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Study on high performance ice slurry formed by cooling emulsion in ice storage (discussion on adaptability of emulsion to thermal storage material)

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Abstract

This study focuses on an emulsion as a new thermal storage material for ice storage. Two types of emulsions were formed using an oil–water mixture with a small amount of additive. A silicone, light and lump oils were used. The water contents of the emulsions were 70, 80 and 90%. The additive was an amino group modified silicone oil. No depression of freezing point was observed for the emulsions because of their hydrophobic properties. In order to determine the structure of the emulsions, their electrical resistances were measured. Moreover, components of the liquids separating from the emulsions were analyzed. The results indicated that one emulsion was a W/O type emulsion, while the other was an O/W type. Finally, adaptability of the two emulsions to ice storage was discussed, it was concluded that a high performance ice slurry could be formed by the W/O type emulsion.

Keywords: Ice slurry; Thermal storage; Experiment; Binary mixture; Water; Oil; Performance

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Etude sur la performance élevée d'un système de production de coulis de glace à base de refroidissement d'émulsion et d'accumulation thermique de glace: discussion sur l'utilisation de l'émulsion en tant que matériau utilisé dans l'accumulation thermique

Mots clés : Coulis de glace ; Accumulation thermique ; Expérimentation ; Mélange binaire ; Eau ; Huile ; Performance

1. Introduction

In Japan, a peak cut and peak shift of the demand for electric power can be achieved by spreading out the usage of power for ice storage systems by employing nighttime electric power, instead of the much more costly daytime electric power. In addition, the release of CO_2 gas can be much reduced by the spread because of the characteristics of nighttime electric power. Thus, the spread of ice storage systems can reduce the environmental load.

An ice storage equipment can be smaller because the amount of thermal storage per unit volume is larger than that required for other thermal storage systems. Especially, in a dynamic ice storage system, the ice slurry used as the thermal storage material has good fluidity. Thus, a large amount of cold energy can be transported with less pumping work. The dynamic system can also respond quickly to changes in heat load because the ice particles have a large surface area.

Many researchers have studied the formation methods of ice slurries [1–3], however, the IPF (Ice Packing Factor) of formed ice is low at present.

In our study [4], we reported that a high-IPF ice slurry could be formed without adhesion of ice to the cooling wall by cooling and stirring a functional fluid of 10 vol% silicone oil and 90 vol% water with a small amount of additive (silane-coupler) in a resin beaker. Moreover, the ice particles in the slurry remained granular and well-dispersed even after the slurry was preserved for a long time in a frozen state. In our previous study [5], we reported that at a very small depression of the freezing point, all the water in the functional fluid could be frozen because the additive combined with ice by hydrogen bonding.

However, the latent heat of fusion of an ice slurry made from the functional fluid dropped according to the depression of freezing point, though the depression of freezing point was very small. Moreover, in the case of using a metal beaker, ice adhesion to the cooling beaker wall often occurred.

In order to solve the above problems, a new thermal storage material was developed. As additive, an amino group modified silicone oil was used, rather than the silane-coupler. This silicone oil is hydrophobic, hence, it seems that the latent heat of fusion does not drop. Two types of emulsions were formed using an oil–water mixture with a small amount of the amino group modified silicone oil.

The present study investigates the structure and characteristics of the two emulsions. Moreover, their performance as thermal storage material is assessed from the viewpoints of IPF, fluidity, and ice adhesion to cooling wall. The optimal emulsion is selected for ice storage.

2. Experiment

2.1. Experimental apparatus

The experimental apparatus and procedure are the same as in our previous study [5]. Thus, only a summary is provided in the present study. Fig. 1 schematizes the experimental apparatus. PMP (polymethylpentene) and stainless steel beakers were used. Their height and inner diameter were about 190 mm and 130 mm, respectively. The temperatures of the emulsion and ice slurry were measured by a platinum resistance thermometer. The temperature measurement points were 600 mm above the beaker bottom and 15 mm and 65 mm radially from the center of the beaker. The stirring velocity was 250 rpm. The emulsion was formed

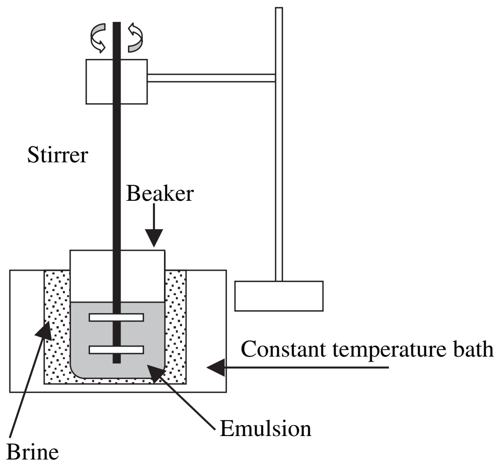

Fig. 1. Experimental apparatus.