MTLP100 - Heating and hardening of an infinite bar with square section

Abstract:

The purpose of this test is providing a metallurgy computation of reference, in postprocessing of an evolutionary computation of plane thermal linear which one knows the analytical solution. More concretely, this test validates two-dimensional computations of linear thermal with conditions of exchange and provides values of reference for the model of austenitic transformation to the heating, like for the model of decomposition of austenite to cooling.

It is noted that the program making it possible to seize diagrams TRC to produce command DEFI_TRC is united with the benchmark in the file mtlp100a.66:

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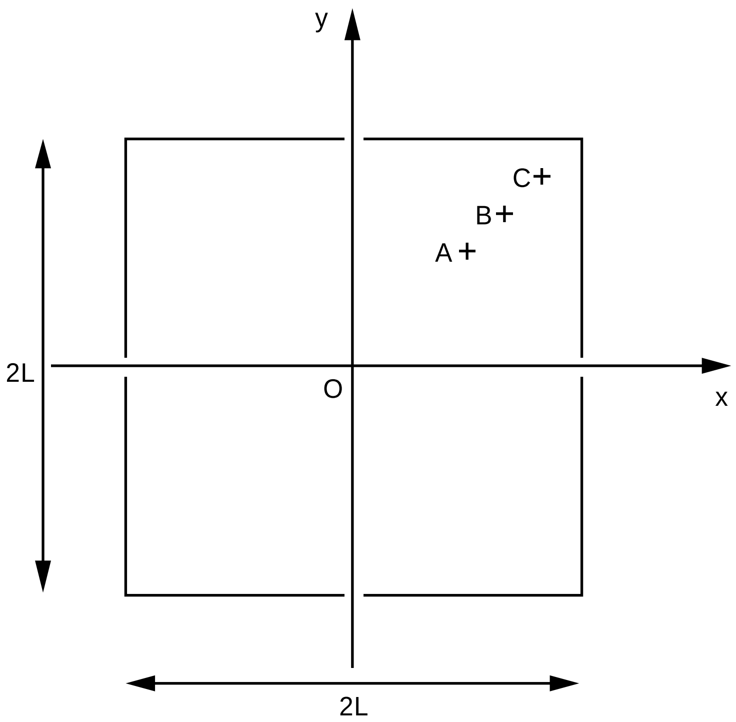
1 Problem of reference

1.1 Geometry



infinite Bar to square section:

side $2L = 0{,}10\,m$

Coordinated of the points (in meters):

	A	B	C	O
x	0.026	0.350	0.041	0.0
y	0.026	0.350	0.041	0.0

1.2 Properties of the material

(Steel 16MND5)

$\rho C_P = 5260000\, J.m^{-3}.°C^{-1}$

$\lambda = 33.5\, W.m^{-1}.°C^{-1}$

Coefficients for the metallurgy:

“Standard ” TRC

$AR3 = 830°C \quad alpha = -0.0306$

$MS0 = 400°C \quad AC1 = 724°C \quad AC3 = 846°C$

$\tau_1 = 0.034$, $\tau_3 = 0.034$

Microhardness of the différenres metallurgical phases:

- for ferrite $d = 200.\, HV$
- for the pearlite $d = 200.\, HV$

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- for bainite $d = 300. HV$
- for martensite $d = 400. HV$
- for austenite $d = 100. HV$

1.3 Boundary conditions and loadings

$$T_{\infty} = 15\,°C$$

$$h = 1675\, W.m^{-2}.°C^{-1}$$

1.4 Initial conditions

$$T(x, y, 0) = 700\,°C.$$

$$Zf(x, y, 0) = 0.7$$
$$Zb(x, y, 0) = 0.3$$

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2 Reference solution

2.1 Method of calculating used for the reference solution

- To the heating, one imposes a rise in uniform temperature of 700 on $900°C$ in $200s$.
- Analytical solution for thermal computation (with cooling since $900°C$).

$$T(x,y,t)=\theta(x,y,t)(T(x,y,0)-T_{\infty})+T_{\infty}$$

where:

$$\theta(x,y,t)=\sum_{i=1}^{\infty} A_i e^{-\omega_i^2\frac{\lambda}{\rho C_P}t}\cos\omega_i x\times\sum_{A}^{\infty}{}_i\, e^{-\omega_i^2\frac{\lambda}{\rho C_P}t}\cos\omega_i y$$

with ω_i checking:

$$\omega_i L\,tg(\omega_i L)=\frac{hL}{\lambda}=5.00$$

and:

$$A_i=\frac{4\sin(\omega_i L)}{2\omega_i L\sin(\omega_i L)}$$

- The values of reference for the metallurgical evolutions depend on the model and integration in time of the behavior models. One does not have values of reference.
- The hardness of a material point depend on the metallurgical proportions of each phase, one does not have values of reference.

2.2 Results of reference

(Thermal computation):

- temperature at the points A B , C at time $t=300s$,
- proportion of bainite at the points A B , C at times $t=410,300$ and $300s$ respectively,
- proportion of martensite at the points A B , C at time $t=410$ s ,
- proportion of austenite at the point A at times $t=30$ s and 140 s .
- hardness at the point O at times $t=30$ s , 140 s , $300s$ and $410s$.

2.3 Uncertainty on the solution

Lower than 1% with 30 modes for each sum.

2.4 Bibliographical references

[1]F.P. INCROPERA, D.P. OF WITT, J. WILEY. Fundamentals of heat and farmhouse transfer. Third Edition. 1990.

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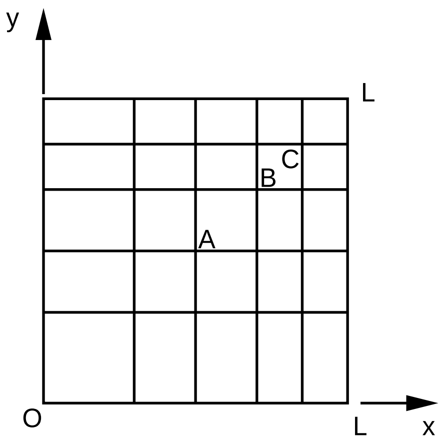
3 Modelization A

3.1 Characteristic of the modelization

Elements **2D "PLANE"**

By reason of symmetry, one nets only one quarter of square section and one refines in $x=L$ and $y=L$.



Cutting: 5 meshes QUAD8 according to the axis of x
the 5 meshes QUAD8 according to the axis of y

the Boundary conditions:

on $x=0$ and $y=0$	$\phi=0$
on $x=L$ and $y=L$	$-\lambda \partial T/\partial n=h(T(x,y,t)-T_\infty)$

Gauss points:

A : do not net $m13$ point 1
B : do not net $m19$ point 1
C : do not net $m19$ point 3

The node is outside the field of definition with a right profile of the EXCLU type node:

O : node $N1$

3.2 Characteristics of the mesh

Many nodes: 96
Number of meshes and types: 25 QUAD8, 20 SEG3

3.3 Remarks

165 computation steps of 0 with $410\ s$ (40 steps of $5\ s$, then 40 steps of $1\ s$, then 85 steps of $2\ s$).

3.4 Quantities tested and results

Option `META_ELNO` and `DURT_ELNO` :

Identification	Quantities	Reference	*Aster*	% difference
$t=30\ s$ $M13$ ($PG1$)	P	0.0489	0.0489	1.64 10-6 absolute
$t=140\ s$ $M13$ ($PG1$)	P	0.9505	0.9505	4.10 10-5 absolute

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$t=300\ s$	$M13\ (PG1)$	TPG	464.1	464.37	0.058
$t=300\ s$	$M19\ (PG1)$	TPG	338.5	338.79	0.086
$t=300\ s$	$M19\ (PG3)$	TPG	245.4	245.68	0.116
$t=410\ s$	$M13\ (PG1)$	ZB		0.7828	
$t=300\ s$	$M19\ (PG1)$	ZB		0.5873	
$t=300\ s$	$M19\ (PG3)$	ZB		0.3113	
$t=410\ s$	$M13\ (PG1)$	ZM		0.2156	
$t=410\ s$	$M19\ (PG1)$	ZM		0.4103	
$t=410\ s$	$M19\ (PG3)$	ZM		0.6846	
$t=30\ s$	$N1$	HV		223.643	
$t=140\ s$	$N1$	HV		106.430	
$t=300\ s$	$N1$	HV		100.000	
$t=410\ s$	$N1$	HV		308.248	

TPG : temperature at the Gauss point
ZB : proportion of bainite
ZM : proportion of martensite
P : proportion of austenite.
HV : hardness of Vickers

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4 Summary of the results

the temperatures calculated at the points A , B and C are obtained with a margin of 0.1%. The proportions of austenite are perfectly given.

The proportions of bainites, martensite and the computation of hardness are results making it possible to check non regression code (not reference solution).

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