I. MELTING OF ICE IN THE RECTANGULAR ENCLOSURE WITH ISOTHERMAL VERTICAL WALLS

Schematic view of the problem with boundary and initial conditions are shown in Fig 1. Temperature values are: initial temperature, T_i= -5 °C; temperature of the hot wall (west), T_W=10 °C; temperature of the cold wall (east), T_E= -5 °C

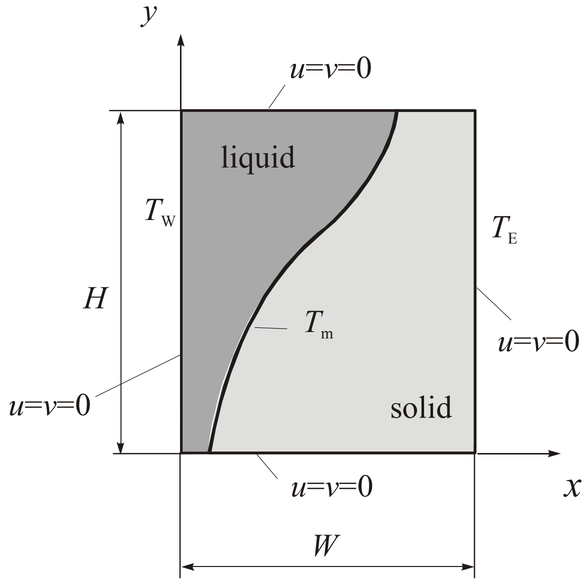

Fig. 1. Schematic view of the ice melting problem

The temperature dependent density of water can be approximated by the following equation for the temperature range 0-20°C (Vasseur and Robillard, 1980.)

$$\rho = \frac{\rho_0}{1 + k_1 T + k_2 T^2 + k_3 T^3 + k_4 T^4}$$

ρ_0 = 999,8396 kg/m^3
k_1 = - 0,6789645$\cdot 10^{-4}$ (1/ °C)
k_2 = 0,907294338$\cdot 10^{-5}$ (1/ °C^2)
k_3 = - 0,96456812$\cdot 10^{-7}$ (1/ °C^3)
k_4 = 0,873702983$\cdot 10^{-9}$ (1/ °C^4)

$\rho_{max} = \rho$(3,98 °C)= 999,971964 kg/m^3

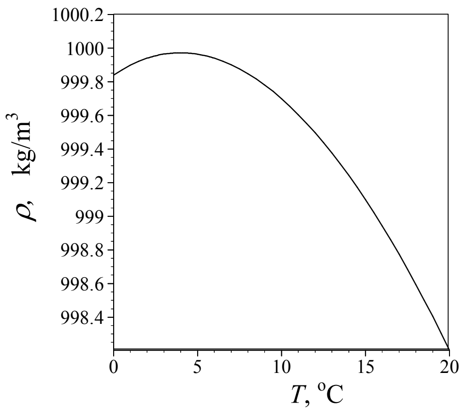

Fig 2. Water density versus temperature

Definition of non-dimensional parameters:

Rayleigh number

$$Ra = \frac{g\left(\rho_{max} - \rho(10^0\mathrm{C})\right)H^3}{\rho(10^0\mathrm{C})\,\nu_l\,a_l}$$

Prandtl number : $Pr = \dfrac{\nu_l}{a_l}$

Stefan number: $Ste = \dfrac{c_l \Delta T_l}{h_L}$

Subcooling number: $Sb = \dfrac{\Delta T_s}{\Delta T_l}$

$$\tau = Fo \cdot Ste = a_l \cdot t \cdot Ste / H^2$$

$$\theta_l = \frac{T - T_m}{\Delta T_l} \qquad \theta_s = \frac{T - T_m}{\Delta T_s}$$

$\Delta T_l = T_W - T_m$, $\Delta T_s = T_m - T_E$

I. Melting of ice in the rectangular enclosure with isothermal vertical walls

The average Nusselt number at the hot (west boundary) and at the cold (east boundary) wall

$$\overline{Nu}_{\mathrm{W}} = \frac{\Phi_{\mathrm{W}} \cdot W}{\lambda_{1} \cdot \Delta T_{1} \cdot H \cdot B}, \qquad \overline{Nu}_{\mathrm{E}} = \frac{\Phi_{\mathrm{E}} \cdot W}{\lambda_{1} \cdot \Delta T_{1} \cdot H \cdot B}$$

Values of the water density (0-15 $^{\circ}$C)

***T*, $^{\circ}$C**	*ρ*, kg/m^3
0	999,839600
1	999,898513
2	999,939852
3	999,964162
4	999,971964
5	999,963765
6	999,940049
7	999,901282
8	999,847910
9	999,780358
10	999,699033
11	999,604321
12	999,496588
13	999,376180
14	999,243421
15	999,098616

Values of non-dimensional parameters and properties of the PCM	
Ra	**$1{,}619 \cdot 10^{6}$**
Gr	**$1{,}395 \cdot 10^{5}$**
Pr	**11,6**
Ste	**0,126**
Sb	**0,5**
λ_s, W/(m·K)	2,243
λ_l, W/(m·K)	0,572
c_s, J/(kg·K)	2045
c_l, J/(kg·K)	4205
ρ_s, kg/m^3	917
ρ_l, (5°C) kg/m^3	999,964
a_s, m^2/s	$1{,}19 \cdot 10^{-6}$
a_l, m^2/s	$1{,}36 \cdot 10^{-7}$
ν_l, m^2/s	$1{,}52 \cdot 10^{-6}$
h_L J/kg	$3{,}3350 \cdot 10^{5}$
T_m, $^{\circ}$C	0
ΔT_s, $^{\circ}$C	5
ΔT_l, $^{\circ}$C	10
H, m	0,05
W, m	0,05
B, m	1

The mesh independent solution is obtained:

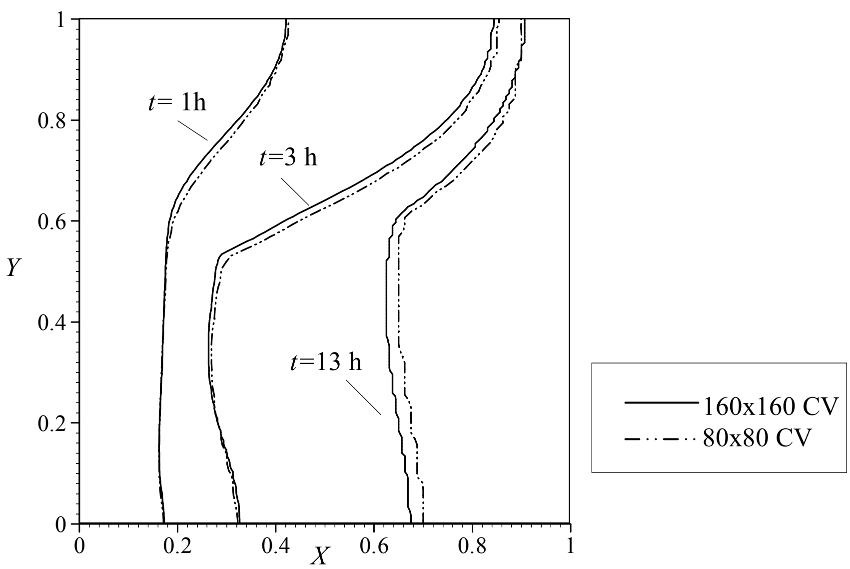

Fig. 3. Interface position – comparison of results obtained on two grids 80x80 C.V. and 160x160 C.V.

I. Melting of ice in the rectangular enclosure with isothermal vertical walls

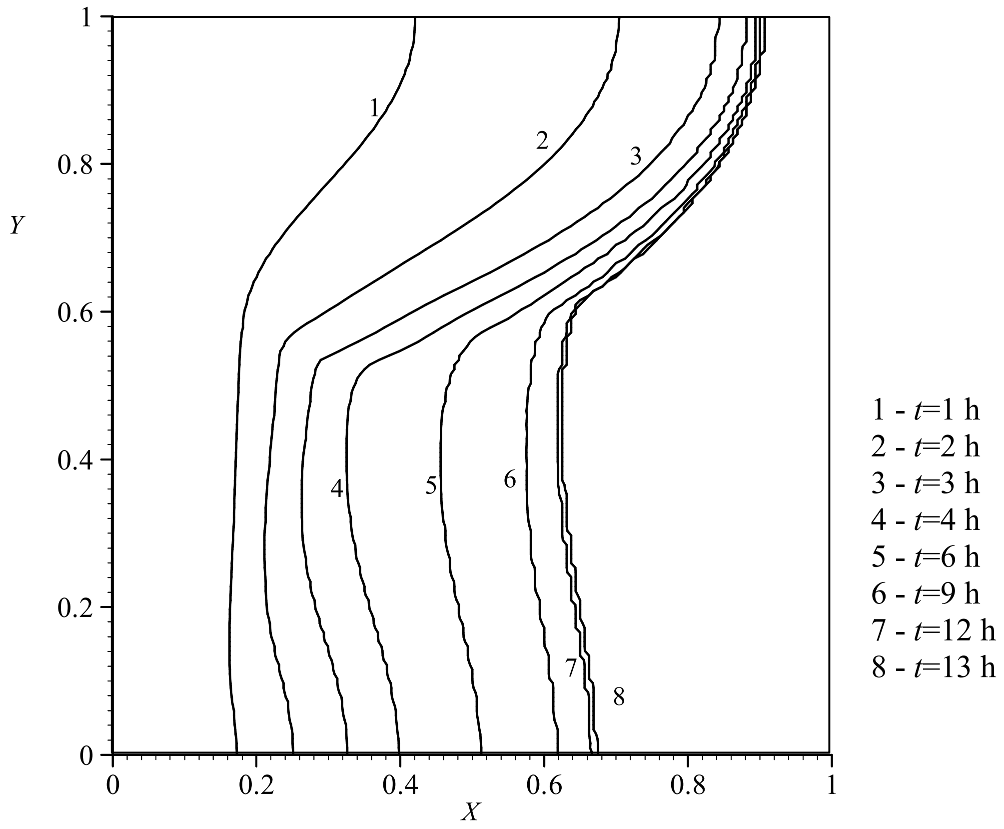

Fig. 4. Interface positions at different times

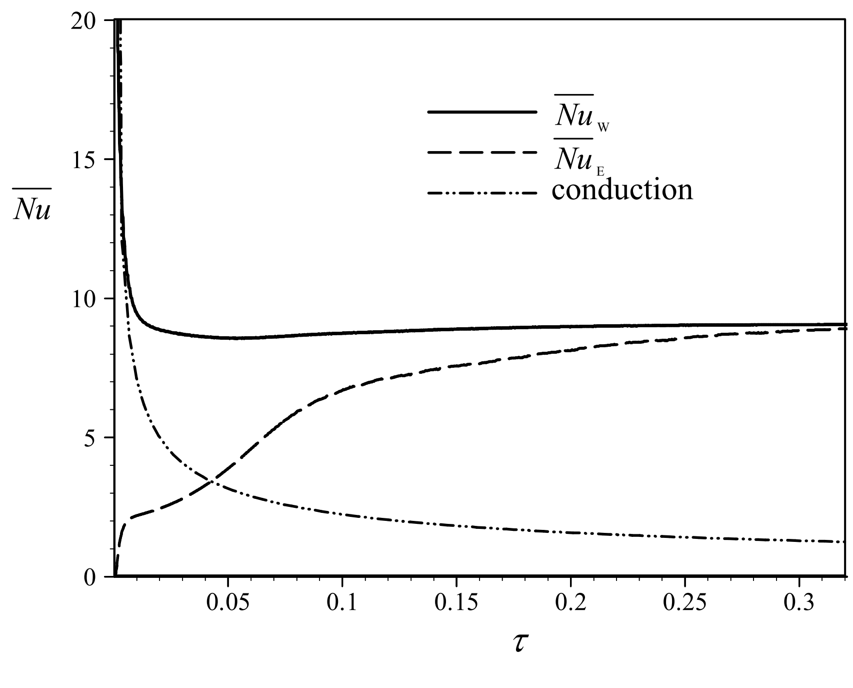

Fig.5. Time evolution of the average Nusselt number at the hot wall $\overline{Nu}_W$ and at the cold wall $\overline{Nu}_E$

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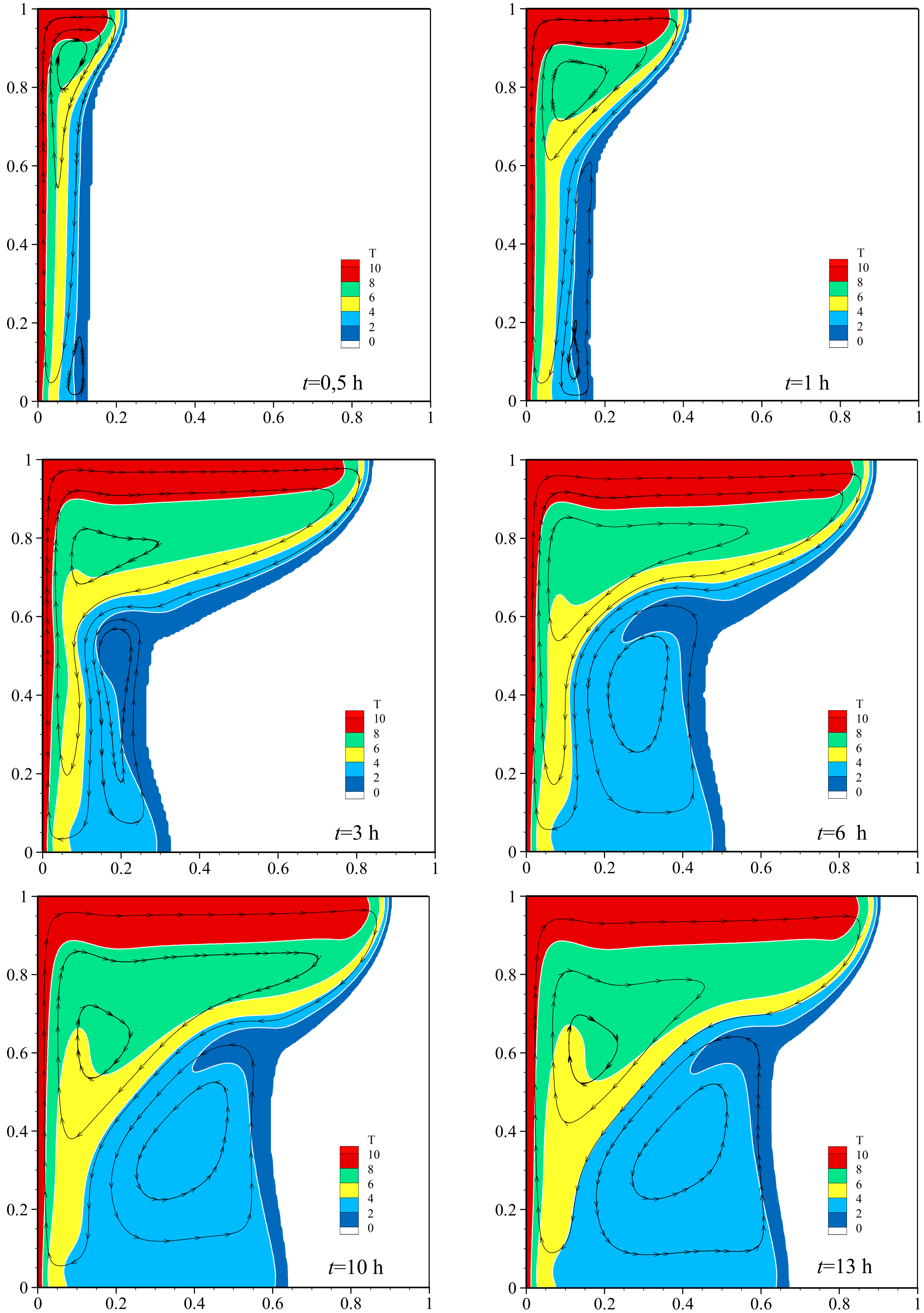

Fig. 6. Streamlines and isotherms at different times

Symbols

a	- thermal diffusivity, m^2/s
B	- length of rectangular cavity, m
c_l, c_s	- specific heat capacity of liquid, solid phase, J/(kg·K)
H	- height of the of the rectangular enclosure, m
t	- time, s
T	- temperature, K
T_m	- melting temperature, K
u	- velocity in the x direction, m/s
v	- velocity in the y direction, m/s
W	- width of the rectangular cavity, m
x	- Cartesian coordinate direction
$X = \frac{x}{W}$	- dimensionless x coodinate
y	- Cartesian coordinate direction
$Y = \frac{y}{W}$	- dimensionless y coodinate
Δt	- time step, s
Φ, Φ_W, Φ_E	- heat flux, at the west boundary, at the east boundary, W
λ_l, λ_s	- thermal conductivity of liquid, solid phase, W/(m·K)
ν_l,	- kinematic viscosity of liquid , m^2/s
ρ_l, ρ_s	- density of liquid, solid phase, kg/m^3