TTLP304 - Heat transfer in an orthotropic plate: summarized imposed

flux:

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

It is about a problem 2D plane represented by a modelization (plane).

The features tested are the following ones:

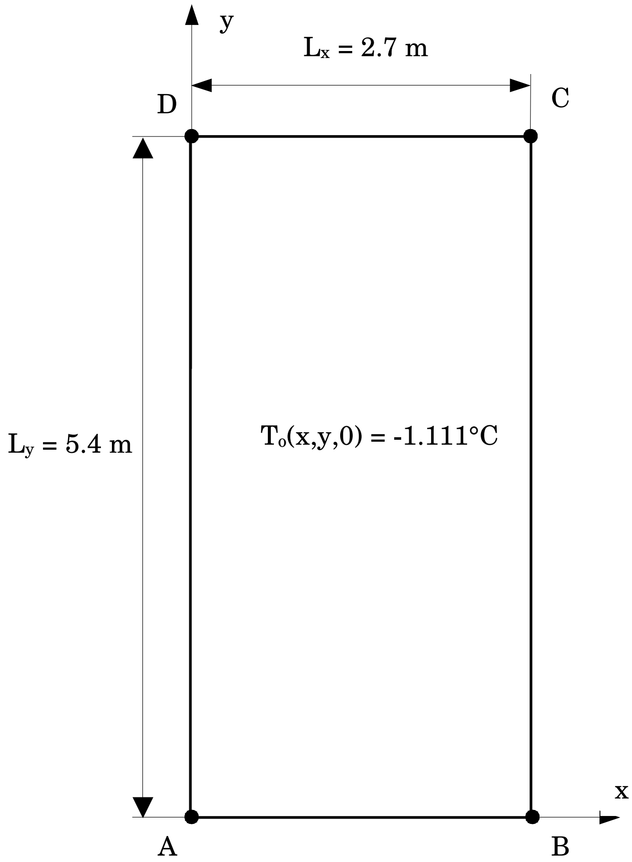
- plane thermal element,
- orthotropic material,
- algorithm of transient thermal,
- conditions limiting: imposed flux.

The interest of the test lies in the taking into account of an orthotropic material.

The results are compared with an analytical solution.

1 Problem of reference

1.1 Geometry



1.2 Properties of the thermal

$\lambda_x = 2.638\,W/m\,°C$	material conductivity along the thermal x
$\lambda_y = 0.633\,W/m\,°C$	axis conductivity along the voluminal y
$\rho C = 1899.1\,J/m^3\,°C$	axis heat

1.3 Boundary conditions and loadings

Contour $[AB]$ $[BC]$ $[CD]$: $T = -17.778\,°C$
Side $[AD]$: $\varphi = 0$

1.4 Initial conditions

$T(t=0) = -1.111\,°C$

2 Reference solution

2.1 Method of calculating used for the reference solution

$$T(x,y,t)=\sum_{n=1}^{\infty}\sum_{j=1}^{\infty} B_n \cos\frac{(2\mathrm{n}-1)\pi x}{2L_x}\sin\frac{j\pi y}{L_y}\exp\left[-\left(\frac{\lambda_x(2\mathrm{n}-1)^2\pi^2}{4L_x^2}+\frac{\lambda_y j^2\pi^2}{L_y^2}\right)t\right]$$

where $B_n=\left[\frac{8T_i}{\pi^2 j(2\mathrm{n}-1)}(-1)^{n+2}[(-1)^j-1]-32\right]\frac{5}{9}$ $\qquad T_i=\frac{5}{9}T_0+32$

Temperature in $°F$ **to** $t=1.2\,hr(4320\mathrm{s})$

2.7	– 15,6151	– 15,6480	– 15,7455	– 15,9049	– 16,1211	– 16,3876	– 16,6964	– 17,0381	– 17,4022	– 17,7778
2.4	– 15,6462	– 15,6786	– 15,7748	– 15,9318	– 16,1449	– 16,4076	– 16,7120	– 17,0487	– 17,4076	– 17,7778
2.1	– 15,7391	– 15,7700	– 15,8620	– 16,0122	– 16,2160	– 16,4673	– 16,7584	– 17,0805	– 17,4238	– 17,7778
1.8	– 15,8921	– 15,9208	– 16,0058	– 16,1447	– 16,3333	– 16,5657	– 16,8349	– 17,1328	– 17,4503	– 17,7778
1.5	– 16,1025	– 16,1279	– 16,2035	– 16,3269	– 16,4944	– 16,7009	– 16,9401	– 17,2048	–17,4869	– 17,7778
1.2	– 16,3655	– 16,3869	– 16,4506	– 16,5547	– 16,6959	– 16,8700	– 17,0716	– 17,2947	– 17,5325	– 17,7778
0.9	– 16,6744	– 16,6911	– 16,7409	– 16,8222	– 16,9325	– 17,0685	– 17,2261	– 17,4004	– 17,5862	– 17,7778
0.6	– 17,0203	– 17,0318	– 17,0660	– 17,1218	– 17,1975	– 17,2909	– 17,3991	– 17,5187	– 17,6462	– 17,7778
0.3	– 17,3923	– 17,3982	– 17,4156	– 17,4440	– 17,4825	– 17,5300	– 17,5851	– 17,6459	– 17,7108	– 17,7778
0.0	– 17,7778	– 17,7778	– 17,7778	– 17,7778	– 17,7778	– 17,7778	– 17,7778	– 17,7778	– 17,7778	– the 17,7778
$Y\uparrow$ $X\rightarrow$	0.0.0.3.0. 6			0.9.1.2.1. 5			1.8.2.1.2. 4			2.7

values of reference are obtained with $n=j=1000$

2.2 Results of reference

$t=1.2\mathrm{hr}(4320\mathrm{s})$: temperature at the following points:

- in $x=0.0$: for $y=0.6, 1.5, 2.7$,
- in $x=0.9$: for $y=0.6, 1.5, 2.7$,
- in $x=1.8$: for $y=0.6, 1.5, 2.7$.

2.3 Uncertainty on the analytical

solution Solution.

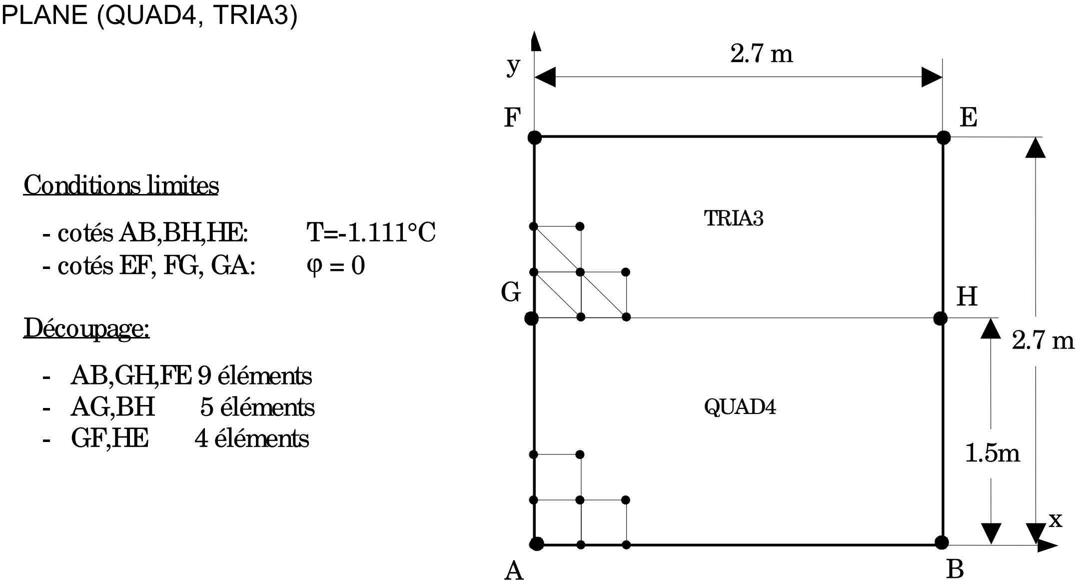
2.4 Bibliographical references

- J.C. Bruch Jr., G. Zyroloski, "Transient two-dimensional heat conduction problems solved by the finite element method", Int. J. num. Meth. Engng, flight 8, n°3, pp 481-494, 1974.

3 Modelization A

3.1 Characteristic of the modelization

PLANE (QUAD4, TRIA3)



3.2 Characteristic of the mesh

Many nodes:	100
Number of meshes and types:	117 (45 QUAD4, 72 TRIA3)

3.3 Remarks

the discretization in time step is the following one:

10 steps for	$[0., 5.00D0]$	either	$\Delta t=0.5$
9 steps for	$[5.00D0, 5.00D1]$	or	$\Delta t=5.$
9 steps for	$[5.00D1, 5.00D2]$	or	$\Delta t=50.$
38 steps for	$[5.00D2, 4.30D3]$	or	$\Delta t=100.$
1 step for	$[4.30D3, 4.32D3]$	or	$\Delta t=20.$

4 Results of the modelization A

4.1 Values tested

			relative Variation %		Absolute Deviation	
Identification	**Reference**	***Aster***	**difference**	**tolerance**	**difference**	**tolerance**
Temperature in $°F$						
$x=0.0$						
$N3(y=0.6)$	~ 17.0203	~ 17.0146	~ 0.033	1%	0.006	0.05
$N6(y=1.5)$	~ 16.1025	~ 16.0957	~ 0.042	1%	0.007	0.05
$N10(y=2.7)$	~ 15.6151	~ 15.5784	~ 0.235	1%	0.037	0.05
$x=0.9$						
$N33(y=0.6)$	~ 17.1218	~ 17.1167	0.029	1%	0.005	0.05
$N36(y=1.5)$	~ 16.3269	~ 16.3127	-0.087	1%	0.014	0.05
$N40(y=2.7)$	~ 15.9049	~ 15.8905	~ 0.091	1%	0.014	0.05
$x=1.8$						
$N63(y=0.6)$	~ 17.3991	~ 17.3961	~ 0.017	1%	0.003	0.05
$N66(y=1.5)$	~ 16.9401	~ 16.9297	~ 0.061	1%	0.010	0.05
$N70(y=2.7)$	~ 16.6964	~ 16.6930	~ 0.020	1%	0.003	0.05

5 Synthesis results

the got results are satisfactory, the maximum change obtained is of 0.235%.

For the points of observation selected, the variations are more important with the nodes belonging to meshes the TRIA3.