4$ (entering flow),

- convection on interior surface: $h = 377.0\,W/m2\,°C$,
- convection on external surface: $h = 339.3\,W/m2\,°C$,

- linear variation of the outside temperatures:
  - on surface R_i : $T_i^e = 130\,°C$ in $z=0$; $T_i^e = 135\,°C$ in $z=0.4$ $(T_i^e = 130 + 12.5\,z)$
  - on surface R_e : $T_e^e = 20\,°C$ in $z=0$; $T_e^e = 25\,°C$ in $z=0.4$ $(T_e^e = 20 + 12.5\,z)$

1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that given in card TPLA07/89 of guide VPCS.

Temperature: $T(r,z) = -117.46 \log r + 12.5 z - 311.87$

2.2 Results of reference

- temperature in $r = 0.03, 0.035, 0.04$ and 0.05 and for $z = 0., 0.2$ and 0.4,
- density flux on interior and external surface,
- density flux following the axis z.

2.3 Uncertainty on the solution

Analytical solution.

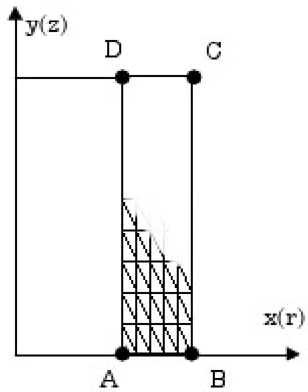
2.4 Bibliographical references

1) 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

AXIS (TRIA6)



Boundary conditions:

Side AB : $\varphi=500.\,W/m^2$

Side CD : $\varphi=-500.\,W/m^2$

Side DA : $h=377.\,W/m^2\,°C$
$T_i^e=130.+12.5\,z$

Side BC : $h=339.3\,W/m^2\,°C$
$T_e^e=20.+12.5\,z$

Cutting:

49 elements according to y

5 elements according to x

3.2 Characteristics of the grid

Many nodes: 1089
Many meshs and types: 490 TRIA6 (and 108 SEG3)

3.3 Remarks

Voluminal heat $\rho\,C_P$ does not intervene in this test, but must be declared for *Code_Aster*. One takes $\rho\,C_P=1.0\,J/m^3\,°C$.

The limiting condition $\varphi=0$ is implicit on the free edges.

3.4 Values tested

The values tested are the temperatures and the densities flux calculated with the option `FLUX_NOEU`.

Identification	Coordinates		Temperature ($°C$)
	R	Z	Reference
N1	0.03	0.0	45.01
N5	0,034	0.0	54.8
N6	0,038	0.0	65.49
N7	0,042	0.0	77.24
N8	0,046	0.0	90.31
N2	0.05	0.0	105.01
N3	0.05	0.4	100.01
N57	0,046	0.4	85.31
N58	0,042	0.4	72.24
N59	0,038	0.4	60.49
N60	0,034	0.4	49.8
N4	0.03	0.4	40.01
N32	0.05	0,196	42.46
N33	0.05	0,204	42.56
N84	0.03	0,204	102.56
N85	0.03	0,196	102.46
N132	0,034	0,196	87.76
N133	0,034	0,204	87.86
N180	0,038	0,196	74.69
N181	0,038	0,204	74.8
N228	0,042	0,196	62.94
N229	0,042	0,204	63.04
N276	0,046	0,196	52.25
N277	0,046	0,204	52.35

Identification	Coordinates		Density flux φ_z (W/m^2)
	R	Z	reference
N1	0.03	0.0	-500
N5	0,034	0.0	-500
N6	0,038	0.0	-500
N7	0,042	0.0	-500
N8	0,046	0.0	-500
N2	0.05	0.0	-500
N3	0.05	0.4	-500
N57	0,046	0.4	-500
N58	0,042	0.4	-500
N59	0,038	0.4	-500
N60	0,034	0.4	-500
N4	0.03	0.4	-500
N32	0.05	0,196	-500
N33	0.05	0,204	-500
N84	0.03	0,204	-500
N85	0.03	0,196	-500
N132	0,034	0,196	-500
N133	0,034	0,204	-500
N180	0,038	0,196	-500
N181	0,038	0,204	-500
N228	0,042	0,196	-500
N229	0,042	0,204	-500
N276	0,046	0,196	-500
N277	0,046	0,204	-500

Identification	**Coordinates**		**Density flux φ_{R_i} (W/m^2)**
	R	Z	**Reference**
N1	0.03	0.0	11315.3
N5	0,034	0.0	9984.1
N6	0,038	0.0	8933.14
N7	0,042	0.0	8082.37
N8	0,046	0.0	7379.55
N2	0.05	0.0	6789.19
N3	0.05	0.4	6789.19
N57	0,046	0.4	7379.55
N58	0,042	0.4	8082.37
N59	0,038	0.4	8933.14
N60	0,034	0.4	9984.1
N4	0.03	0.4	11315.3
N32	0.05	0,196	6789.19
N33	0.05	0,204	6789.19
N84	0.03	0,204	11315.3
N85	0.03	0,196	11315.3
N132	0,034	0,196	9984.1
N133	0,034	0,204	9984.1
N180	0,038	0,196	8933.14
N181	0,038	0,204	8933.14
N228	0,042	0,196	8082.37
N229	0,042	0,204	8082.37
N276	0,046	0,196	7379.55
N277	0,046	0,204	7379.55

Tests of the thermal field of energy `ETHE_ELEM` :

Isotropic material

Mesh	Value of reference	Precision (in %)	Reference
`M129`	-0.14396043186377	0.1	`AUTRE_ASTER`

Orthotropic material

Mesh	Value of reference	Precision (in %)	Reference
`M129`	-0.15972226753427	1,00E-006	`NON_REGRESSION`

4 Summary of the results

The got results are satisfactory in temperature and of density flux, the maximum departures obtained are the following:

- 0.02% in temperature,
- 1.05% for flow along the axis z ,
- 0.33% for flow according to the ray.