TTLV300 - Parallelepiped subjected to a density flux on its faces

Summary:

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

It is about a voluminal problem represented by a modeling 3D.

The features tested are the following ones:

- voluminal thermal element,
- transitory algorithm of thermics,
- limiting conditions: imposed flow.

The results are compared with a three-dimensional analytical solution.

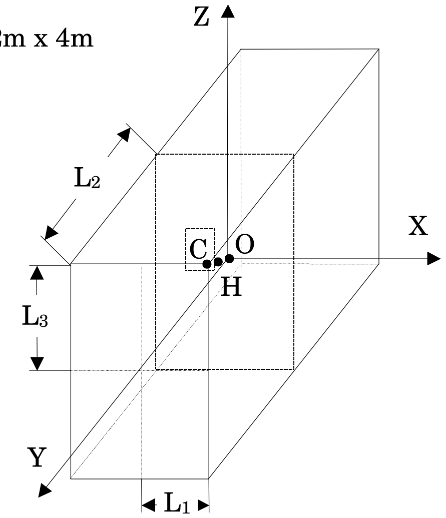
1 Problem of reference

1.1 Geometry

Dimensions du parallélépipède: 2m x 3.2m x 4m

- L_1 = 1.0 m
- L_2 = 1.6 m
- L_3 = 2.0 m

Point O (0.,0.,0.)
Point H (0.5,0.8,1.0)
Point C (1.0,1.6,2.0)



1.2 Properties of material

$\lambda=1.\,W/m\,°C$	thermal conductivity
$c_p=1.\,J/kg\,°C$	specific heat
$\rho=1.\,kg/m^3$	density

1.3 Boundary conditions and loadings

Flow imposed on the 6 faces $q=0.5\,W/m^2=q_w$

1.4 Initial conditions

$T(t=0)=1\,°C=T_0$

2 Reference solution

2.1 Method of calculating used for the reference solution

$T(x,y,z,t)=T_0+2q_w\frac{\sqrt{\alpha t}}{\lambda}(A+B+C)$ with:

$$A=\sum_{m=0}^{\infty}\left[i.erfc\left[\frac{(2m-1)L_1+x}{2\sqrt{\alpha t}}\right]+i.erfc\left[\frac{(2m-1)L_1-x}{2\sqrt{\alpha t}}\right]\right]$$

$$B=\sum_{m=0}^{\infty}\left[i.erfc\left[\frac{(2m-1)L_2+y}{2\sqrt{\alpha t}}\right]+i.erfc\left[\frac{(2m-1)L_2-y}{2\sqrt{\alpha t}}\right]\right]$$

$$C=\sum_{m=0}^{\infty}\left[i.erfc\left[\frac{(2m-1)L_3+z}{2\sqrt{\alpha t}}\right]+i.erfc\left[\frac{(2m-1)L_3-z}{2\sqrt{\alpha t}}\right]\right]$$

$$\alpha=\frac{\lambda}{\rho C_p}$$

The values of reference are obtained with $m=1000.$

2.2 Results of reference

Temperature at the points: $O(0,0,0)$, $H(0.5,0.8,1.)$ and $C(1.,1.6,2.)$

2.3 Uncertainty on the solution

Analytical solution.

2.4 Bibliographical references

- M.J Chang, L.C Chow, W.S Chang, “Improved alternating direction implicit for solving transient three dimensional heat diffusion problems”, Numerical Heat Transfer, flight 19, pp 69-84, 1991.

3 Modeling A

3.1 Characteristics of modeling

3D (HEXA8, PENTA6)

Modélisation 1/8 du parallélépipède

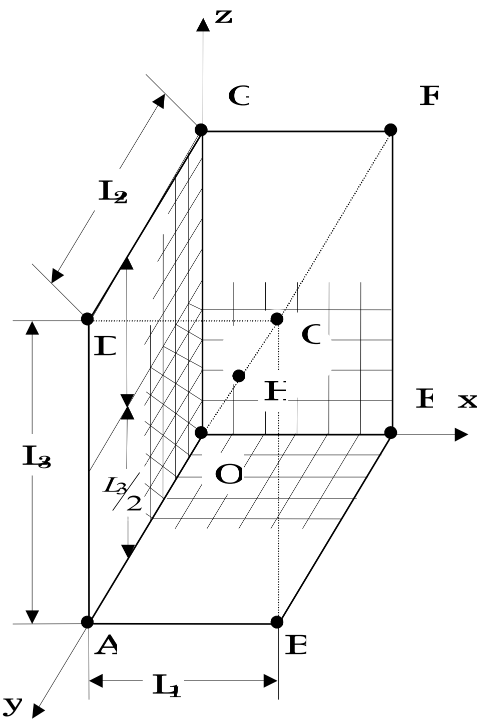
Maillage:

- 6 éléments suivant x
- 8 éléments suivant y
- 10 éléments suivant z

Conditions limites:

- faces [ABCD], [BEFC], [DCFG]: $q_v = 0.5$
- faces [ABEO], [AOGD], [OEFG]: $\phi = 0.$

Points	x	y	z	Noeud
O	0.00	0.00	0.00	N2
H	0.50	0.8	1.00	N409
C	1.00	1.6	2.00	N814



3.2 Characteristics of the grid

Many nodes:	819
Many meshs and types:	288 HEXA8, 576 PENTA6 (168 QUAD4, 96 TRIA3)

3.3 Remarks

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

Discretization of time: 36 intervals, enters $0.s$ and $10\,s$ (of $0.005\,s$ with $1.s$ by interval).

4 Results of modeling A

4.1 Values tested

Identification	**Reference**	***Aster***	**% difference**	**Tolerance**
Not O				
(N2) T = 0.05 S	1.0001	1.00000443	-0,010	1%
T = 0.1 S	1.00398	1.003172	-0,080	1%
T = 0.2 S	1.03331	1.03127	-0,198	1%
T = 0.3 S	1.08533	1.08227	-0,282	1%
T = 0.5 S	1.23086	1.2266	-0,345	1%
T = 1. S	1.69979	1.6945	-0,311	1%
T = 5. S	5.9292	5.9234	-0,098	1%
T = 10. S	11,242	11,236	-0,054	1%
Not H				
(N409) T = 0.05 S	1.0083	1.006472	~ -0,181	1%
T = 0.1 S	1.03819	1.03573	~ -0,237	1%
T = 0.2 S	1.12556	1.1229	~ -0,235	1%
T = 0.3 S	1.22594	1.2233	-0,217	1%
T = 0.5 S	1.43580	1.4331	-0,188	1%
T = 1. S	1.96667	1.9639	-0,140	1%
T = 5. S	6.2167	6.2139	-0,045	1%
T = 10. S	11,529	11,526	-0,023	1%
Not C				
(N814) T = 0.05 S	1.3785	1.3726	-0,429	1%
T = 0.1 S	1.5352	1.5308	-0,290	1%
T = 0.2 S	1.7572	1.7536	-0,206	1%
T = 0.3 S	1.9295	1.9261	-0,176	1%
T = 0.5 S	2.2142	2.2110	-0,146	1%
T = 1. S	2.8085	2.8054	-0,112	1%
T = 5. S	7.0792	7.0762	-0,043	1%
T = 10. S	12,392	12,389	-0,027	1%

5 Summary of the results

The got results are satisfactory. The maximum change (0.43%), is located on surface external of the parallelepiped (Not C) at the moment t weakest. At the end of $10\,s$, this variation decreases, the maximum is then of 0,054% (not O : center of the parallelepiped).

This test made it possible to test in linear transient modeling `3D` with meshs `HEXA8` and `PENTA6`.