TTLP304 - Transfer of heat in a plate orthotropic: imposed flows

Summary:

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

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

The features tested are the following ones:

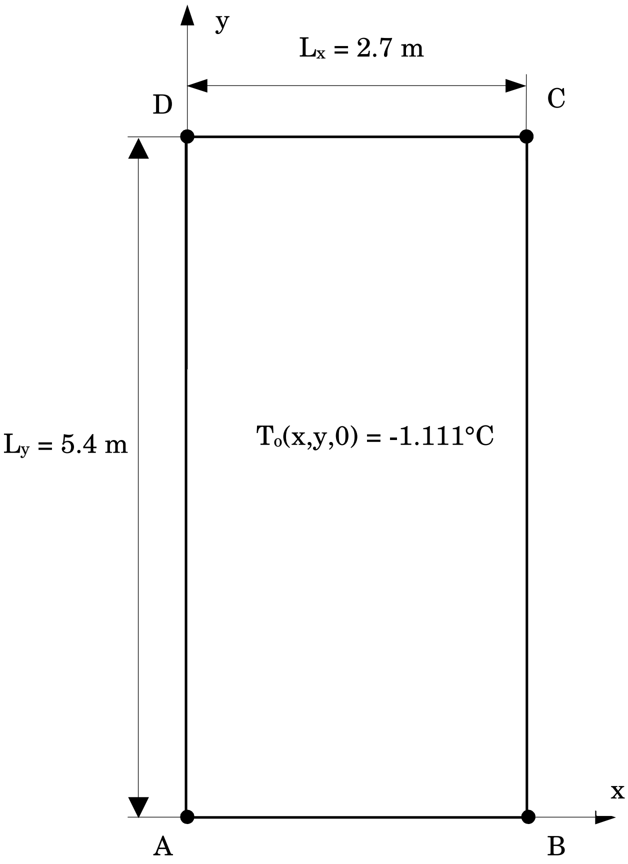
- thermal element plan,
- orthotropic material,
- transitory algorithm of thermics,
- limiting conditions: imposed flow.

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 material

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

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

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

Temperature in $°F$ **with** $t=1.2\,hr(4320s)$

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	– 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

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

2.2 Results of reference

$t=1.2\text{hr}(4320\text{s})$: 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 solution

Analytical solution.

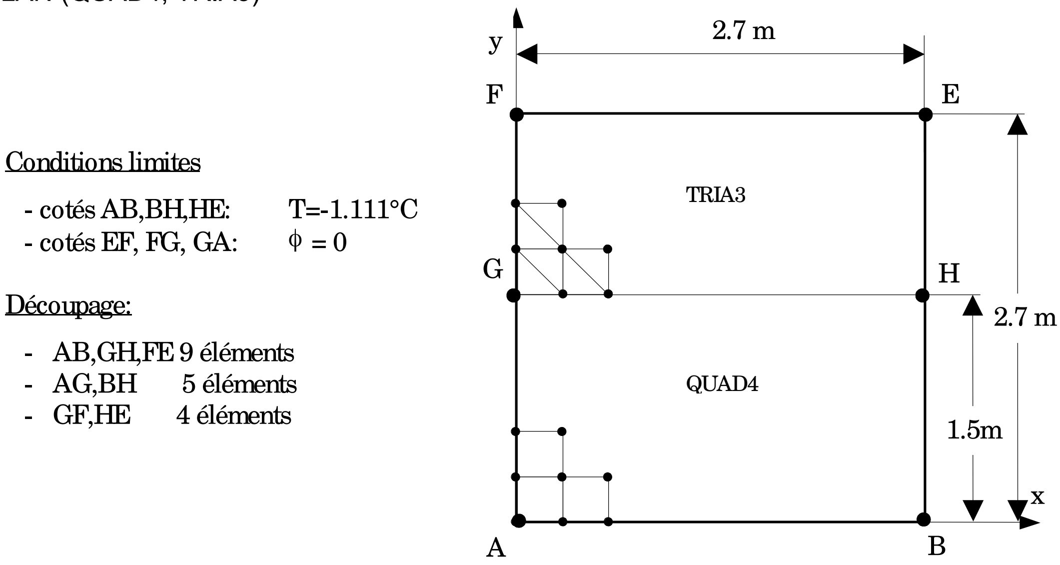
2.4 Bibliographical references

- 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 Modeling A

3.1 Characteristics of modeling

PLAN (QUAD4, TRIA3)



3.2 Characteristics of the grid

Many nodes:	100
Many meshs and types:	117 (45 QUAD4, 72 TRIA3)

3.3 Remarks

The discretization in step of time is the following one:

10 pas	for	$[0., 5.00D0]$	that is to say $\Delta t=0.5$
9 pas	for	$[5.00D0, 5.00D1]$	that is to say $\Delta t=5.$
9 pas	for	$[5.00D1, 5.00D2]$	that is to say $\Delta t=50.$
38 pas	for	$[5.00D2, 4.30D3]$	that is to say $\Delta t=100.$
1 pas	for	$[4.30D3, 4.32D3]$	that is to say $\Delta t=20.$

4 Results of modeling 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 Summary of the 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 meshs TRIA3.