TTLV301 - Parallelepiped subjected to a temperature imposed on its sides

Summarized:

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

It is about a voluminal problem represented by only one modelization (3D).

The features tested are the following ones:
•voluminal thermal element,
•algorithm of transient thermal,
•conditions limiting: imposed temperature.

The results are compared with an analytical solution.

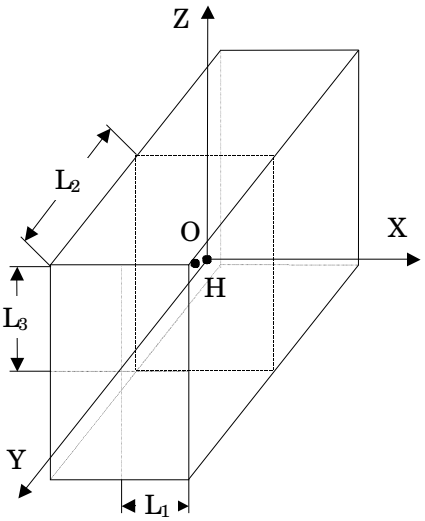
1 Problem of reference

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)



1.2 Properties of the thermal

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

1.3 Boundary conditions and loadings

Temperature imposed on the 6 sides $T = 2°C = T_w$

1.4 Initial conditions

$T(t=0) = 1°C = T_0$

2 Reference solution

2.1 Method of calculating used for the reference solution

$$T_{(x,y,z,t)}=T_w+\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\sum_{l=1}^{\infty}a_{nml}\exp(-\kappa_{mnl}^2\alpha.t)Tcos_{(x,y,z,m,n,l)}$$

with $Tcos_{(x,y,z,m,n,l)}=\cos\left(\frac{(2m-1)\pi x}{2L_1}\right)\cos\left(\frac{(2n-1)\pi y}{2L_2}\right)\cos\left(\frac{(2l-1)\pi z}{2L_3}\right)$

$$a_{mnl}=\frac{64(T_0-T_w)}{\pi^3(2m-1)(2n-1)(2l-1)}\sin\left(\frac{(2m-1)\pi}{2}\right)\sin\left(\frac{(2n-1)\pi}{2}\right)\sin\left(\frac{(2l-1)\pi}{2}\right)$$

$$\kappa_{mnl}=\left(\frac{(2m-1)\pi}{2L_1}\right)^2+\left(\frac{(2n-1)\pi}{2L_2}\right)^2+\left(\frac{(2l-1)\pi}{2L_3}\right)^2$$

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

the values of reference are obtained with $m=n=l=100.$

2.2 Results of reference

Temperature to the points: $O(0,0,0)$ and $H(0.5,0.8,1.)$

2.3 Uncertainty on the analytical

solution 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 Modelization A

3.1 Characteristic of the modelization

3D (HEXA27)

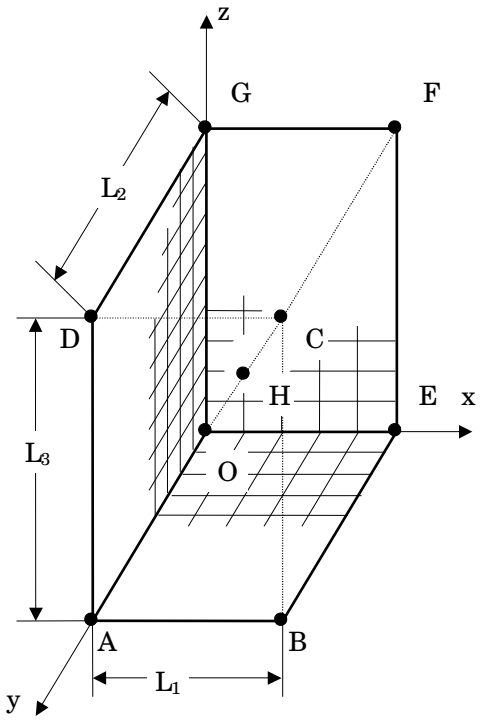
Modélisation 1/8 du parallélépipède

Maillage:

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

Conditions limites:

- faces [ABCD], [BEFC], [DCFG]: T = 2°C
- faces [ABEO], [AOGD], [OEFG]: φ = 0.



Points	x	y	z	Noeud
O	0.00	0.00	0.00	N5
H	0.50	0.80	1.00	N1075

3.2 Characteristic of the mesh

Many nodes: 3927
Number of meshes and types: 400 HEXA27

3.3 Remarks

the limiting condition $\varphi=0.$ are implicit on free edges.
Discretization of time: 24 intervals enters $0.$ and $1.2\,s$:

of $t=0.00$	with $t=0.02$	: 4	0.005 seconds intervals	.
of $t=0.02$	with $t=0.05$	: 3	0.01 seconds intervals	.
of $t=0.05$	with $t=0.15$	: 4	0.025 seconds intervals	.
of $t=0.15$	with $t=0.4$	: 5	0.05 seconds intervals	.
of $t=0.4$	with $t=1.2$	: 8	0.1 seconds intervals	.

4 Results of the modelization A

4.1 Values tested

Identification	Reference	*Aster*	% difference	Tolerance
Point O				
$N5(0.,0.,0.)$				
$t=0.1\,s$	1.05137	1.04934	-0.193	1%
$t=0.2\,s$	1.24768	1.24181	-0.471	1%
$t=0.3\,s$	1.45136	1.44378	-0.522	1%
$t=0.5\,s$	1.73684	1.72955	-0.420	1%
$t=0.7\,s$	1.88010	1.87516	-0.263	1%
$t=1.0\,s$	1.96406	1.96191	-0.110	1%
$t=1.2\,s$	1.98398	1.98282	-0.059	1%
Item H				
$N1075(0.5,0.8,1.0)$				
$t=0.1\,s$	1.33579	1.32490	-0.816	1%
$t=0.2\,s$	1.61081	1.60337	-0.462	1%
$t=0.3\,s$	1.75959	1.75424	-0.304	1%
$t=0.5\,s$	1.90017	1.89718	-0.157	1%
$t=0.7\,s$	1.95657	1.95478	-0.091	1%
$t=1.0\,s$	1.98723	1.98646	-0.039	1%
$t=1.2\,s$	1.99433	1.99391	-0.021	1%

5 Summary of the results

the got results are satisfactory. The maximum change obtained (0.816%), is located at the point H placed halfway between surface external and the center of the parallelepiped. At the end of 1.2s , this variation decreases, the maximum obtained is then of 0.059% (point: O center parallelepiped).

This test made it possible 3D to test in linear transient `the modelization` with meshes `HEXA27`.