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STUDY ON THERMAL PROPERTIES OF A NEW PHASE CHANGE COOL STORAGE MATERIAL

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ABSTRACT

The thermal properties of phase storage material including the freezing point, melting point, heat of fusion, and thermal stability during the phase change process are investigated. In the analysis, the Differential Scanning Calorimeter (DSC) was used to determine the heat of fusion of the phase change material (PCM), and the temperature sensor was used to determine the freezing point and melting point of the PCM. The results show that the PCM can be considered as an efficient cool storage material for cool storage air conditioning system.

1. INTRODUCTION

Cool storage air conditioning system can meet the same total cooling load as conventional air conditioning system over a given period of time with a smaller chiller. The reduction in size and cost of the cooling equipment can thus partially or completely offset the cost of storage equipment. Therefore, a proper cool storage air conditioning system can reduce the operating costs, and the size of the chilling equipment, provide back-up cooling capacity, and extend the capacity of an conventional air conditioning system [1].

Cool storage systems can be classified into chilled water storage, ice storage and phase change material storage systems according to the type of thermal storage medium. Chilled water storage system is widely used for thermal energy storage because water is cheap and has favorable thermal properties. Chilled water storage uses its sensible heat for thermal energy storage, and it has a low energy storage density resulting in a big storage system. Ice storage system uses the latent heat of fusion of water for thermal energy storage. Ice thermal energy storage stores cooling in the form of ice at its freezing point 0 ^{o}C. To store this energy, refrigeration equipment must operate at temperatures well below the normal operating range for air conditioning applications. Due to operation at low temperatures, chiller efficiency decreases. Most PCM storage systems use inorganic salt hydrates and mixtures of these for thermal energy storage. They have been employed due to their high latent heat of transition, and high densities. The major problem is that most of them melt incongruently. Another problem with salt hydrates is that they have poor nucleating properties resulting in supercooling of the liquid salt hydrate prior to freezing. A third problem is that they have short service lives and high costs [2,3]. If PCMs are to be used for cooling storage air conditioning system, they should have a melting temperature of approximately 5 to 10 ^{o}C.

The purpose of the study is to determine the thermal properties of a new PCM for cool storage. The thermal properties investigated include the melting point, freezing point, heat of fusion and thermal stability of the phase change process. A Differential Scanning Calorimeter (DSC) was used to determine the heat of fusion of the PCM. A temperature sensor was used to determine the freezing point and melting point of the PCM.

2. EXPERIMENT

2.1 Melting and Freezing Point of the PCM

The PCM was transferred to a test tube. A beaker was filled with ice and maintained at 0^{o}C. The test tube was immersed in the beaker and a temperature sensor was inserted into the test tube. The temperature reading of the PCM was observed continuously. The temperature decreased continuously until it reached a constant value (the freezing point of the PCM). The temperature started to decrease further after the entire PCM was frozen.

The test tube with the frozen contents was then immersed in a beaker of water (the water was at room temperature). The temperature of the PCM increased slowly until it reached the melting point. The entire PCM melted and the temperature then increased faster than before.

2.2 Heat of Fusion of the PCM

The thermal properties of the PCM were recorded using a Perkin-Elmer Differential Scanning Calorimeter Pyris 1 DSC. Indium was used as standard for temperature calibration. Samples were placed in aluminium pans that were hermetically sealed before being placed on the calorimeter thermocouples. The sample space was cooled by a two-stage compression refrigeration system. The cooling rate was 10 ^oC min^{-1} from 50 ^oC to -50 ^oC, the heating rate was 10 ^oC min^{-1} from -50 ^oC to 50 ^oC. At first, the DSC cell containing a PCM sample was cooled to a lower temperature than the melting temperature of the sample. A heating block was heated at a constant rate, the temperature of the reference sample pan also increased at a constant rate. If there was no phase change in the PCM sample pan, the temperature difference between the PCM sample and the reference sample pan produced an almost horizontal straight line. If there was a phase change in the PCM sample pan, the temperature difference between the two pans followed a curve that deviated from the straight line. The area between the straight line and the curve represents the energy consumed for the phase change, which is integrated numerically by a program built into the DSC. Both the melting transition temperature and the heat of fusion were recorded during a heating scan [4,5].

2.3 Thermal Stability of the PCM

A PCM with a melting point of 5.3 ^oC was subjected to sixty heating and cooling cycles. The PCM was first cooled to below freezing point, and then heated to 25 ^oC. During these cycles, the freezing point of the PCM was measured by a temperature sensor.

3. RESULTS AND DISCUSSION

The temperature was measured using a temperature sensor while the phenomena of freezing and melting were observed. The freezing point and melting point were obtained from temperature curves shown in Figs. 1 and 2. Fig. 1 shows that the freezing point of the PCM lies between 5.7 to 3.9 ^oC and the PCM has no supercooling phenomena prior to freezing. Fig. 2 shows that the melting point of the PCM lies between 5.3 to 8.4 ^oC. The freezing point and melting point of the PCM can meet the need of working temperature range of cooling storage air conditioning system during charging and discharging.

A typical DSC output curve of the PCM is shown in Figs. 3 and 4. The horizontal axis indicates temperature, and the vertical axis indicates heat flow rate. Fig. 3 shows that the PCM has only one freezing peak, onset of freezing temperature is 3.9^oC and the latent heat of solidification is 218.4 $kJkg^{-1}$. Fig. 4 shows that the PCM has only one melting peak, onset of melting temperature is 5.3^oC and the heat of fusion is 222.5 $kJkg^{-1}$. The specific heat of the PCM was also measured by DSC. The specific heat of the liquid PCM is 2.25 $kJkg^{-1 o}C^{-1}$, and the specific heat of the solid PCM is 2.01 $kJkg^{-1 o}C^{-1}$. The heat of fusion of this PCM is larger than that of most inorganic salt hydrates, and the phase change temperature of this PCM is higher than that of ice. Therefore, this PCM can be used in cooling storage air conditioning system.

The cooling storage material showed good thermal stability during sixty heating and cooling cycles. The freezing point of the PCM remained at the smaller change range in Fig. 5, showing that the phase change is reversible without degradation. The cycling will be continued in cooling storage air conditioning system.

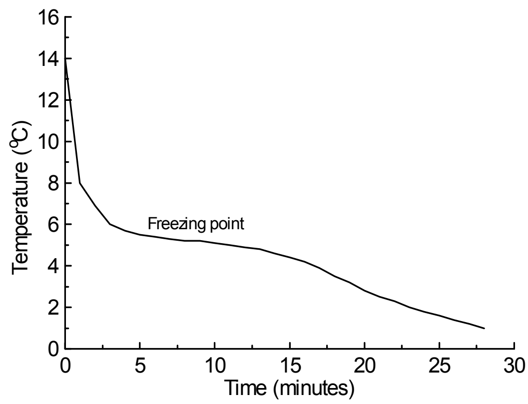

Fig. 1: Temperature change of the PCM during freezing

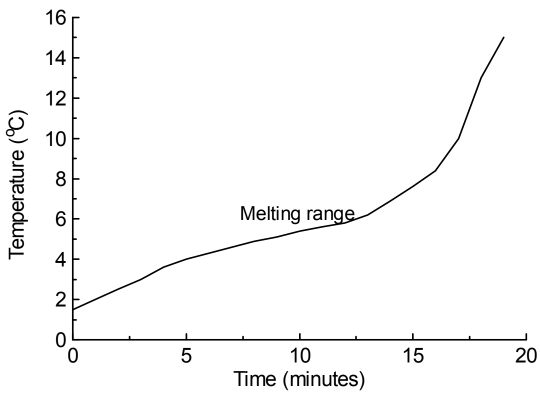

Fig. 2: Temperature change of the PCM during melting

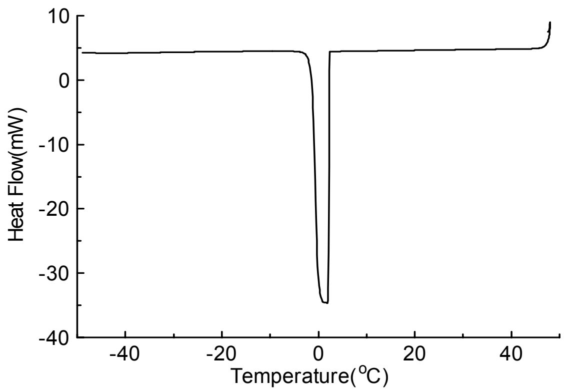

Fig. 3: A DSC output curve of the PCM during freezing

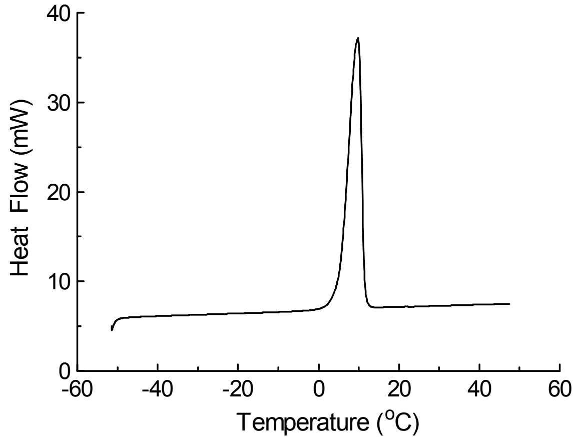

Fig. 4: A DSC output curve of the PCM during melting

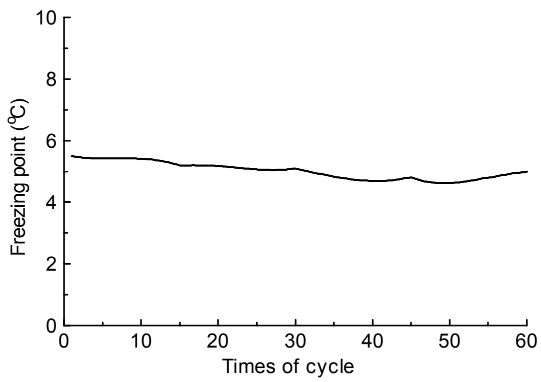

Fig. 5: The freezing point during a sequence of heating and cooling cycles

4. CONCLUSIONS

The phase change temperature and the heat of fusion of the PCM were obtained respectively by thermosensor measurements and DSC analysis. The freezing temperature of the investigated PCM lies between 5.7°C to 3.9 °C and the heat of fusion is 222.5 $kJkg^{-1}$.

The experimental results indicate that the PCM can be used in cool storage air conditioning system due to its availability in phase change temperature range and its reasonably high heat of fusion. Furthermore, it is able to melt congruently and freeze without supercooling. It also shows a good stability over a large number of heating and cooling cycles. This PCM is therefore an excellent candidate for cool storage air conditioning system.

ACKNOWLEDGEMENTS

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