TPLV305 - Heat gradient in a cylinder (Fourier)

Summary:

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

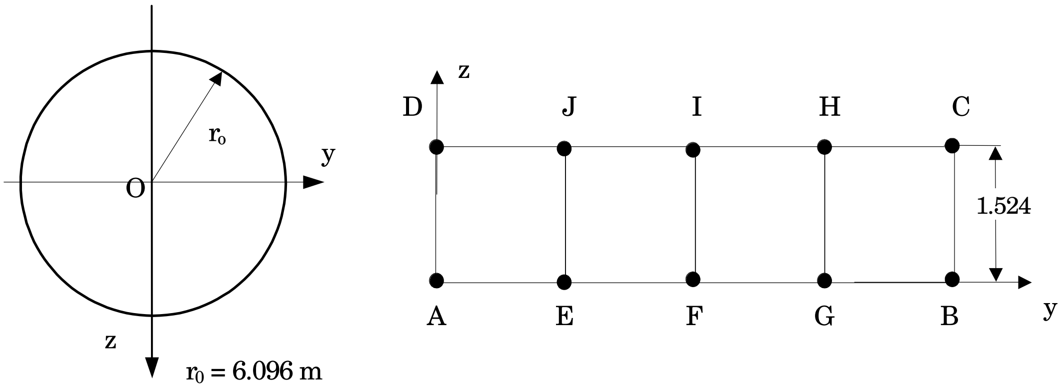
It validates the axisymmetric thermal elements of harmonic resolution (AXIS_FOURIER) and voluminal with for boundary conditions of the temperatures imposed according to a harmonic function (mode 1).

It comprises two modelings, one 3D and the other using of the axisymmetric thermal elements “Fourier”.

The interest of this test is the validation of the thermal elements AXIS_FOURIER and of the ordering of assembly of the fields (CREA_CHAMP, option ADZE).

1 Problem of reference

1.1 Geometry



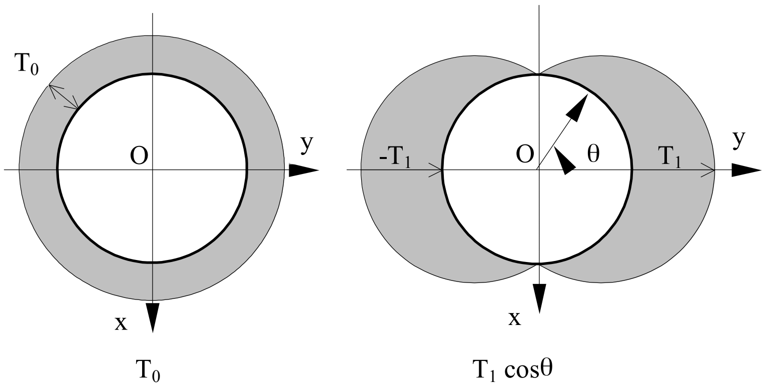
1.2 Properties of material

$\lambda = 1.7307\ W/m.°C$ Thermal conductivity

1.3 Boundary conditions and loadings

The limiting condition is applied to the external surface of the cylinder, it breaks up into:

- a symmetrical limiting condition of revolution associated with harmonic 0:
  $CL1\ :\ T_0 = -17.778\ °C$
- a symmetrical limiting condition compared to θ associated with harmonic 1:
  $CL2\ :\ T_1 \cos\theta = 44.444 \cos\theta\ (°C)$



1.4 Initial conditions

Without object.

2 Reference solution

2.1 Method of calculating used for the reference solution

The original reference solution given in the book [bib1] is based on an analytical approach. This reference is quoted in the handbook of checking of ANSYS [bib2]

2.2 Results of reference

- Temperature at the points A , E , F , G , B for mode 0 ($CL1$),
- Temperature at the points A , E , F , G , B mode 0 and recombined mode 1 ($CL1+CL2$) for $\theta=0°,45°,90°$ and $180°$.

2.3 Uncertainty on the solution

Unknown factor, it was not possible to get the original reference (delivers old, more published).

2.4 References

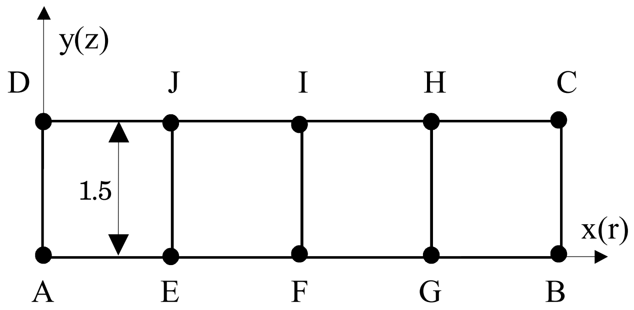
[1] Kreith, F., “Principles of heat transfer”, International Textbook Co., Scranton, Pennsylvania, 2nd Printing, 1959.

[2] ANSYS: “Checking manual”, 1 St edition, June 1.1976

3 Modeling A

3.1 Characteristics of modeling

`AXIS_FOURIER` (QUAD4)



Conditions limites:

- cotés AB, CD $\phi = 0$
- coté BC
  . mode 0 T = -17.778
  . mode (0 +1) T = -17.778 +44.444 cos θ

Points	x	noeuds
A	0.000	N1 , N2
E	1.524	N3 , N4
F	3.048	N5 , N6
G	4.572	N7 , N8
B	6.096	N9 , N10

3.2 Characteristics of the grid

Many nodes: 10
Many meshs and types: 4 QUAD4

3.3 Sizes tested and results

				Relative variation %		Absolute deviation	
	Identification	Reference	*Aster*	difference	tolerance	difference	tolerance
Temperature $(°C)$							
CL1 (mode = 0)							
	N1, N2	-17,778	-17,778	0,000	1%	-1.14e-12	0.01
	N3, N4	-17,778	-17,778	0,000	1%	-9.09e-13	0.01
	N5, N6	-17,778	-17,778	0,000	1%	-6.82e-13	0.01
	N7, N8	-17,778	-17,778	0,000	1%	-3.41e-13	0.01
	N9, N10 *	-17,778	-17,778	0,000	1%	0.000e+0	0.01
$CL1+CL2$ (mode 0 and 1)							
$\theta=0$	N1, N2	-17,778	-17,778	0,000	1%	-1.14e-12	0.01
	N3, N4	-6,667	-6,667	0,000	1%	1.820e-8	0.01
	N5, N6	4,444	4,444	0,000	1%	3.650e-8	0.01
	N7, N8	15,556	15,555	~ 0,006	1%	-1.000e-3	0.01
	N9, N10 *	26,667	26,666	~ 0,004	1%	-1.000e-3	0.01
$\theta=45$	N1, N2	-17,778	~ 17,778	0,000	1%	-1.14e-12	0.01
	N3, N4	-9,921	-9,921	0,003	1%	-3.370e-4	0.01
	N5, N6	-2,064	-2,065	0,033	1%	-6.730e-4	0.01
	N7, N8	5,792	5,792	0,000	1%	-1.040e-5	0.01
	N9, N10	13,649	13,649	~ 0,003	1%	-3.460e-4	0.01
$\theta=90$	N1, N2	-17,778	-17,778	0,000	1%	-1.14e-12	0.01
	N3, N4	-17,778	-17,778	0,000	1%	-9.09e-13	0.01

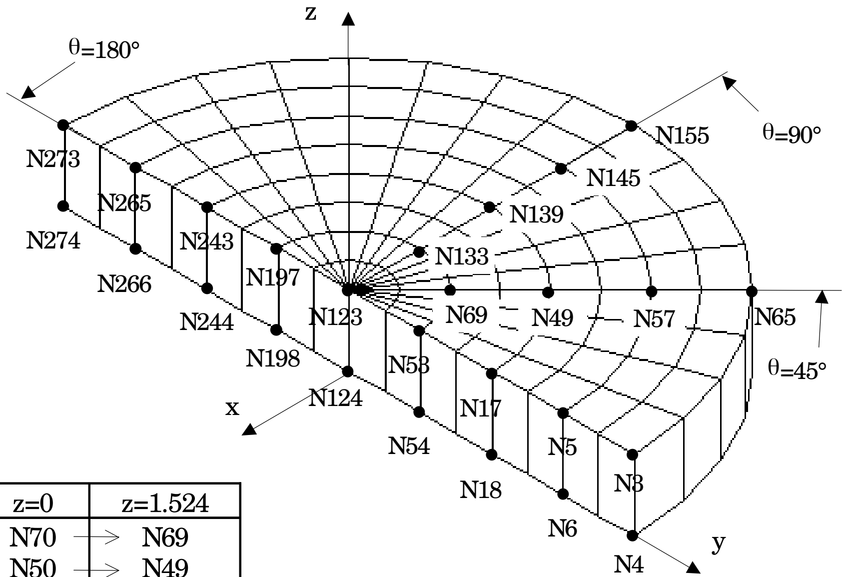
	N5, N6	-17,778	-17,778	0,000	1%	-5.68e-13	0.01
	N7, N8	-17,778	-17,778	0,000	1%	-2.27e-13	0.01
	N9, N10	-17,778	-17,778	0,000	1%	2.27e-13	0.01
$\theta=180$	N1, N2	-17,778	-17,778	0,000	1%	-1.14e-12	0.01
	N3, N4	-28,889	-28,889	0,000	1%	-1.820e-8	0.01
	N5, N6	-40,000	-40,000	0,000	1%	-3.650e-8	0.01
	N7, N8	-51,111	-51,111	0,000	1%	1.040e-6	0.01
	N9, N10	-62,222	-62,222	0,000	1%	2.27e-13	0.01

* imposed temperatures

4 Modeling B

4.1 Characteristics of modeling

3D (PENTA6, HEXA8)



θ	z=0	z=1.524
45°	N70 →	N69
	N50 →	N49
	N58 →	N57
	N66 →	N65
90°	N134 →	N133
	N140 →	N139
	N146 →	N145
	N155 →	N154

<u>Conditions limites:</u>

- face externe (N8,N155,N273)
  $T = -17.778 + 44.444 \cos\theta$
- face interne (N8, N123, N273)
  $\phi = 0$

4.2 Characteristics of the grid

Many nodes:	274
Many meshs and types:	128 (16 PENTA6, 112 HEXA8)

4.3 Remarks

Calculations were carried out by considering the complete loading $CL1+CL2$:

$$T_{imp}=-17.778+44.444\cos\theta$$

4.4 Sizes tested and results

				Relative variation %		Absolute deviation	
Identification		Reference	*Aster*	difference	tolerance	difference	tolerance
$CL1+CL2$							
Temperature $(°C)$							
$\theta=0$	N123, N124	-17,778	-17,778	0,000	1%	-3.330e-5	0.01
	N53, N54	-6,667	- 6,667	0,000	1%	1.330e-7	0.01
	N17, N18	4,444	4,444	0,001	1%	2.840e-5	0.01
	N5, N6	15,556	15,555	-0,006	1%	-9.730e-4	0.01
	N3, N4 *	26,667	26,666	-0,004	1%	-1.000e-3	0.01
$\theta=45$	N69, N70	-9,921	-9,921	0,003	1%	-3.460e-4	0.01
	N49, N50	-2,064	-2,065	0,031	1%	-6.480e-4	0.01
	N57, N58	5,792	5,792	0,001	1%	8.240e-5	0.01
	N65, N66 *	13,649	13,649	0,000	1%	-5.68e-13	0.01
$\theta=90$	N133, N134	-17,778	-17,778	0,000	1%	-3.750e-5	0.01
	N139, N140	-17,778	-17,778	0,000	1%	-5.030e-5	0.01
	N145, N146	-17,778	-17,778	0,000	1%	-6.990e-5	0.01
	N155, N156 *	-17,778	-17,778	0,000	1%	9.09e-13	0.01
$\theta=180$	N197, N198	-2,889	-2,889	0,000	1%	-6.440e-5	0.01
	N243, N244	-40,000	-40,000	0,000	1%	-7.680e-5	0.01
	N265, N266	-5.1111	-5.1111	0,000	1%	-5.210e-5	0.01
	N273, N274 *	-62,222	-62,222	0,000	1%	+6.82e-13	0.01

* imposed temperatures

5 Summary of the results

Two modelings carried out (AXIS_FOURIER and 3D) give excellent results, the maximum change is of -0.006% for two modelings

This test made it possible to test in AXIS_FOURIER the order CREA_CHAMP with the following operands:

- COMB_FOURIER to calculate the temperature in an angle given,
- ADZE to carry out a linear combination of modes 0 and 1.