TPLA06 - Bar cylindrical with convection

Summary:

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

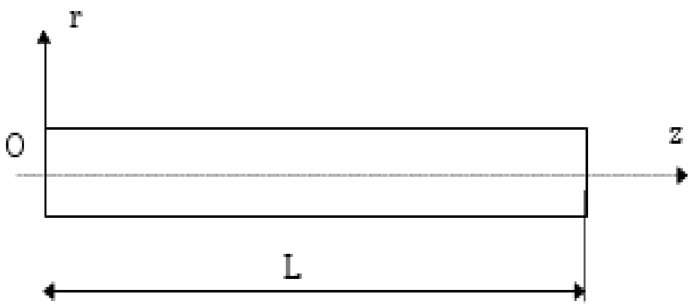
It is about an axisymmetric problem 2D represented by two modelings, the first using of the voluminal elements, the second of the axisymmetric elements 2D.

Boundary conditions in imposed temperature and of convection are taken into account.

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

1 Problem of reference

1.1 Geometry



$r=0.01\,m$ (ray of the cylinder)
$L=1\mathrm{m}$

1.2 Properties of material

$\lambda=33.33\,W/m\,°C$ Thermal conductivity

1.3 Boundary conditions and loadings

- Imposed temperatures,

  $T=0\,°C$ in $z=0.$
  $T=500\,°C$ in $z=1.$

- Convection on cylindrical surface.

  $h=10\mathrm{W}/m^2\,°C$
  $T_e=0\,°C$ (outside temperature)

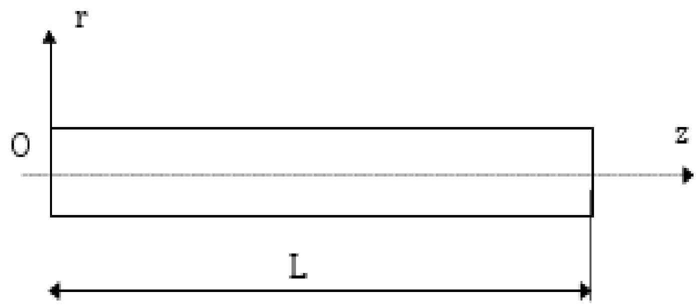
1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is that given in card TPLA06/89 of guide VPCS



- Temperature according to z : $T(z)=T_1 \frac{\sinh(az)}{\sinh(aL)}$ where $a=\sqrt{\left(\frac{2h}{\lambda r}\right)}$
- $T(z=0)=0$ $\quad T(z=L)=T_1$.

2.2 Results of reference

Temperature in $z=0.,0.1,0.2,\ldots,0.8,0.9,1.0$

2.3 Uncertainty on the solution

$<1\%$
Approximate analytical solution (approximation: $T=cte$, for all r)

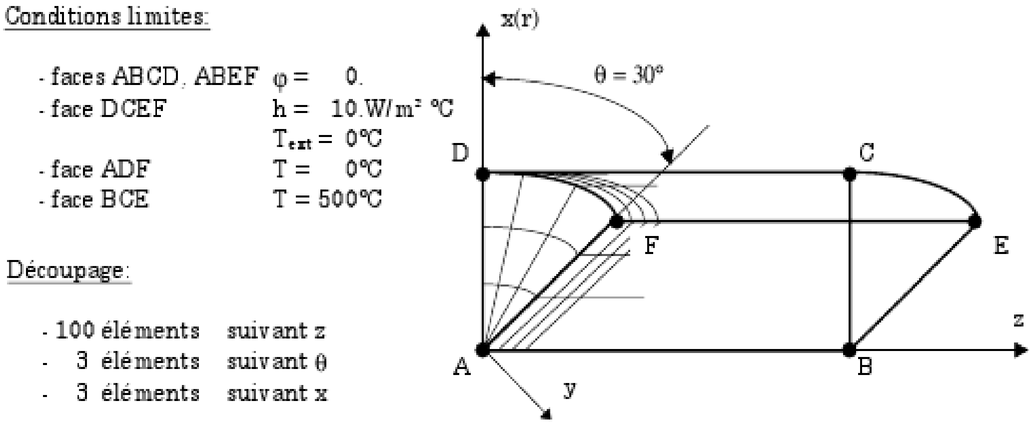
2.4 Bibliographical references

[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

3D (PENTA6, HEXA8)



3.2 Characteristics of the grid

Many nodes:	1313
Many meshs and types:	300 PENTA6, 600 HEXA8 (and 300 QUAD4)

3.3 Sizes tested and results

Identification	Reference	tolerance
Temperature ($°C$)		
$z=0.0$ $r=.0$ ($n1$: A)	0.0000	.00001
$r=.01$ ($n13$: D)	0.0000	.00001
$z=0.1$ $r=.0$ ($n131$)	0.3694	1%
$r=.01$ ($n143$)	0.3694	1%
$z=0.2$ $r=.0$ ($n261$)	0.9718	1%
$r=.01$ ($n273$)	0.9718	1%
$z=0.3$ $r=.0$ ($n391$)	2.1870	1%
$r=.01$ ($n403$)	2.1870	1%
$z=0.4$ $r=.0$ ($n521$)	4.7815	1%
$r=.01$ ($n533$)	4.7815	1%
$z=0.5$ $r=.0$ ($n651$)	10,392	1%
$r=.01$ ($n663$)	10,392	1%
$z=0.6$ $r=.0$ ($n781$)	22,555	1%
$r=.01$ ($n793$)	22,555	1%
$z=0.7$ $r=.0$ ($n911$)	48,944	1%
$r=.01$ ($n923$)	48,944	1%
$z=0.8$ $r=.0$ ($n1041$)	106.20	1%
$r=.01$ ($n1053$)	106.20	1%
$z=0.9$ $r=.0$ ($n1171$)	230.44	1%
$r=.01$ ($n1183$)	230.44	1%
$z=1.0$ $r=.0$ ($n1301$: B)	500.00	.00001
$r=.01$ ($n1313$: C)	500.00	.00001

(*: Imposed temperature)

3.4 Remarks

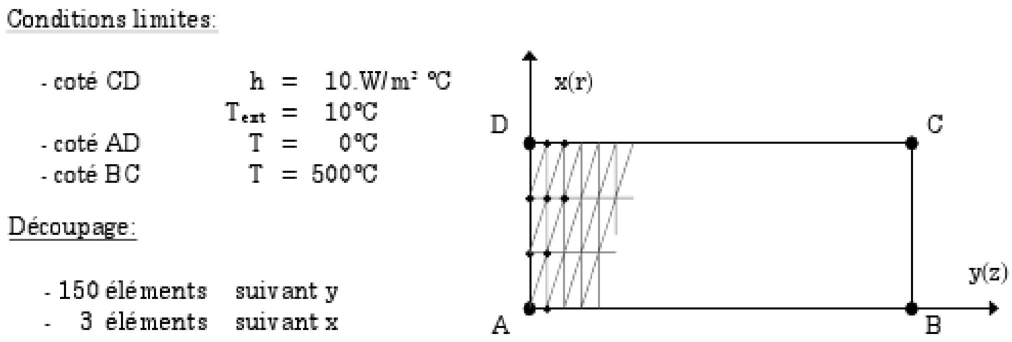
Voluminal heat ρC_P does not intervene in this test, but must be declared for *Code_Aster*. One takes $\rho C_P = 1.0 J/m^3 °C$.

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

4 Modeling B

4.1 Characteristics of modeling

AXIS (TRIA3)



4.2 Characteristics of the grid

Many nodes: 604
Many meshs and types: 900 TRIA3 (and 150 SEG2)

4.3 Sizes tested and results

Identification	Reference	tolerance
Temperature ($°C$)		
$z=0.0$ $r=.0$ ($n1$: A)	0.0000	.00001
$r=.01$ ($n4$: D)	0.0000	.00001
$z=0.1$ $r=.0$ ($n61$)	0.3694	1%
$r=.01$ ($n64$)	0.3694	1%
$z=0.2$ $r=.0$ ($n121$)	0.9718	1%
$r=.01$ ($n124$)	0.9718	1%
$z=0.3$ $r=.0$ ($n181$)	2.1870	1%
$r=.01$ ($n184$)	2.1870	1%
$z=0.4$ $r=.0$ ($n241$)	4.7815	1%
$r=.01$ ($n244$)	4.7815	1%
$z=0.5$ $r=.0$ ($n301$)	10,392	1%
$r=.01$ ($n304$)	10,392	1%
$z=0.6$ $r=.0$ ($n361$)	22,555	1%
$r=.01$ ($n364$)	22,555	1%
$z=0.7$ $r=.0$ ($n421$)	48,944	1%
$r=.01$ ($n424$)	48,944	1%
$z=0.8$ $r=.0$ ($n481$)	106.20	1%
$r=.01$ ($n484$)	106.20	1%
$z=0.9$ $r=.0$ ($n541$)	230.44	1%
$r=.01$ ($n544$)	230.44	1%
$z=1.0$ $r=.0$ ($n601$: B)	500.00	.00001
$r=.01$ ($n604$: C)	500.00	.00001

(*: Imposed temperature)

4.4 Remarks

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

5 Summary of the results

Modeling A, carried out in 3D with linear meshs (PENTA15, HEXA8), gives results whose four values (out of 22) exceed the tolerance fixed initially. The maximum change obtained is of 1.24% for a tolerance of 1%. This going beyond the tolerance is observed for values of the temperature close to 0.

By account modeling B, carried out in AXIS with linear meshs (TRIA3), gives satisfactory results, the maximum change obtained is of 0.25%.

Modeling AXIS is adapted to model this cylindrical bar than modeling 3D. Cutting circonférenciel in 3D is not enough dense to represent the cylinder, and a finer cutting would improve the results.

The results got by modeling 3D are regarded as acceptable taking into account the grid used.

The analytical solution which is an approached solution, supposes that the report r/L is much higher than 1. For this digital test, the report r/L was taken equal to 100.