TTNL303 - Infinite wall subjected to a jump of temperature with variable properties

Summary:

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

It is about a linear problem 1D represented by four modelings, two plane and two voluminal.

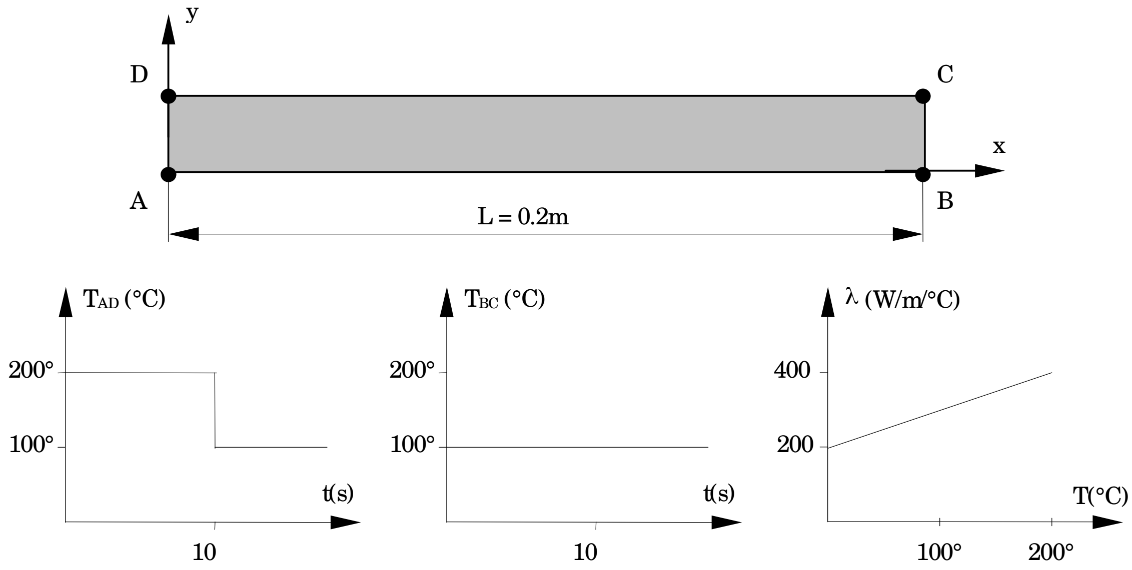
The features tested are the following ones:

- thermal element plan,
- voluminal thermal element,
- variable thermal conductivity,
- non-linear transitory thermal algorithm,
- limiting conditions: temperature imposed with jump.

The interest of the test lies in the taking into account of variable properties in transitory analysis and the variation of the temperatures imposed according to time.

1 Problem of reference

1.1 Geometry



1.2 Properties of material

$\lambda=200+T(W/m\,°C)$ thermal conductivity

$\rho C=8.10^6(J/m^3\,°C)$ voluminal heat

1.3 Boundary conditions and loadings

$x=0$ $T=200\,°C$ $0<t\leq 10\,s$

$T=100\,°C$ $t>10\,s$

$x=L$ $T=100\,°C$ $t\geq 0\,s$

1.4 Initial conditions

$T(x,0)=100\,°C$ for all x

2 Reference solution

2.1 Method of calculating used for the reference solution

The reference solution was obtained with the computation software by finite elements "IVOHEAT" [bib2] quoted in the reference [bib1]. This solution is based on network made up of 20 isoparametric elements with 4 nodes of identical size, by using a method of Crank-Nicolson modified with a precision of 10^{-6} .

2.2 Results of reference

Temperature with:

- $t=10\,s$ for $x=0.01, 0.02, 0.04, 0.06, 0.08$ and 0.1 ,
- $t=13\,s$ for $x=0.01, 0.02, 0.04, 0.06, 0.08$ and 0.1 .

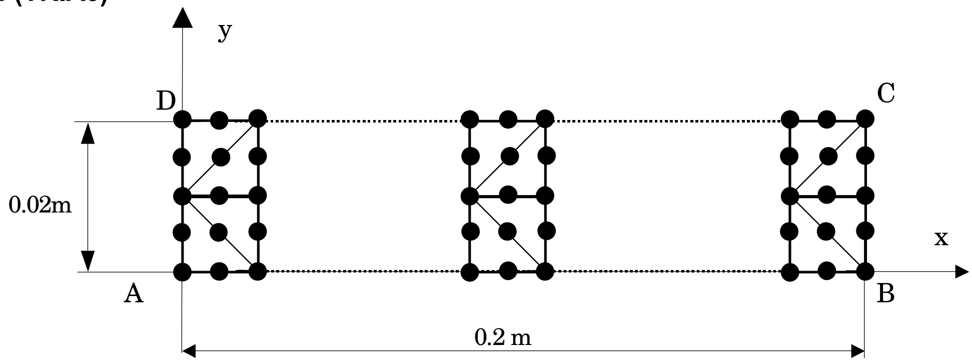
2.3 Bibliographical references

- S. Orivuori, "Efficient method for solution of nonlinear heat conduction problems", Int. J. num. Meth. Engng, flight 14, n°10, pp 1461-1476, 1979
- S. Orivuori, "with finite element method applied to the solution of the transient heat conduction problème', Licentiate Thesis, Tech. Univ., Helsinki (1977), in Finish.

3 Modeling A

3.1 Characteristics of modeling

PLAN (TRIA6)



Conditions limites:

- cotés AB, CD $\phi = 0$
- coté AD | T = 200°C $0 < t \leq 10$ s
  | T = 100°C $t > 10$ s
- coté BC T = 100°C $t \geq 0$ s

Noeuds	x	y
N11	0.01	0.00
N21	0.02	0.00
N41	0.04	0.00
N61	0.06	0.00
N81	0.08	0.00
N101	0.10	0.00

3.2 Characteristics of the grid

Many nodes: 205
Many meshs and types: 80 TRIA6

3.3 Remarks

The discretization in step of time is the following one:

10 pas for	$[0., 1.D-3]$	that is to say	$\Delta t = 1.D^{-4}$
9 pas for	$[1.D-3, 1.D-2]$	that is to say	$\Delta t = 1.D^{-3}$
9 pas for	$[1.D-2, 1.D-1]$	that is to say	$\Delta t = 1.D^{-2}$
9 pas for	$[1.D-1, 1.D0]$	that is to say	$\Delta t = 1.D^{-1}$
9 pas for	$[1.D0, 10.D0]$	that is to say	$\Delta t = 1.0$
3 pas for	$[10.D0, 13.D0]$	that is to say	$\Delta t = 1.0$

4 Results of modeling A

4.1 Values tested

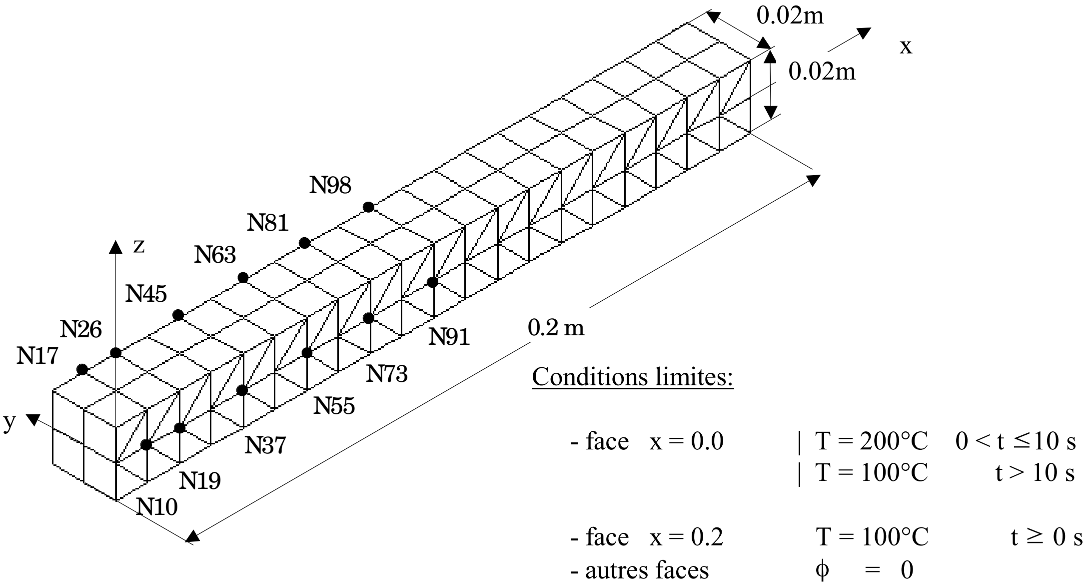
Identification	Reference	*Aster*	% difference	tolerance
Temperature $(°C)$ with $t=10\,s$				
N11	176,165	174,954	-0,687	2%
N21	153,213	151,049	-1,412	2%
N41	118,600	116,576	-1,707	2%
N61	103,715	103,195	-0,502	2%
N81	100,368	100,417	0,049	2%
N101	100,014	100,088	0,074	2%

Temperature $(°C)$ with $t=13\,s$				
N11	128,125	128,377	0,197	2%
N21	139,970	139,846	-0,089	2%
N41	124,719	122,209	-2,013	2%
N61	107,182	106,279	-0,842	2%
N81	101,290	101,186	-0,103	2%
N101	100,134	100,203	0,067	2%

5 Modeling B

5.1 Characteristics of modeling

3D (PENTA6)



5.2 Characteristics of the grid

Many nodes:	189
Many meshs and types:	160 PENTA6

5.3 Remarks

The discretization in step of time is the following one:

10 pas for	$[0., 1.D-3]$	that is to say	$\Delta t = 1.D^{-4}$
9 pas for	$[1.D-3, 1.D-2]$	that is to say	$\Delta t = 1.D^{-3}$
9 pas for	$[1.D-2, 1.D-1]$	that is to say	$\Delta t = 1.D^{-2}$
9 pas for	$[1.D-1, 1.D0]$	that is to say	$\Delta t = 1.D^{-1}$
9 pas for	$[1.D0, 10.D0]$	that is to say	$\Delta t = 1.0$
3 pas for	$[10.D0, 13.D0]$	that is to say	$\Delta t = 1.0$

6 Results of modeling B

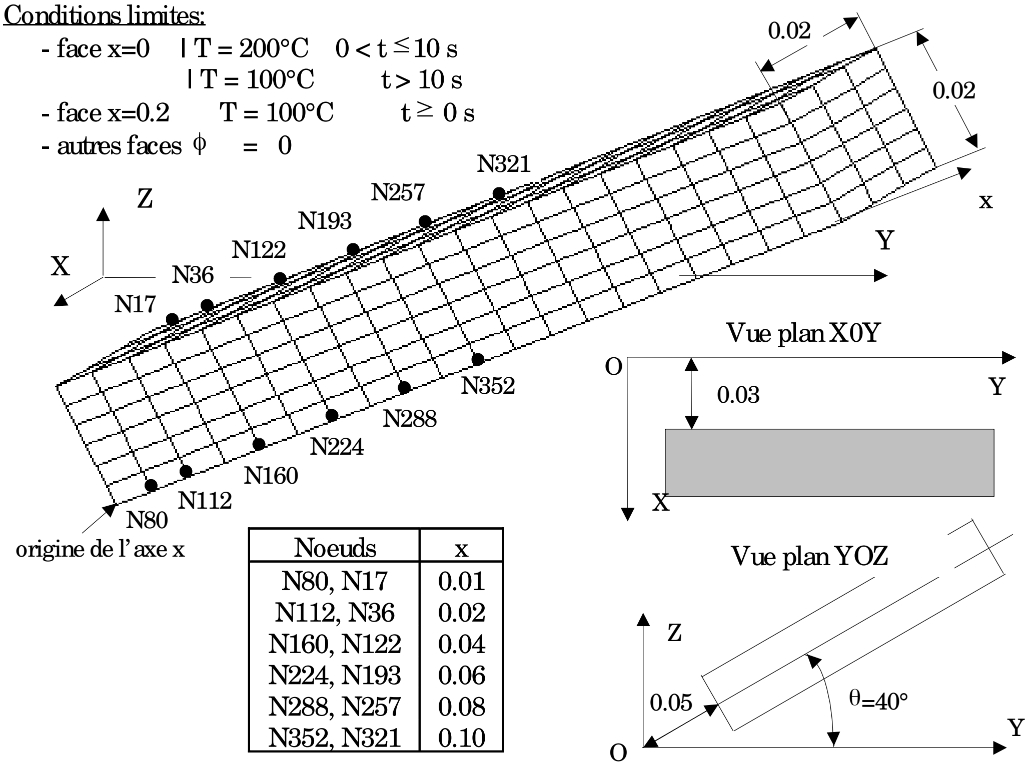
6.1 Values tested

Identification	Reference	*Aster*	% difference	tolerance
Temperature $(°C)$ with $t=10s$				
N10	176,165	175,087	-0,612	2%
N17	176,165	174,910	-0,713	2%
N19	153,213	151,182	-1,326	2%
N26	153,213	151,020	-1,431	2%
N37	118,600	116,314	-1,928	2%
N45	118,600	116,379	-1,872	2%
N55	103,715	102,759	-0,921	2%
N63	103,715	102,892	-0,793	2%
N73	100,368	100,239	-0,129	2%
N81	100,368	100,285	-0,083	2%
N91	100,014	100,060	0,046	2%
N98	100,014	100,066	0,052	2%
Temperature $(°C)$ with $t=13s$				
N10	128,125	129,395	0,991	2%
N17	128,125	128,291	0,130	2%
N19	139,970	139,819	-0,108	2%
N26	139,970	140,209	-0,171	2%
N37	124,719	122,986	-1,390	2%
N45	124,719	122,569	-1,724	2%
N55	107,182	105,967	-1,134	2%
N63	107,182	106,050	-1,056	2%
N73	101,290	100,945	-0,341	2%
N81	101,290	101,005	-0,282	2%
N91	100,134	100,126	~ 0,008	2%
N98	100,134	100,142	0,008	2%

7 Modeling C

7.1 Characteristics of modeling

3D (HEXA8)



Noeuds	x
N80, N17	0.01
N112, N36	0.02
N160, N122	0.04
N224, N193	0.06
N288, N257	0.08
N352, N321	0.10

7.2 Characteristics of the grid

Many nodes: 588
Many meshs and types: 360 HEXA8

7.3 Remarks

The discretization in step of time is the following one:

10 pas for	$[0., 1.D-3]$	that is to say	$\Delta t = 1.D^{-4}$
9 pas for	$[1.D-3, 1.D-2]$	that is to say	$\Delta t = 1.D^{-3}$
9 pas for	$[1.D-2, 1.D-1]$	that is to say	$\Delta t = 1.D^{-2}$
9 pas for	$[1.D-1, 1.D0]$	that is to say	$\Delta t = 1.D^{-1}$
9 pas for	$[1.D0, 10.D0]$	that is to say	$\Delta t = 1.0$
3 pas for	$[10.D0, 13.D0]$	that is to say	$\Delta t = 1.0$

8 Results of modeling C

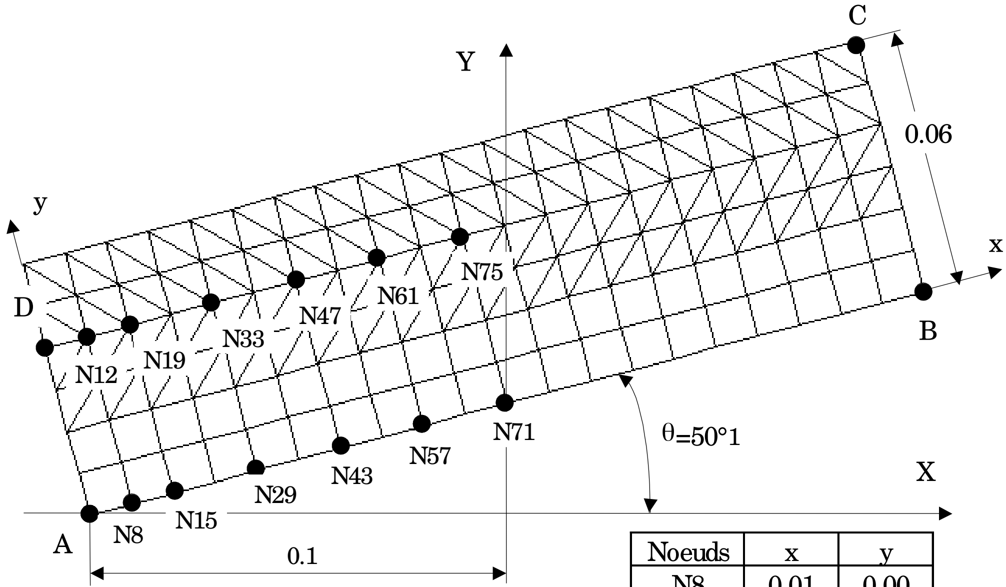
8.1 Values tested

			Relative variation %		Absolute deviation	
Identification	**Reference**	***Aster***	**difference**	**tolerance**	**difference**	**tolerance**
Temperature $(°C)$						
$t=10s$						
N80	176,165	174,992	-0,666	2%	-1.17	3.0
N17	176,165	174,992	-0,666	2%	-1.17	3.0
N112	153,213	151,092	-1,384	2%	-2.12	3.0
N36	153,213	151,092	-1,384	2%	-2.12	3.0
N160	118,600	116,331	-1,913	2%	-2.27	3.0
N122	118,600	116,331	-1,913	2%	-2.27	3.0
N224	103,715	102,817	-0,866	2%	-0,898	3.0
N193	103,715	102,817	-0,866	2%	-0,898	3.0
N288	100,368	100,265	-0,102	2%	-0,103	3.0
N257	100,368	100,265	-0,102	2%	-0,103	3.0
N352	100,014	100,066	0,052	2%	0,052	3.0
N321	100,014	100,066	0,052	2%	0,052	3.0
$t=13s$						
N80	128,125	128,829	0,550	2%	0,704	3.0
N17	128,125	128,829	0,550	2%	0,704	3.0
N112	139,970	139,893	-0,055	2%	-0,077	3.0
N36	139,970	139,893	-0,055	2%	-0,077	3.0
N160	124,719	122,718	-1,605	2%	-2.00	3.0
N122	124,719	122,718	-1,605	2%	-2.00	3.0
N224	107,182	105,988	-1,114	2%	-1.19	3.0
N193	107,182	105,988	-1,114	2%	-1.19	3.0
N288	101,290	100,974	-0,312	2%	-0,316	3.0
N257	101,290	100,974	-0,312	2%	-0,316	3.0
N352	100,134	100,136	0,002	2%	0,002	3.0
N321	100,134	100,136	0,002	2%	0,002	3.0

9 Modeling D

9.1 Characteristics of modeling

PLAN (TRIA3, QUAD4)



Conditions limites:

- cotés AB, CD $\phi = 0$
- coté AD | T = 200°C $0 < t \leq 10$ s
  | T = 100°C $t > 10$ s
- coté BC T = 100°C $t \geq 0$ s

Noeuds	x	y
N8	0.01	0.00
N15	0.02	0.00
N29	0.04	0.00
N43	0.06	0.00
N57	0.08	0.00
N71	0.10	0.00

9.2 Characteristics of the grid

Many nodes: 147
Many meshs and types: 200 (40 QUAD4, 160 TRIA3)

9.3 Remarks

The discretization in step of time is the following one:

10 pas for $[0.,1.D-3]$ that is to say $\Delta t=1.D^{-4}$
9 pas for $[1.D-3,1.D-2]$ that is to say $\Delta t=1.D^{-3}$
9 pas for $[1.D-2,1.D-1]$ that is to say $\Delta t=1.D^{-2}$
9 pas for $[1.D-1,1.D0]$ that is to say $\Delta t=1.D^{-1}$
9 pas for $[1.D0,10.D0]$ that is to say $\Delta t=1.0$
3 pas for $[10.D0,13.D0]$ that is to say $\Delta t=1.0$

10 Results of modeling D

10.1 Values tested

			Relative variation %		Absolute deviation	
Identification	**Reference**	***Aster***	**difference**	**tolerance**	**difference**	**tolerance**
Temperature $(°C)$						
$t=10\,s$						
N8	176,165	174,997	-0,663	2%	-1.17	3.0
N12	176,165	175,154	-0,574	2%	-1.01	3.0
N15	153,213	151,117	-1,368	2%	-2.10	3.0
N19	153,213	151,246	-1,284	2%	-1.97	3.0
N29	118,600	116,416	-1,842	2%	-2.18	3.0
N33	118,600	116,246	-1,985	2%	-2.35	3.0
N43	103,715	102,884	-0,801	2%	-0,831	3.0
N47	103,715	102,664	-1,014	2%	-1.05	3.0
N57	100,368	100,283	-0,084	2%	-0,085	3.0
N61	100,368	100,208	-0,159	2%	-0,160	3.0
N71	100,014	100,067	0,053	2%	0,053	3.0
N75	100,014	100,057	0,043	2%	0,044	3.0
$t=13\,s$						
N8	128,125	128,512	0,302	2%	0,387	3.0
N12	128,125	129,103	0,764	2%	0,978	3.0
N15	139,970	139,689	-0,201	2%	-0,281	3.0
N19	139,970	140,233	0,188	2%	0,263	3.0
N29	124,719	122,723	-1,601	2%	-2.00	3.0
N33	124,719	123,198	-1,220	2%	-1.52	3.0
N43	107,182	106,051	-1,055	2%	-1.13	3.0
N47	107,182	105,887	-1,209	2%	-1.30	3.0
N57	101,290	101,004	-0,282	2%	-0,286	3.0
N61	101,290	100,902	-0,383	2%	-0,388	3.0
N71	100,134	100,143	0,009	2%	0,009	3.0
N75	100,134	100,116	0,018	2%	0,018	3.0

11 Summary of the results

A modeling among four modelings carried out give results whose value exceeds little the tolerance fixed initially (2%). The maximum change is of:

- 2,013% for modeling PLAN (TRIA6),
- 1,928% for modeling 3D (PENTA6),
- 1,913% for modeling 3D (HEXA8),
- 1,985% for modeling PLAN (TRIA3, QUAD4).

It is noted that this variation is whatever the modeling close to 2%, all modelings carried out, have same cutting in the direction of propagation of the temperature.

The got results are regarded as acceptable for the whole of modelings

This test made it possible to test the taking into account of a variable thermal conductivity with a limiting condition varying in the course of time.