TTLV100 - Thermal shock in a pipe with condition of Summarized

exchange:

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

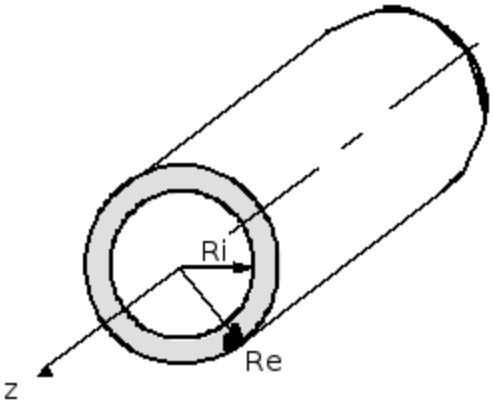
The shock is modelled by a linear slope $\Delta T = -269\,°C$ in $12\,s$.

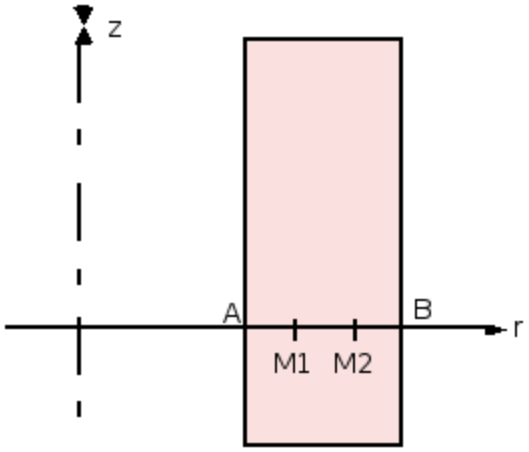
With the problem is dealt into axisymmetric and 3D.
The reference solution is obtained on a fine network.
The test is carried out on 3 modelizations: (TRIA3, QUAD4), (TRIA6, QUAD9) in AXIS_DIAG and (HEXA8, PENTA6) in 3D_DIAG.

One tests the algorithm of linear thermal transitory when the mass matrix is diagonalized (modelization 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

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

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 any r

Discretization in time (t):

12	steps for	$[0.,12.]$	either	$\Delta t=1.\,s$
2	steps for	$[12.,20.]$	or	$\Delta t=4.\,s$
4	steps for	$[20.,100.]$	or	$\Delta t=20.\,s$
2	steps for	$[100.,200.]$	or	$\Delta t=50.\,s$
2	steps for	$[200.,400.]$	or	$\Delta t=100.\,s$

8 steps for $[400., 2000.]$ or $\Delta t = 200. s$

2 Reference solution

2.1 Method of calculating used for the reference solution

the reference solution are obtained on a fine mesh comprising 99 quadratic elements QUAD8 in L" thickness without option of diagonal thermal mass matrix.

2.2 Results of reference

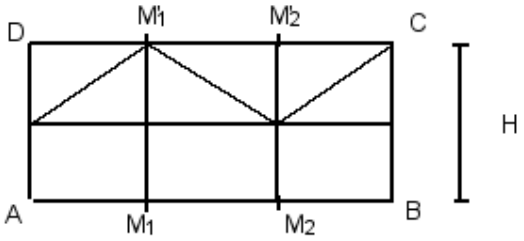
Temperatures to the points $M1$ ($r=443.33$) and $M2$ ($r=469.67$), and to various times ($t=12.,100.,600.$ and $2000.$).

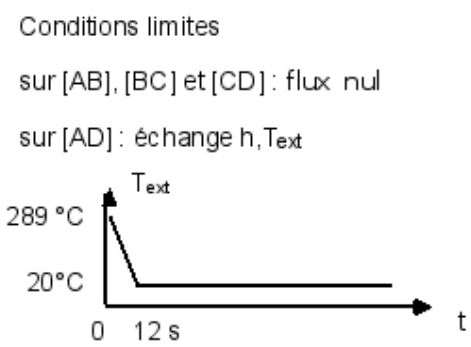
3 Modelization A

3.1 Characteristic of modelization

TRIA3, QUAD4

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





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 mesh

Many nodes: 12
Number of meshes and types: 3 QUAD4, 6 TRIA6

3.3 Quantities tested and results

Identification	Reference	*Aster*	% difference
M1 (R = 443.33)			
T = 12.	288.64	282.63	– 2.08
T = 100.	202.76	199.84	– 1.44
T = 600.	93.027	92.821	– 0.22
T = 2000.	29.419	29.865	+1.51
m2 (R = 469.67)			
T = 12.	289.00	288.84	– 0.06
T = 100.	275.04	268.63	– 2.32
T = 600.	143.00	142.74	– 0.18
T = 2000.	35.858	36.629	+2.15
Me 1 (R = 443.33)			
T = 12.	288.64	283.09	– 1.92
T = 100.	202.76	206.66	+1.92
T = 600.	93.027	93.731	+0.76
T = 2000.	29.419	29.988	+1.93
Me 2 (R = 469.67)			
T = 12.	289.00	288.82	– 0.06

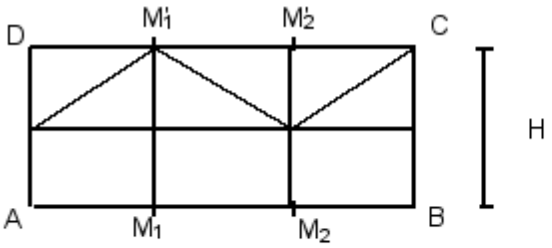
T = 100.	275.04	267.66	– 2.68
T = 600.	143.00	141.57	– 1.00
T = 2000.	35.858	36.470	+1.71

4 Modelization B

4.1 Characteristic of modelization

TRIA6, QUAD9

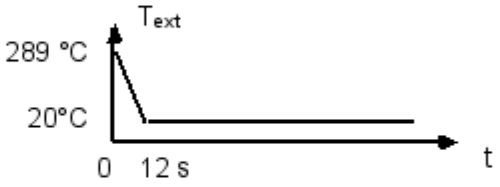
the infinite cylinder being supposed, one net only one slice height $H = 40\,mm$ with 2 layers of elements.



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	469.67	40.
	6		

Conditions initiales
T = 289 °C

4.2 Characteristics of the mesh

Many nodes: 35
Number of meshes and types: 3 QUAD9, 6 TRIA6

4.3 Quantities tested and results

Identification	Reference	*Aster*	% difference
M1 (R = 443.33)			
T = 12.	288.64	286.80	– 0.63
T = 100.	202.76	202.25	– 0.25
T = 600.	93.027	92.955	– 0.08
T = 2000.	29.419	29.524	+0.36
m2 (R = 469.67)			
T = 12.	289.00	288.99	+0.00
T = 100.	275.04	273.35	– 0.61
T = 600.	143.00	142.99	– 0.00
T = 2000.	35.858	36.050	+0.54
Me 1 (R = 443.33)			
T = 12.	288.64	287.13	– 0.52
T = 100.	202.76	205.35	+1.28
T = 600.	93.027	93.378	+0.38
T = 2000.	29.419	29.580	+0.55

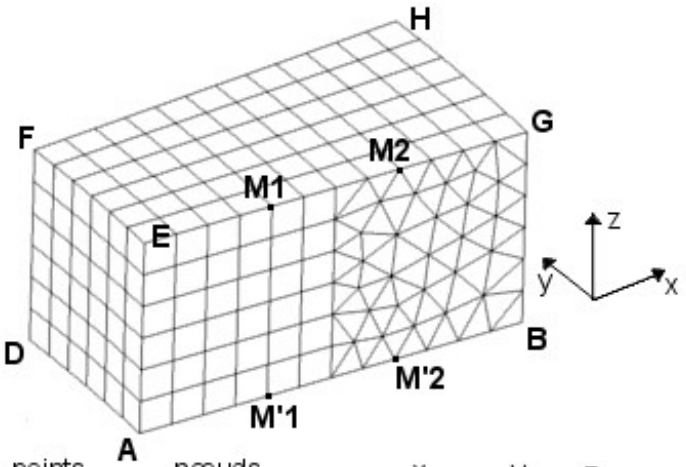
Me 2 (R = 469.67)			
T = 12.	289.00	288.99	+0.00
T = 100.	275.04	272.65	– 0.87
T = 600.	143.00	142.39	– 0.43
T = 2000.	35.858	35.972	+0.32

5 Modelization C

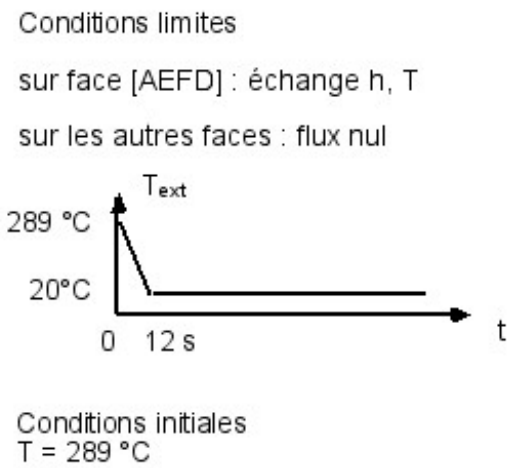
5.1 Characteristic of modelization

TRIA6, QUAD9

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



points	nœuds	x	y	z
M1	N179	443.33	0.0	20.0
M2	N616	469.67	0.0	20.0
M'1	N384	443.33	0.0	-20.0
M'2	N325	469.67	0.0	-20.0



5.2 Characteristics of the mesh

Many nodes: 637
Number of meshes and types: 216 HEXA8, 432 PENTA6

5.3 Quantities tested and results

Identification	Reference	*Aster*	% difference
M1 (R = 443.33)			
T = 12.	288.64	286.08	-0.88
T = 100.	202.76	199.12	-1.80
T = 600.	93.027	92.43	-0.64
T = 2000.	29.419	29.34	-0.17
Temperature max	289.00	289.00	0
m2 (R = 469.67)			
T = 12.	289.00	289.00	0
T = 100.	275.04	272.79	-0.82
T = 600.	143.00	141.96	-0.72
T = 2000.	35.858	35.77	-0.24
Me 1 (R = 443.33)			
T = 12.	288.64	286.08	-0.88
T = 100.	202.76	199.04	-1.83

T = 600.	93.027	92.42	-0.65
T = 2000.	29.419	29.37	-0.17
Me 2 (R = 469.67)			
T = 12.	289.00	289.00	0
T = 100.	275.04	272.80	-0.81
T = 600.	143.00	141.97	-0.72
T = 2000.	35.858	35.77	-0.24

6 Summary of results

The modelization AXIS_DIAG give rather satisfactory results. Although the mesh comprises only 3 elements in the thickness, the variation on the temperatures remains lower than 2.7 %.

The modelization 3D_DIAG gives satisfactory results. The variation on the temperatures remains lower than 2%.

In spite of the violence of the thermal shock, the diagonalization of the mass matrix makes it possible to obtain a solution in temperature which does not oscillate during the transient.