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Study on formation of ice slurry by W/O emulsion (discussion for promoting propagation of supercooling dissolution due to DC voltage impression)

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ABSTRACT

This study is focused on a W/O (water-in-oil) emulsion with 60–80% water contents for formation of ice slurry in ice storage system. The emulsion is made of oil–water mixture with a little amino group modified silicone oil additive. Ice slurry could be formed by cooling the emulsion without ice adhesion to a cooling wall because of its structural feature. However, it was found that propagation of supercooling dissolution of the emulsion hardly started and the propagation rate was much slower. In this study, in order to promote propagation of supercoolng dissolution of the emulsion without ice nucleus charging, the DC voltage is applied to the emulsion during the cooling process. And then, influences of the magnitude of applied voltage, the composition ratio of water and oil (water content), and the distance between electrodes on the propagation process are clarified.

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Etude sur la génération de coulis de glace à l’aide d’une émulsion eau-huile (discussion sur la proportion de la propagation de la dissolution surrefroidie sous l’effet d’une tension électrique continue)

Mots clés : Coulis de glace ; Émulsion ; Eau ; Huile ; Enquête ; Procédé ; Champ électrique ; Courant continu

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1. Introduction

Ice slurry used in ice storage systems has a large amount of thermal storage per unit volume, a good fluidity, etc (Kozawa et al., 2005). Moreover, recently, application of ice slurry to a cold storage of foods is also noticed. In the process of ice slurry formation, it is important to prevent ice adhesion to a cooling wall. However, it is especially difficult under the condition of higher ice formation rate.

Authors have studied formation of ice slurries using a water-in-oil (W/O) emulsion, which overcomes some of the problems including ice adhesion to the cooling wall. Simultaneously, it has been confirmed that propagation of supercooling dissolution for W/O emulsions hardly starts and the propagation rate is much slower than that for a liquid such as water (Matsumoto et al., 2006).

In the ice storage system, it is essential to build more convenient method for promotion of propagation. Therefore, authors have also studied the several methods, such as ultrasonic wave impression and charging of an ice nucleus immediately after DC voltage impression (Matsumoto et al., 2007, 2008).

Dissolution of supercooling of pure water with a very small volume due to DC voltage impression was discussed (Hozumi et al., 2003; Okawa, et al., 1998 (in Japanese), 1997) and its validity was confirmed.

However, the propagation process of supercooling dissolution of W/O emulsion is much more complicated phenomenon compared with the case of pure water. Thus, the results of experiments using pure water cannot be directly applied to the propagation process of W/O emulsion.

In this paper, promotion of propagation due to DC voltage impression without charging of an ice nucleus is investigated. And times taken from voltage impression to start of propagation of supercooling dissolution of W/O emulsion and from start of propagation to end are measured, respectively, varying the magnitudes of applied voltage, the composition ratios of water and oil of the W/O emulsion (water contents) and the distances between electrodes. And influences of the above parameters on the propagation process are discussed.

2. Experiment

2.1. Compositions of W/O emulsions

In this paper, W/O emulsions with several composition ratios were used. And, the oil and water used were a silicone oil and tap water, respectively, and water contents of the emulsions were 60, 70 and 80%, respectively. The kinematic viscosity of the silicone oil was 10 mm^2/s at 25 °C. A mino-group-modified silicone oil with 0.9 vol% was used as a surface-active agent.

Those compositions are shown in Table 1, respectively. Hereafter, the word "emulsion" represents a W/O emulsion.

Table 1 – Compositions of W/O type emulsions.

Tap water	880 ml	770 ml	660 ml
Silicone oil	220 ml	330 ml	440 ml
Additive	10 ml	10 ml	10 ml
Volumetric ratio of water and oil	8:2	7:3	6:4

(Additive: amino group modified silicone oil).

2.2. Measurement of propagation of supercooling dissolution due to voltage impression

When one ice nucleus is charged at 0 °C, the examples of time dependency of propagation of supercooling dissolution for the emulsion and that of dissolution of supercooling for pure water are shown in Fig. 1, respectively. From Fig. 1, supercooling of water was dissolved and its temperature returned to 0 °C immediately after charging of one ice nucleus. However it took a long time to finish propagation of supercooling dissolution of the emulsion because very small water droplets covered with oil were dispersed. The experimental apparatus to investigate influence of voltage impression on propagation of supercooling dissolution is shown in Fig. 2. A PMP (polymethylpentene) vessel with an inner diameter of about 130 mm was used. The emulsion of 1.1 l in the vessel was directly cooled by cold brine of −5.4 °C with stirring of 250 rpm. Two stirrer wings made of stainless steel were used. A stirrer rod was made of glass. In order to prevent a heat loss, a lid made of thermal insulator was set to an opening of the vessel. When the emulsion reached a fixed supercooling degree, an electrodes made of aluminum was set in the emulsion, as shown in Fig. 2, and a certain DC voltage was applied to the emulsion to start propagation of supercooling dissolution. A schematic diagram of the electrodes used is shown in Fig. 3. A part except the part of 1 mm from a tip of the electrodes was electrically insulated. The tip was sharpened because an electric current density became a maximum at the tip.

After end of propagation, it was confirmed that structure of W/O type was supported. If the magnitude of applied voltage was too large, it was confirmed that the emulsion changed into oil and water (two layers) because it was broken. Change of supercooling degree was carried out by change of the brine temperature.

The representative temperature of the emulsion was measured using a platinum resistance thermometer located at a distance of 15 mm from the wall towards the center of the vessel and 10 mm upward from the bottom.

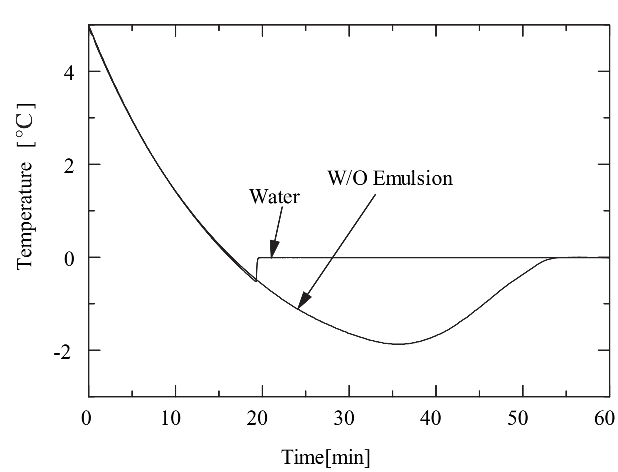

Fig. 1 – Time dependency of propagation of supercooling dissolution of supercooling.

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