TTLV100 - Thermal shock in a pipe with condition of exchange

Summary:

This test of transitory linear thermics consists in imposing a cold thermal shock on a presumedly infinite hollow roll using a limiting condition of exchange.

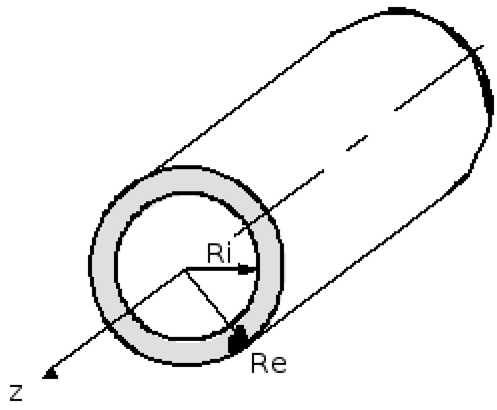
The shock is modelled by a linear slope $\Delta T=-269°C$ in $12s$.

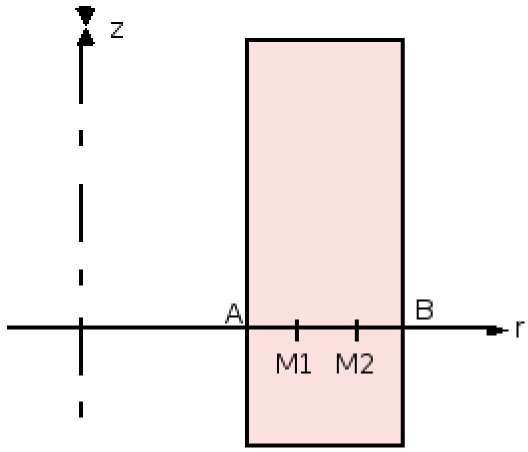
With the problem is dealt into axisymmetric and 3D.
The reference solution is obtained on a fine network.
The test is carried out on 3 modelings: (TRIA3, QUAD4), (TRIA6, QUAD9) in AXIS_DIAG and (HEXA8, PENTA6) in 3D_DIAG.

One tests the algorithm of linear thermics transitory when the matrix of mass is diagonalisée (modeling AXIS_DIAG and 3D_DIAG with ''*farmhouse lumping*'').

1 Problem of reference

1.1 Geometry





Ri = 417 mm
Re = 496 mm

$r(A)=417\,mm$
$r(B)=496\,mm$
$r(M1)=443.43\,mm$
$r(M2)=469.67\,mm$

1.2 Material properties

$\lambda=19.97\,W/m\,°C$
$\rho C_p=4.89488\,10^6\,J/m^3\,°C$

1.3 Boundary conditions and loadings

Exchange $\lambda\frac{\partial T}{\partial n}|_{r=r_i}=h\left(T_{ext}-T(r,t)\right)$

with $h=40000\ W/m^2\,°C$
$T_{ext}(A)_{t=0s}=289\ °C$
$T_{ext}(A)_{t=12s}=20\ °C$

1.4 Initial conditions

$T(r,0)=289\,°C$ for all r

Discretization in time (t) :

12	not for	$[0.,12.]$	that is to say	$\Delta t=1.s$
2	not for	$[12.,20.]$	that is to say	$\Delta t=4.s$
4	not for	$[20.,100.]$	that is to say	$\Delta t=20.s$

2	not for	$[100.,200.]$	that is to say	$\Delta t=50.s$
2	not for	$[200.,400.]$	that is to say	$\Delta t=100.s$
8	not for	$[400.,2000.]$	that is to say	$\Delta t=200.s$

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution is obtained on a fine network comprising 99 quadratic elements `QUAD8` in the thickness without option of matrix of diagonal thermal mass.

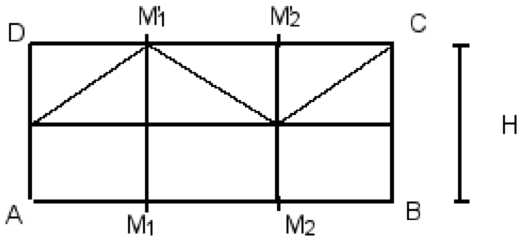
2.2 Results of reference

Temperatures at the points $M1$ ($r=443.33$) and $M2$ ($r=469.67$),
and at various moments ($t=12.,100.,600.$ and $2000.$).

3 Modeling A

3.1 Characteristics of modeling

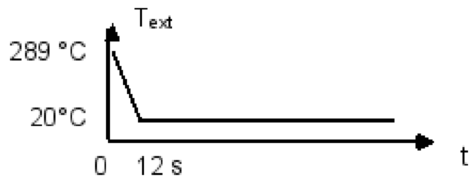
The infinite cylinder being supposed, one nets only one slice height $H=40\,mm$ with 2 layers of elements.



Conditions limites

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

sur [AD] : échange h, T_{ext}



points	nœuds	r	z
M1	N10	443.33	0.0
M2	N5	469.67	0.0
M'1	N11	443.33	40.
M'2	N7	469.67	40.

Conditions initiales
T = 289 °C

3.2 Characteristics of the grid

Many nodes: 12
Many meshs and types: 3 QUAD4, 6 SORTED3

3.3 Sizes tested and results

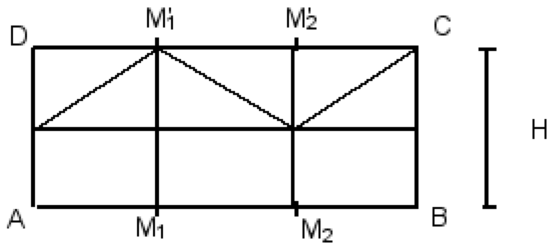
Identification	Type of reference	Value of reference	Precision (%)
M1 (R = 443.33)			
T = 12.	'AUTRE_ASTER'	288.64	0.5
T = 100.	'AUTRE_ASTER'	202.76	0.1
T = 600.	'AUTRE_ASTER'	93,027	0.1
T = 2000.	'AUTRE_ASTER'	29,419	0.1
M2 (R = 469.67)			
T = 12.	'AUTRE_ASTER'	289.00	0.1
T = 100.	'AUTRE_ASTER'	275.04	0.5
T = 600.	'AUTRE_ASTER'	143.00	0.1
T = 2000.	'AUTRE_ASTER'	35,858	0.5
Me 1 (R = 443.33)			
T = 12.	'AUTRE_ASTER'	288.64	0.5
T = 100.	'AUTRE_ASTER'	202.76	0.1
T = 600.	'AUTRE_ASTER'	93,027	0.1
T = 2000.	'AUTRE_ASTER'	29,419	0.1

Me 2 (R = 469.67)			
T = 12.	'AUTRE_ASTER'	289.00	0.1
T = 100.	'AUTRE_ASTER'	275.04	0.5
T = 600.	'AUTRE_ASTER'	143.00	0.1
T = 2000.	'AUTRE_ASTER'	35,858	0.5

4 Modeling B

4.1 Characteristics of modeling

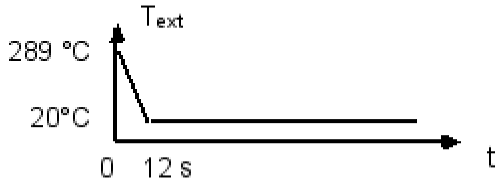
The infinite cylinder being supposed, one nets only one slice height $H=40\,mm$ with 2 layers of elements.



Conditions limites

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

sur [AD] : échange h, T_{ext}



points	nœuds	r	z
M1	N25	443.33	0.0
M2	N9	469.67	0.0
M'1	N28	443.33	40.
M'2	N1 6	469.67	40.

Conditions initiales
T = 289 °C

4.2 Characteristics of the grid

Many nodes: 35
Many meshs and types: 3 QUAD9, 6 TRIA6

4.3 Sizes tested and results

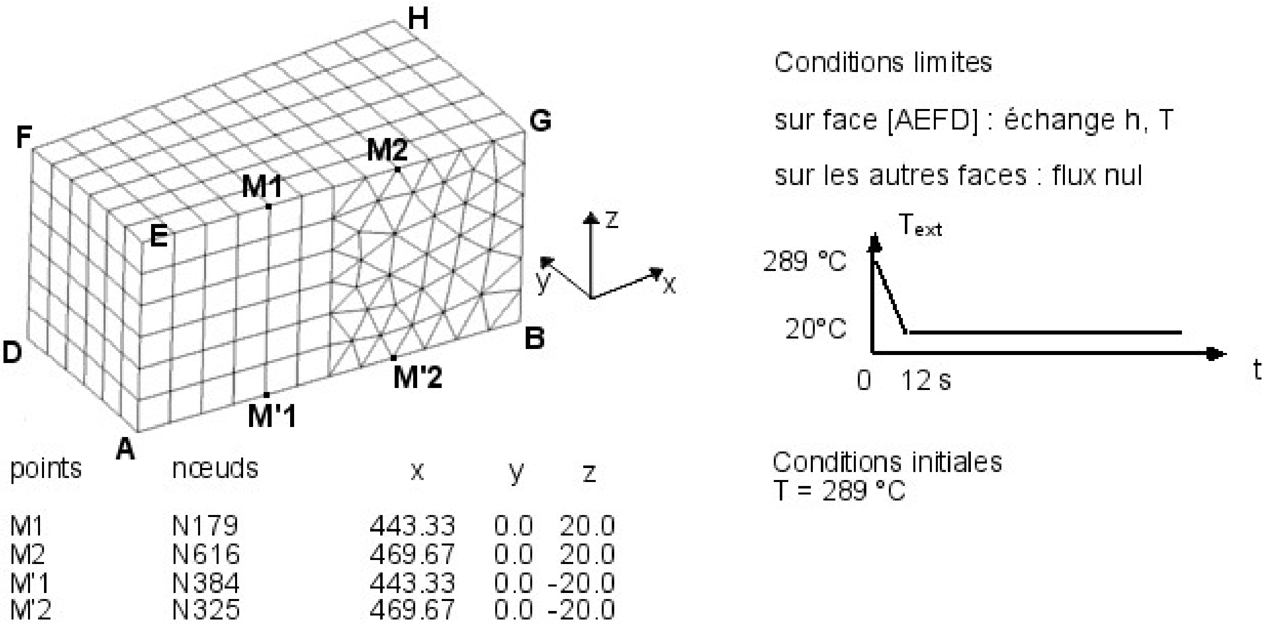
Identification	Type of reference	Value of reference	Precision (%)
M1 (R = 443.33)			
T = 12.	'AUTRE_ASTER'	288.64	0.5
T = 100.	'AUTRE_ASTER'	202.76	0.1
T = 600.	'AUTRE_ASTER'	93,027	0.1
T = 2000.	'AUTRE_ASTER'	29,419	0.1
M2 (R = 469.67)			
T = 12.	'AUTRE_ASTER'	289.00	0.1
T = 100.	'AUTRE_ASTER'	275.04	0.5
T = 600.	'AUTRE_ASTER'	143.00	0.1
T = 2000.	'AUTRE_ASTER'	35,858	0.5
Me 1 (R = 443.33)			
T = 12.	'AUTRE_ASTER'	288.64	0.5
T = 100.	'AUTRE_ASTER'	202.76	0.1
T = 600.	'AUTRE_ASTER'	93,027	0.1
T = 2000.	'AUTRE_ASTER'	29,419	0.1

Me 2 (R = 469.67)			
T = 12.	'AUTRE_ASTER'	289.00	0.1
T = 100.	'AUTRE_ASTER'	275.04	0.5
T = 600.	'AUTRE_ASTER'	143.00	0.1
T = 2000.	'AUTRE_ASTER'	35,858	0.5

5 Modeling C

5.1 Characteristics of modeling

The infinite cylinder being supposed, one nets only one slice height $H=40\,mm$.



5.2 Characteristics of the grid

Many nodes: 637
Many meshs and types: 216 HEXA8, 432 PENTA6

5.3 Sizes tested and results

Identification	Type of reference	Value of reference	Precision (%)
Max ($TEMP$) – GROUP_NO 'M1'	'ANALYTICAL'	289.0	0.1
M1 (R = 443.33)			
T = 12.	'AUTRE_ASTER'	288.64	0.5
T = 100.	'AUTRE_ASTER'	202.76	0.1
T = 600.	'AUTRE_ASTER'	93,027	0.1
T = 2000.	'AUTRE_ASTER'	29,419	0.1
M2 (R = 469.67)			
T = 12.	'AUTRE_ASTER'	289.00	0.1
T = 100.	'AUTRE_ASTER'	275.04	0.5
T = 600.	'AUTRE_ASTER'	143.00	0.1
T = 2000.	'AUTRE_ASTER'	35,858	0.5
Me 1 (R = 443.33)			
T = 12.	'AUTRE_ASTER'	288.64	0.5
T = 100.	'AUTRE_ASTER'	202.76	0.1

T = 600.	'AUTRE_ASTER'	93,027	0.1
T = 2000.	'AUTRE_ASTER'	29,419	0.1
Me 2 (R = 469.67)			
T = 12.	'AUTRE_ASTER'	289.00	0.1
T = 100.	'AUTRE_ASTER'	275.04	0.5
T = 600.	'AUTRE_ASTER'	143.00	0.1
T = 2000.	'AUTRE_ASTER'	35,858	0.5

6 Summary of the results

Modeling AXIS_DIAG give rather satisfactory results. Although the grid comprises only 3 elements in the thickness, the variation on the temperatures remains lower than 0.5 %.

Modeling 3D_DIAG give satisfactory results. The variation on the temperatures remains too lower than 0.5 %.

In spite of the violence of the thermal shock, the diagonalisation of the matrix of mass allows thus to obtain a solution in temperature which does not oscillate during the transient.