

Investigation on Thermal Properties of Phase Change Materials for Cool Storage Air-Conditioning System

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Abstract: The thermal properties of phase change cool storage materials including freezing and melting point, freezing and melting latent heat during the phase change process are investigated. The cool storage material is composed of two kinds of phase change materials. In the thermal analysis, the Differential Scanning Calorimeter (DSC) was used to determine the latent heat of the phase change material (PCM), and the infrared spectra instrument was used to determine the structure change of the PCM. The melting latent heat of the investigated PCM is 118.996 kJ/kg, and melting onset point of the PCM is 6.399°C. The heat capacity of the PCM investigated is larger than that of ordinary salt hydrates, and melting point of the PCM is higher than that of ice. The results show that the new PCM can be considered as an efficient cool storage material for cool storage air conditioning system.

Keywords: thermal properties, phase change material, cool storage, air-conditioning

1. INTRODUCTION

Cool storage is considered one of most important advanced energy technologies and can play an important role in thermal applications, such as buildings, aircraft, solar energy system, heat recovery system, industrial processing and so on. The basic types of cool storage techniques may be classified as sensible heat storage and latent heat storage. Latent heat cool storage is a particularly attractive technique, since it provides a high energy storage density and has the capacity to store heat as latent heat of fusion at a constant temperature corresponding to the phase transition temperature of the phase change materials (PCMs). PCMs undergo solid-solid, liquid-gas, and solid-liquid phase transformations. Solid-liquid PCMs are useful because they store a relatively large quantity of heat over a narrow temperature range, without a corresponding large volume change.

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 properly cool storage air conditioning system can reduce operating costs, the size of the chilling equipment, provide back-up cooling capacity, and extend the capacity of a conventional air conditioning system.

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°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, 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. If PCMs are to be used for cooling storage air conditioning system, they should have a melting temperature of approximately 5~9°C.

In order to solve these problems, performance of all kinds of cool storage materials has been studied by some researchers. An emulsion of a mixture of alkane in water has been elaborated for thermal energy storage and transport by L.Royon and G.Guilfant^[1]. The measured temperature of fusion and crystallization is, respectively, 9.5°C and 3.9°C, which clearly show a supercooling phenomenon. The latent heat of the dispersed phase of the emulsion is 78.9J/g. The mixture of capric acid and lauric acid(C-L acid), with the respective mole composition of 65% and 35%, is a potential phase change material. Its melting point of 18.0°C however, is considered high for cooling application of thermal energy storage. The

thermophysical and heat transfer characteristics of the C-L acid with some organic additives are investigated [2]. The methyl salicylate in the C-L acid provided the most effective additive in the C-L acid. The capric-lauric acid and pentadecane combination with a melting point of 9.9 °C as phase change material for cooling applications is proposed [3]. The thermal characteristics of the combination of the C-L acid with pentadecane (CL:P) in different volume ratio are investigated employing the DSC analysis. Thermal characteristics of manganese (II) nitrate hexahydrate as a phase change material for cooling systems is investigated [4]. Experiments on the modulation of the melting point of manganese (II) nitrate hexahydrate and reduction of supercooling were made by dissolving small amounts of salts in the material.

The purpose of this study has been to determine the thermal properties of a new PCM for cool storage. The thermal properties of phase storage material including freezing and melting point, freezing and melting latent heat during the phase change process are investigated. In the analysis, the Differential Scanning Calorimeter (DSC) is used to determine the latent heat of the phase change material (PCM), and the infrared spectra instrument is used to determine the structure change of the PCM.

2. EXPERIMENTAL

2.1 The 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 5 °C/min from 30 °C to -30 °C, the heating rate was 5 °C/min from -30 °C to 30 °C. At first, the DSC cell containing a PCM sample was cooled to a lower temperature than the melting temperature of the sample. The 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 phase transition temperature and the latent heat of phase change were recorded during a heating scan.

2.2 The Structure Change of the PCM

The cool storage material is composed of two kinds of phase change materials. In order to determine molecular structure change of the PCM investigated, the infrared spectra instrument was

used to analyze the infrared spectra absorbance change of the PCM.

3. RESULTS AND DISCUSSION

The typical DSC output curves of the PCM A, B, C and D is shown in Figure 1, 2, 3 and 4, respectively. The horizontal axis indicates temperature, and the vertical axis indicates heat flow rate. The Figure 1 shows the PCM A onset of melting temperature is 44.206 °C and the melting latent heat is 181.927 kJ/kg, the onset of freezing temperature is 42.118 °C and the freezing latent heat is 180.398 kJ/kg. The Figure 2 shows the PCM B onset of melting temperature is 9.803 °C and the melting latent heat is 111.124 kJ/kg, the onset of freezing temperature is 3.867 °C and the freezing latent heat is 114.955 kJ/kg. The Figure 3 shows the PCM C onset of melting temperature is 1.142 °C and the melting latent heat is 111.492 kJ/kg, the onset of freezing temperature is -4.417 °C and the freezing latent heat is 112.017 kJ/kg. The Figure 4 shows the PCM D onset of melting temperature is 6.399 °C and the melting latent heat is 118.996 kJ/kg, the onset of freezing temperature is 5.008 °C and the freezing latent heat is 80.277 kJ/kg. The PCM A cannot meet requirement of cool storage air conditioning system since its melting temperature is very high. The melting temperature of the PCM B is a little higher than that of air conditioning system requirement (5~9 °C), therefore it can not be used in cool storage air conditioning system. The PCM C is composed of the PCM A and the PCM B in 25:75 mass ratio. The Figure 3 shows the freezing temperature of the PCM C is very low. The PCM D is composed of the PCM A and the PCM B in 40:60 mass ratio. The Figure 4 shows the PCM D can meet requirement of cool storage air conditioning system. The melting latent heat of the PCM D is larger than that of most inorganic salt hydrates (60~70 kJ/kg), and the phase change temperature of the PCM D is higher than that of ice (0 °C). Therefore, the PCM D can be used in cooling storage air conditioning system.

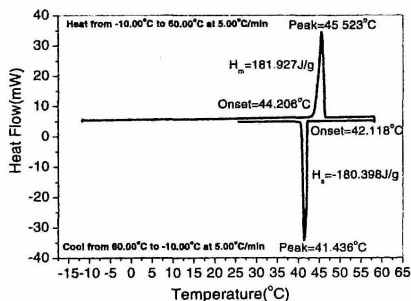


Figure 1: DSC output curve of the PCM A

The infrared spectra curve of the PCM A, B, C and D is shown in Figure 5, 6, 7 and 8, respectively. The Figure 5 and Figure 6 show the infrared spectra of the PCM A and B is the same. This indicates that the PCM A and B are the same kind of chemical substance. The Figure 7 and Figure 8 show the infrared spectra of the PCM C and D is the same as that of the PCM A and B. It could be concluded there are no significant changes in chemical bonding in the new cool storage PCM from the infrared spectra data. This indicates that the new PCM D has better stability in molecular structure. It is important for long use of cool storage material.

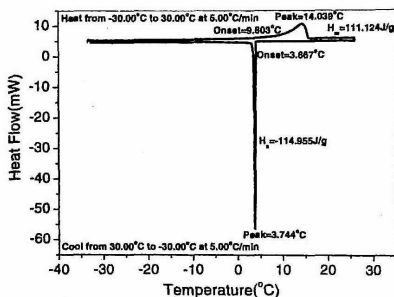


Figure 2: DSC output curve of the PCM B

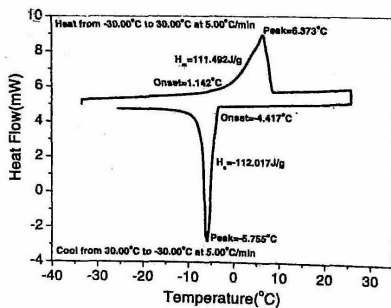


Figure 3: DSC output curve of the PCM C

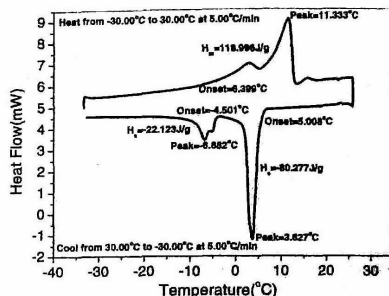


Figure 4: DSC output curve of the PCM D

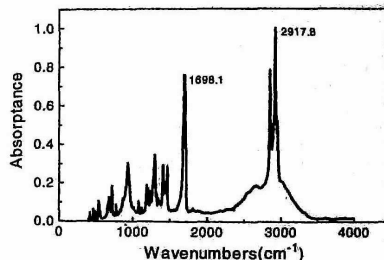


Figure 5: Infrared spectra curve of the PCM A

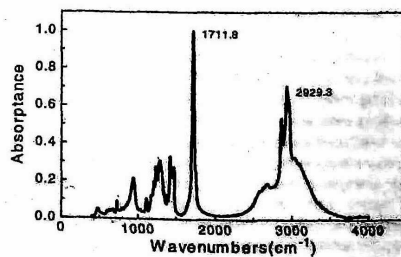


Figure 6: Infrared spectra curve of the PCM B

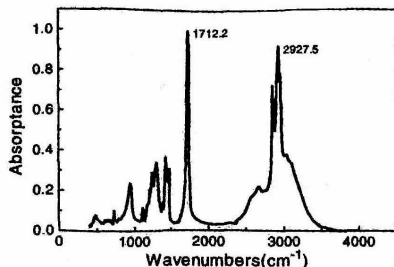


Figure 7: Infrared spectra curve of the PCM C

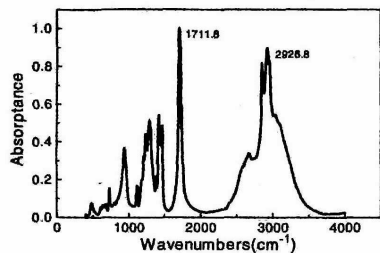


Figure8: Infrared spectra curve of the PCM D

4. CONCLUSION

The new cool storage material is composed of two kinds of phase change materials. The latent heat of phase change of the PCM was obtained by DSC analysis. The structure change of the PCM was analyzed through the infrared spectra instrument. The melting latent heat of the investigated PCM is 118.996 kJ/kg, and melting onset point of the PCM is

6.399°C. The heat capacity of the PCM is larger than that of salt hydrates, and melting point of the PCM is higher than that of ice. There are no significant changes in chemical bonding in the new cool storage phase change material from the infrared spectra data. This indicates that the new cool storage PCM has better stability in molecular structure. The results show that the new PCM can be considered as an efficient cool storage material for cool storage air conditioning system, due to its availability in phase change temperature range and its reasonably large latent heat of phase change.

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