

## TTLL100 - Thermal shock on a wall plan with condition of exchange

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### Summary:

This test of transitory linear thermics consists in imposing a cold thermal shock on a wall infinite plan using a limiting condition of exchange. The shock is modelled by a linear slope  $\Delta T = -100^\circ C$  in  $10^{-2} s$ .

With the problem is dealt in plan.

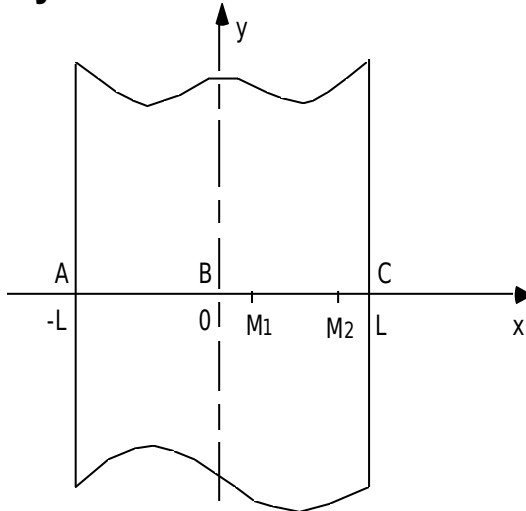
The reference solution is analytical.

The test is carried out on 2 modelings: (TRIA3, QUAD4) and (TRIA6, QUAD9).

One tests the algorithm of linear thermics transitory when the matrix of mass is diagonalisée (modeling PLAN\_DIAG with "farmhouse lumping").

## 1 Problem of reference

### 1.1 Geometry



$$\begin{aligned}\overline{AB} = \overline{BC} = L &= 0.1 \text{ m} \\ x(M1) &= 0.02 \text{ m} \\ x(M2) &= 0.08 \text{ m}\end{aligned}$$

### 1.2 Material properties

$$\begin{aligned}\lambda &= 1 \text{ W/m}^\circ\text{C} \\ \rho C_p &= 1000 \text{ J/m}^3\text{ }^\circ\text{C}\end{aligned}$$

### 1.3 Boundary conditions and loadings

$$\text{exchange } \lambda \frac{\partial T}{\partial n} \Big|_{x=\pm L} = h(T_{ext} - T(x, t))$$

$$\text{with: } h = 100. \text{ W/m}^2\text{ }^\circ\text{C}$$

$$\begin{cases} T_{ext}(C)_{t=0} = 100. \\ T_{ext}(C)_{t=10^{-2}} = 0. \end{cases}$$

### 1.4 Initial conditions

$$T(x, 0) = 100^\circ\text{C} \quad \text{for all } x$$

Discretization in time (T):

10 pas for	[0., 1.D-2]	that is to say	$\Delta t = 10^{-3} \text{ s}$
9 pas for	[1.D-2, 1.D-1]	that is to say	$\Delta t = 10^{-2} \text{ s}$
9 pas for	[1.D-1, 1.]	that is to say	$\Delta t = 10^{-1} \text{ s}$
5 pas for	[1., 2.]	that is to say	$\Delta t = 2. \cdot 10^{-1} \text{ s}$

# Code\_Aster

Version  
default

Titre : TTLL100 - Choc thermique sur un mur plan avec cond[...]  
Responsable : HAELEWYN Jessica

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Clé : V4.21.100 Révision :  
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8 pas for

[2., 10.]

that is  
to say

$\Delta t = 1 s$

## 2 Reference solution

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### 2.1 Method of calculating used for the reference solution

$$\frac{T(x, t) - T_p}{T_0 - T_p} = \sum_{n=1}^{\infty} A_n \exp\left(-\xi_n^2 \frac{\lambda}{\rho C_p L^2} t\right) \cos\left(\xi_n \frac{x}{L}\right)$$

$x =$  X-coordinate  
 $t =$  Time  
 $T_0 =$  Initial temperature  
 $T_p =$  Imposed temperature  
 $n =$  1, 2, 3, ...

With  $\xi_n$  positive roots of  $\xi_n \tan \xi_n = hL/\lambda = 10$ .

$$\text{and } A_n = \frac{4 \sin \xi_n}{2 \xi_n + \sin(2 \xi_n)}$$

### 2.2 Results of reference

Temperatures at the points  $M1$  ( $x=0.02$ ) and  $M2$  ( $x=0.08$ ),  
and at various moments ( $t=0.1, 0.5, 2.0$  and  $10.0$ ).

The values of reference are obtained by calculating the first 30 terms of the series (Mathematica).

### 2.3 Uncertainty on the solution

Analytical solution.

### 2.4 Bibliographical references

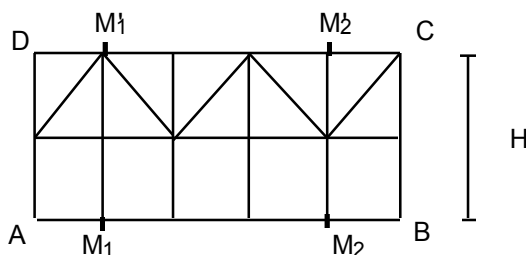
- INCROPERA F.P., OF WITT D.P., Fundamentals of heat and farmhouse transfer. Third Edition. 1990.

## 3 Modeling A

### 3.1 Characteristics of modeling

TRIA3, QUAD4

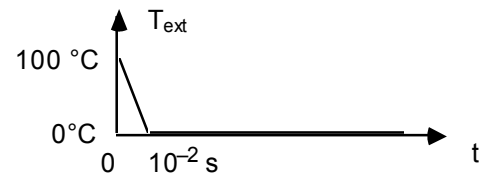
By reason of symmetry, one nets only the half of thickness of the wall. Modeling is made on a height  $H=0.1\text{ m}$  with 2 layers of elements.



Conditions limites

sur [AB], [AD] et [CD] : flux nul

sur [BC] : échange  $h, T_{\text{ext}}$



Conditions initiales  
 $T = 100\text{ °C}$

points	nœuds	x	y
M1	N16	0.02	0.0
M2	N6	0.08	0.0
M'1	N14	0.02	0.1
M'2	N4	0.08	0.1

### 3.2 Characteristics of the grid

Many nodes: 18

Many meshes and types: 5 QUAD4, 10 TRIA3

### 3.3 Values tested

Identification	Reference	Aster	% difference
<i>M1(x=0.02) N16</i>			
$t=0.1$	100.00	99,998	+0.00
$t=0.5$	99,408	99,042	-0.37
$t=2.0$	79,859	79,794	-0.08
$t=10.0$	15,717	16,138	+2.68
<i>M2(x=0.08) N6</i>			
$t=0.1$	93,666	93,380	-0.31
$t=0.5$	63,500	63,813	+0.49
$t=2.0$	35,717	35,667	-0.14
$t=10.0$	6.7948	6.9326	+2.03
<i>M'1(x=0.02) N14</i>			
$t=0.1$	100.00	99,998	+0.00

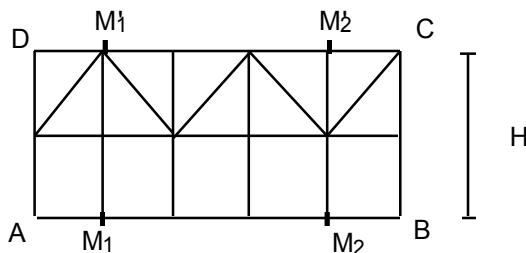
$t=0.5$	99,408	99,077	- 0.33
$t=2.0$	79,859	80,002	+0.18
$t=10.0$	15,717	16,211	+3.14
<hr/>			
$M' 2(x=0.08) N4$			
$t=0.1$	93,666	92,895	- 0.82
$t=0.5$	63,500	61,882	- 2.55
$t=2.0$	35,717	35,331	- 1.08
$t=10.0$	6.7948	6.8885	+1.38

## 4 Modeling B

### 4.1 Characteristics of modeling

#### TRIA6, QUAD9

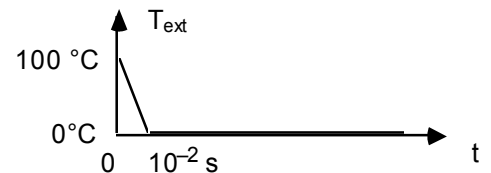
By reason of symmetry, one nets only the half of thickness of the wall. Modeling is made on a height  $H=0.1\text{ m}$  with 2 layers of elements.



Conditions limites

sur [AB], [AD] et [CD] : flux nul

sur [BC] : échange  $h, T_{\text{ext}}$



Conditions initiales  
 $T = 100\text{ °C}$

points	nœuds	x	y
M1	N16	0.02	0.0
M2	N6	0.08	0.0
M'1	N14	0.02	0.1
M'2	N4	0.08	0.1

### 4.2 Characteristics of the grid

Many nodes: 55

Many meshes and types: 5 QUAD9, 10 TRIA6

### 4.3 Values tested

Identification	Reference	Aster	% difference
<i>M1 (x=0.02) N18</i>			
$t=0.1$	100.00	100.00	+0.00
$t=0.5$	99,408	99,278	- 0.13
$t=2.0$	79,859	79,898	+0.05
$t=10.0$	15,717	16,043	+2.07
<i>M2 (x=0.08) N49</i>			
$t=0.1$	93,666	94,077	+0.44
$t=0.5$	63,500	63,979	+0.75
$t=2.0$	35,717	35,825	+0.30
$t=10.0$	6.7948	6.9321	+2.02
<i>M'1 (x=0.02) N12</i>			
$t=0.1$	100.00	100.00	+0.00

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$t=0.5$	99,408	99,311	- 0.10
$t=2.0$	79,859	80,101	+0.30
$t=10.0$	15,717	16,093	+2.39
<hr/>			
$M' 2(x=0.08) N30$			
$t=0.1$	93,666	93,469	- 0.21
$t=0.5$	63,500	62,860	- 1.01
$t=2.0$	35,717	35,641	- 0.21
$t=10.0$	6.7948	6.9068	+1.65



## 5 Summary of the results

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Modeling `PLAN_DIAG` give rather satisfactory results. Although the grid comprises few elements in the thickness, the variation on the temperatures remains lower than 3.2 %.

Although the thermal shock is brutal, the diagonalisation of the matrix of mass makes it possible to obtain a solution in temperature which does not oscillate during the transient.