TPLA06 - Cylindrical bar with convection

Summarized:

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

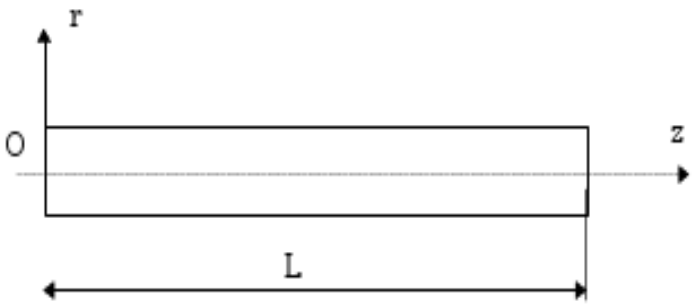
It is about a problem 2D axisymmetric represented by two modelizations, the first using of the voluminal elements, the second of the elements 2D axisymmetric.

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



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

1.2 Properties of the thermal

$\lambda = 33.33\,W/m\,°C$ material Conductivity

1.3 Boundary conditions and loadings

- Temperatures imposed,

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

- Convection on cylindrical surface.

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

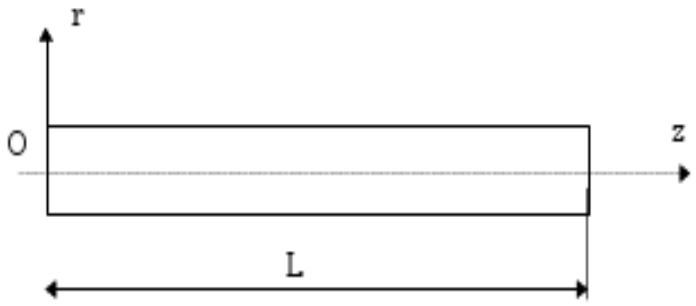
1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating used for the reference solution

the reference solution is that given in file TPLA06/89 of guide VPCS



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

2.2 Results of reference

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

2.3 Uncertainty on the solution

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

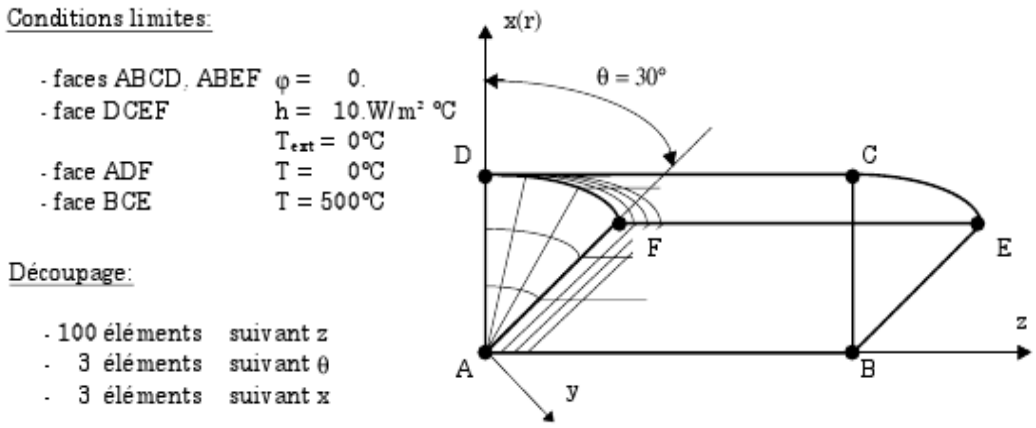
2.4 bibliographical References

[1] 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 (PENTA6, HEXA8)



3.2 Characteristic of the mesh

Many nodes:	1313
Number of meshes and types:	300 PENTA6, 600 HEXA8 (and 300 QUAD4)

3.3 Quantities tested and results

Identification	Reference	tolerance
Temperature ($°C$)		
$z=0.0 \quad r=.0 \quad (n1 \quad : A)$	0.0000	.00001
$r=.01 \ (n13 \quad : D)$	0.0000	.00001
$z=0.1 \quad r=.0 \quad (n131)$	0.3694	1%
$r=.01 \ (n143)$	0.3694	1%
$z=0.2 \quad r=.0 \quad (n261)$	0.9718	1%
$r=.01 \ (n273)$	0.9718	1%
$z=0.3 \quad r=.0 \quad (n391)$	2.1870	1%
$r=.01 \ (n403)$	2.1870	1%
$z=0.4 \quad r=.0 \quad (n521)$	4.7815	1%
$r=.01 \ (n533)$	4.7815	1%
$z=0.5 \quad r=.0 \quad (n651)$	10.392	1%
$r=.01 \ (n663)$	10.392	1%
$z=0.6 \quad r=.0 \quad (n781)$	22.555	1%
$r=.01 \ (n793)$	22.555	1%
$z=0.7 \quad r=.0 \quad (n911)$	48.944	1%
$r=.01 \ (n923)$	48.944	1%
$z=0.8 \quad r=.0 \quad (n1041)$	106.20	1%
$r=.01 \ (n1053)$	106.20	1%
$z=0.9 \quad r=.0 \quad (n1171)$	230.44	1%
$r=.01 \ (n1183)$	230.44	1%
$z=1.0 \quad r=.0 \quad (n1301$: 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 free edges.

4 Modelization B

4.1 Characteristic of modelization

AXIS (TRIA3)

Conditions limites:

- coté CD $h = 10.W/m^2\,°C$, $T_{ext} = 10°C$
- coté AD $T = 0°C$
- coté BC $T = 500°C$

Découpage:

- 150 éléments suivant y
- 3 éléments suivant x

4.2 Characteristic of the mesh

Many nodes:	604
Number of meshes and types:	900 TRIA3 (and 150 SEG2)

4.3 Quantities tested and results

Identification	Reference	tolerance
Temperature ($°C$)		
$z=0.0 \quad r=.0 \quad (n1 \quad : A)$	0.0000	.00001
$r=.01 \quad (n4 \quad : D)$	0.0000	.00001
$z=0.1 \quad r=.0 \quad (n61)$	0.3694	1%
$r=.01 \quad (n64)$	0.3694	1%
$z=0.2 \quad r=.0 \quad (n121)$	0.9718	1%
$r=.01 \quad (n124)$	0.9718	1%
$z=0.3 \quad r=.0 \quad (n181)$	2.1870	1%
$r=.01 \quad (n184)$	2.1870	1%
$z=0.4 \quad r=.0 \quad (n241)$	4.7815	1%
$r=.01 \quad (n244)$	4.7815	1%
$z=0.5 \quad r=.0 \quad (n301)$	10.392	1%
$r=.01 \quad (n304)$	10.392	1%
$z=0.6 \quad r=.0 \quad (n361)$	22.555	1%
$r=.01 \quad (n364)$	22.555	1%
$z=0.7 \quad r=.0 \quad (n421)$	48.944	1%
$r=.01 \quad (n424)$	48.944	1%
$z=0.8 \quad r=.0 \quad (n481)$	106.20	1%
$r=.01 \quad (n484)$	106.20	1%
$z=0.9 \quad r=.0 \quad (n541)$	230.44	1%
$r=.01 \quad (n544)$	230.44	1%
$z=1.0 \quad r=.0 \quad (n601 : B)$	500.00	.00001
$r=.01 \quad (n604 : C)$	500.00	.00001

(*: Imposed temperature)

4.4 Remarks

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

5 Summary of the results

The modelization A, carried out in 3D with the meshes linear ones (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 the modelization B, carried out in AXIS with the meshes linear ones (TRIA3), gives satisfactory results, the maximum change obtained is of 0.25%.

The modelization AXIS is adapted to model this cylindrical bar than the modelization 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 the modelization 3D are regarded as acceptable taking into account the mesh used.

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