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Effects of feed water temperature, pool temperature, and pool side heat transfer coefficient on freezing time of the conventional block ice production

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Abstract

Computational fluid dynamic (CFD) model was developed for predicting the effects of water temperature for producing ice in a box immersed in a pool containing brine water, the pool temperature and the pool side heat transfer coefficient on the water freezing time of the block ice box. Results from the model were agreed very well with those of onsite experiments of the conventional plant. The obtained model was used to predict the effects of the pool temperatures, the feed water temperatures and the pool side heat transfer coefficients ranging from -5°C to -20°C, 0°C to 40°C and 250W/m^2°C to 50,000W/m^2°C respectively on the freezing time of the block ice production having the dimension of 0.27 m x 0.56 m x 1.484 m. It was found that the pool temperature was the major factor. The minor factor was the feed water temperature whereas the heat transfer coefficient had not a significant effect. The freezing time decreased dramatically when the pool temperature not less than -7°C and gradually decreased until the temperature reached -12°C after that it fairly unchanged. The optimum pool temperature was suggested to be -10°C. At that pool temperature, the freezing time could be reduced from 45.20 hr to 44.24 hr when the feed water temperature reduced from 29.5°C to 5°C. The obtained results reveal the useful information for design and optimizing the plant operation which has not found in literature.

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Keywords: block ice; water freezing

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Nomenclature

t_f	freezing time (hr)
T_p	pool temperature (°C)
T_w	wall temperature (°C)
W	width
L	length
H	height
h_s	side heat transfer coefficient (W/m^2•°C)

1. Introduction

Thailand is in the tropical zone. Ice is not only used to consume but reserve anything which can be rotten by the hot weather. Ice tube and ice block have the most demand in the market. Tube ice which has a hollow cylinder in shape with about ¾ inch in diameter and 1 inch[1] long is normally used to consume whereas block ice which has a dimension of 0.27 m x 0.56 m x 1.484 m is usually used in consuming and general purpose.

The conventional process of block ice production starts from filling the water at room temperature into galvanized sheet boxes then immerse them into -12°C brine pool. The pool temperature is controlled by a refrigeration system. In this process, the production times or freezing times vary from 48 – 72 hr. As it has a very long freezing time, in order to have enough ice can be supplied in the peak demand period [2], the pools have to be able to contain a large number of ice boxes. In general, the pool capacities are in the rage from 800 to 2000 boxes.

The large pool size and a very long freezing time lead to high heat loss and energy consumption. However, the size is depended on the time so the energy consumption can be decreased if the freezing time decreases. As far as authors are concerned, information on the parameters effecting on ice block production is lacking. Hence, the aims of this work are to investigate the feed water temperature, pool temperature and pool side heat transfer coefficient on the ice block freezing time.

2. Experiment

Experiments were performed both on model scale and true scale. Model experiment was conducted in the laboratory using a small box to investigate temperature distribution in the box. Onsite experiment was conducted in Mittraphap 2002 ice plant. Data obtained from both experiments was used to validate the simulation results.

2.1. Model experiment

The experiment rig arrangement is shown in Fig. 1. There were nine thermocouples installed inside the box at different positions for measuring the water temperatures. The measured temperatures with respect to time were recorded by a precision data logger with accuracy of 0.1°C.