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

Summary:

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

It is noted that the program allowing to seize diagrams TRC to produce the order `DEFI_TRC` is united with the CAS-test in the file mtlp100a.66:

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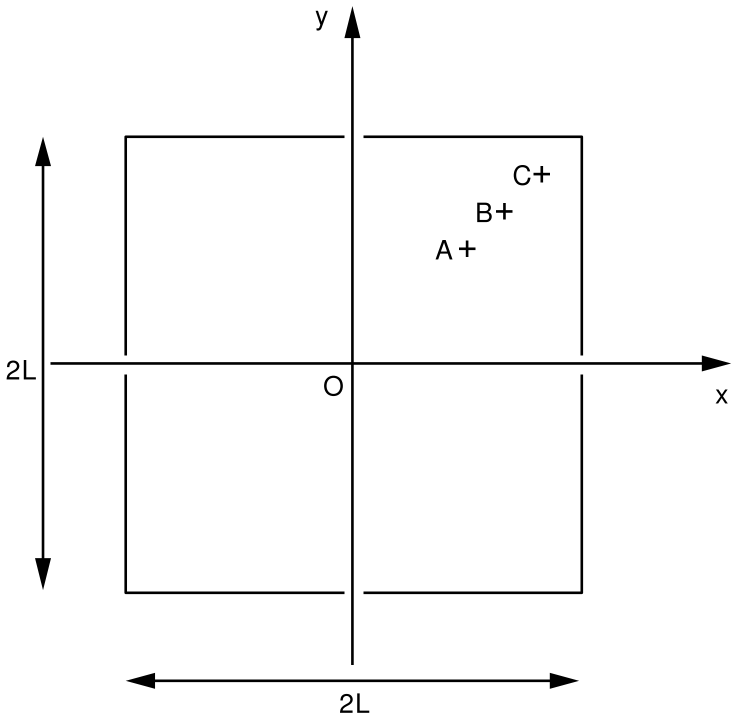
1 Problem of reference

1.1 Geometry



Infinite bar with square section:

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

Coordinates 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 material

(Steel 16MND5)

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

$\lambda = 33.5\ W.m^{-1}.°C^{-1}$

Coefficients for the metallurgy:

TRC " standard "

$AR3 = 830\,°C$, $alpha = -0.0306$

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

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

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

- With the heating, one imposes a rise in uniform temperature of 700 with $900°C$ in $200s$.
- Analytical solution for thermal calculation (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 relations of behaviors. 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 Calculation):

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

2.3 Uncertainty on the solution

Lower than 1% with 30 modes for each nap.

2.4 Bibliographical references

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

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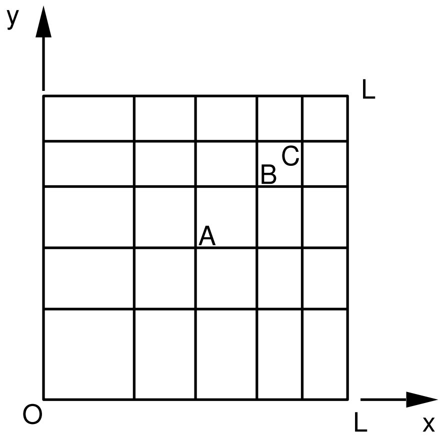
3 Modeling A

3.1 Characteristics of modeling

Elements **2D 'PLAN'**

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



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

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

Points of Gauss:

A : mesh $m13$ point 1
B : mesh $m19$ point 1
C : mesh $m19$ point 3

Node:

O : node $N1$

3.2 Characteristics of the grid

Many nodes: 96
Many meshs and types: 25 QUAD8, 20 SEG3

3.3 Remarks

165 pas de calculation of 0 with $410\ s$ (40 pas de $5\ s$, then 40 pas de $1\ s$, then 85 pas de $2\ s$).

3.4 Sizes tested and results

Option META_ELNO and DURT_ELNO :

Identification	Sizes	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
$t=300\ s$ $M13$ ($PG1$)	TPG	464.1	464.37	0,058

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$t=300\ s$ $M19$ ($PG1$)	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 point of GAUSS,
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

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 calculation of hardness are results making it possible to check to it not regression of the code (not of reference solution).

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