World Academy of Science, Engineering and Technology
International Journal of Chemical and Molecular Engineering
Vol:6, No:1, 2012

# Behavior of Ice Melting in Natural Convention

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***Abstract*—**In this paper, the ice melting in rectangular, cylindrical and conical forms, which are erected vertically against air flow, are experimentally studied in the free convection regime.The results obtained are: Nusslet Number, heat transfer coefficient andGrashof Number, and the variations of the said numbers in relation to the time. The variations of ice slab area and volume are measured, too.

***Keywords*—**Nusselt Number, Heat Transfer, Grashof Number, Heat Transfer Coefficient.

## I. INTRODUCTION

SINCE a long time ago, both heat transfer and ice melting caused by heat transfer and free convection were considered as important phenomena in science and engineering. In such cases, the buoyancy force is an important parameter because it plays a significant role in some industries like food, aviation and environment preservation.

A great number of studies in ice melting caused by heat transfer and convection have been carried out by some researchers to present some numerical and experimental models.Some researchers have worked on the convection-type heat transfer about various horizontal ice surfaces.

Tkachev examined spherical ice melting by taking photos in various conditions [1]. Also, Merk could find some equations for Nusselt Number by boundary layer solution [2]. Schenk and Schenkels explored ice melting and region of dual flow caused by it [3].

Vanier and Tien studied free convection during ice melting when it is submerged in water [4]. Bijan has performed investigations on ice melting when left against air flow [5].

Ice melting in forced convection was studied by Eskandari and Eskandari et al [6, 7]. Anselmo described the theoretical and numerical analysis of ice melting in a spherical form [8].

Hao and Tao quality examined heat transfer by observing ice melting in both spherical and cylindrical forms in various speed of water flow [9, 10]. Ice melting in various Rayleigh Numbers was studied by a photography technique and by using theoretical equations.

In the present essay, ice melting in various rectangular, cylindrical and conical forms suspended vertically against air flow is studied.

## II. THEORY

To measure the Rayleigh Number of ice the (1) is used:

$$Ra = \frac{g\beta(T_\infty - T_W)H^3}{a\nu} \tag{1}$$

Where, $T_w$=0.3°C is the ice surface temperature, $T_\infty$ is chamber temperature, H is the height of ice slab and g is the gravitational acceleration, $\beta$ = 0.004 is the coefficient of thermal expansion, $\alpha$ = 1.92 $\times 10^{-5}$ is the thermal diffusivity and $\nu$ = 1.373$\times 10^{-5}$ kinematic viscosity, are some of the air properties measured by film temperature. (2)

$$T_f = \frac{(T_\infty + T_W)}{2} \tag{2}$$

$(\overline{\frac{dL}{dt}})$ The rate of ice melting is measured by (3).

$$m^{\bullet} = \rho_w HW\,[\overline{\frac{dL}{dt}}] \tag{3}$$

Where, $m^{\cdot}$ is melting rate, $\rho_w = 1\frac{gr}{cm^3}$ is water density in 0°C, H is height and W is width of the ice slab.

Both Nusselt Number and Rayleigh Number are dependent on a specific length.In cylindrical and conical ice, it is necessary to define the specified length at the start of the process because ice deforms easily. Obviously, both the form and geometry of ice piece present an exact estimate of the specified length and area in arbitrary time intervals. In order to calculate the specified length ($L_c$) the (4) is used:

$$L_c = \frac{V_i}{A_{si}} \tag{4}$$

Where, $A_{si}$ is the area of cross section during the first moment and $V_i$ the initial volume. It is possible to have ac in every time interval by calculating the area of cross section (5):

$$A_c = \frac{V}{L_c} \tag{5}$$

To calculate Nusselt Number,(4) is used:

$$\overline{Nu}_H = \frac{\bar{h}H}{k} = \frac{\overline{\overline{q''}}H}{(T_\infty + T_W)} \tag{6}$$

Where, h is heat transfer coefficient, and thermal conductivity of water is k = 0.025, which is measured in film temperature. $\overline{\overline{q''}}$ , is thermal flux, calculated by (5).

$$q'' = \frac{\rho_w}{2} h_{sf} \frac{dl}{dt} \tag{7}$$

Where, $h_{sf}$ is latent heat of fusion. It is $h_{sf} = 333.4\frac{J}{gr}$ for ice.

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Open Science Index, Chemical and Molecular Engineering Vol:6, No:1, 2012 publications.waset.org/13974.pdf

Now, the convectional heat transfer coefficient is calculated by (6). Grashof Number is worked out by (7):

$$Gr = \frac{g\beta(T_\infty - T_W)H^3}{\nu^2} \tag{8}$$

## III. EXPERIMENTAL

Isothermal ambient by outer dimensions of 50×50×45 $cm^3$ made of a material with low conductivity. In order to change the air flow velocity some inlets and outlets were installed. The experiment was carried out in two forms of semi-closed outlet and fully-open one for rectangular form of ice and semi-closed outlet for cylindrical and conical forms. It used deionized water. Ice slabs(rectangular, cylindrical and conical) mold with a minimum of trapped air bubbles (without cracks and bulges).See fig1, fig 2 and fig3.

The ice dimensionsare listed in Table I and II. The ice melting starts by the ice slab being suspend in air. During trial carry out, the ice piece is melted asymmetrically.

In order to make ice slabs some pan with low expansion coefficient were used. The temperature measured by resistance temperature. The quantities that are measured during this study are the melt water flow rate, temperature in surface and temperature in isothermal ambient.

Fig. 1Rectangular ice slab ice

Fig. 2 Melting in Rectangular ice slab

Fig. 3 Melting in Cylindrical ice slab

## IV. RESULTS AND DISCUSSION

The result of ice melting process has been plotted for rectangular ice slab in two forms of semi-closed outlet and fully-open outlet. In the figs (4) and (5) Variation of volume of ice slab at different time plotted. In the figs (6) and (7)variation of heat transfer coefficient at different time plotted and finally Nusselt number at different time in the melting process has been plotted in figures (8) and (9).

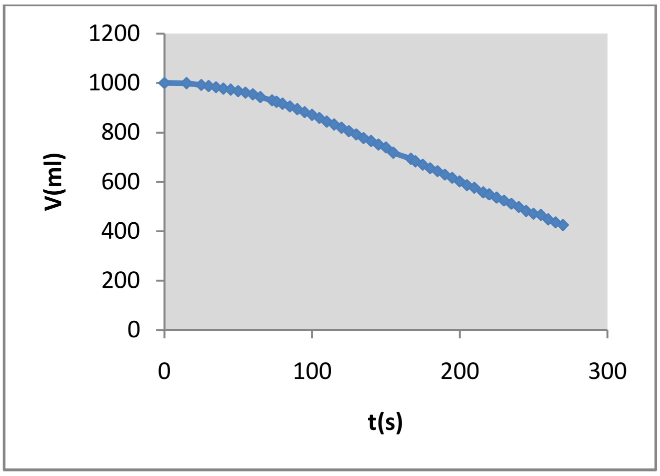

Fig. 4 Variation of volume of ice slab with semi-open outlet at different time

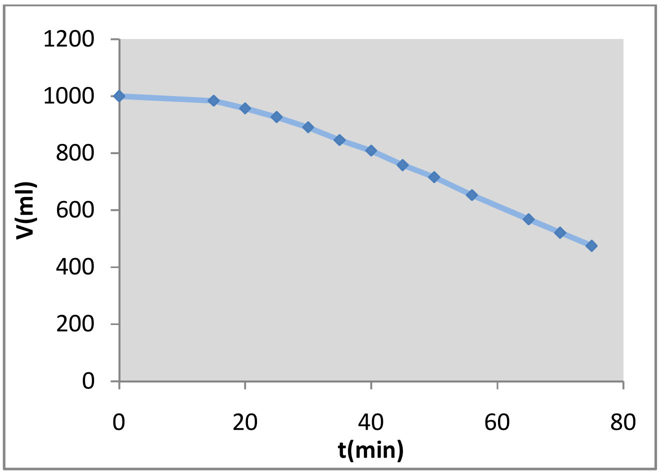

Fig. 5 Variation of volume of ice slab with open outlet at different time

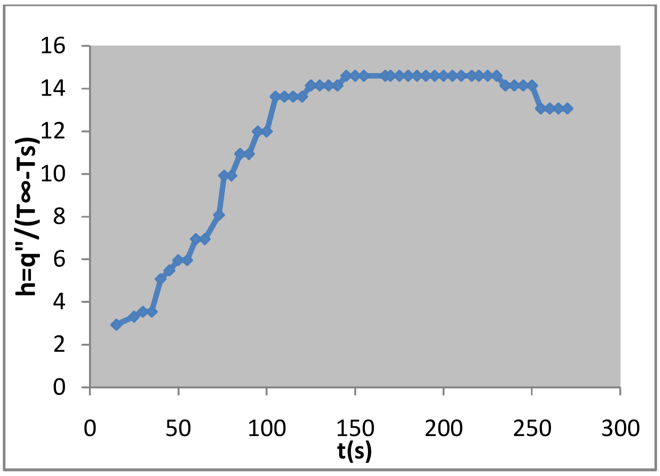

Fig. 6 Variation of heat transfer coefficient with semi-open outlet atdifferent time

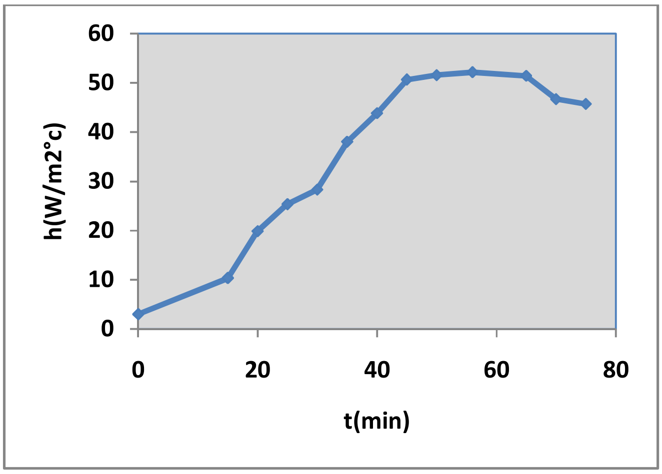

Fig. 7 Variation of heat transfer coefficient with semi-open outletat different time

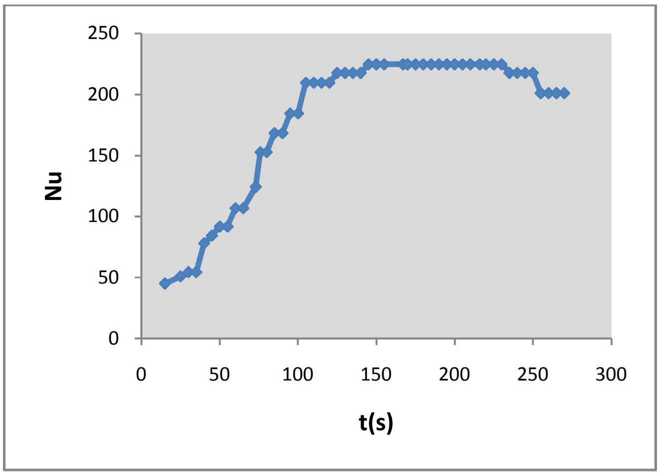

Fig. 8 Nusselt number at different time in the melting process with semi-open outlet

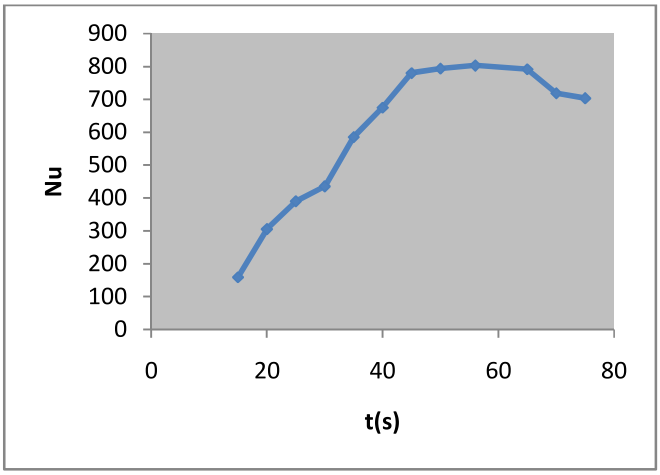

Fig. 9 Nusselt number at different time in the melting process

Increase air velocity made intensification ice melting. Variation in Nusselt number with time was different in temperature between air in and surface ice. Also the experiments are repeated for rectangular, cylindrical and conical molds. The results are shown in Table I and II:

TABLE I
RESULTS OF EXPERIMENT FORRECTANGULAR ICE SLAB

| Shape of ice slab | Rectangular with semi open inlet air | Rectangular with open inlet air |
|---|---|---|
| *Dimension($m^3$)* | 0.01018×0.255×0.385 | 0.01018×0.255×0.385 |
| *Gr* | 66979944 | 74772594 |
| *Nu* | 188.2 | 606 |
| h($w/m^2$°C) | 12 | 39.4 |

TABLE II
RESULTS OF EXPERIMENTFOR CYLANDRICAL AND CONICAL ICE SLABS

| Shape of ice slab | Cylindrical (volume 100 ml) | Conical(300 ml) |
|---|---|---|
| *Dimension($m^3$)* | $\pi\times(0.0224)^2\times0/0634$ | $\pi\div3\times(0.085)^2\times0.159$ |
| *Gr* | 38246606 | 213540410 |
| *Nu* | 716 | 2.11 |
| h($w/m^2$°C) | 176 | 0.215 |

## V. CONCLUSIONS

Of particular interest in ice storage applications and meteorology is the relationship between the melting rate and the bulk temperature of the surrounding air. The present study reveals this information as a relationship between $m^{\cdot}$ and Grashof. The result shows,area and volume versus time decreases always. In initial, ice melting flow rate is in maximum values and then decreases by time.

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