Experimental study on thermal storage performance of binary mixtures of fatty acids

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Abstract. We selected five kinds of fatty acids including the capric acid, stearic acid, lauric acid, palmitic acid and myristic acid and mixed them to prepare 10 kinds of binary mixtures of fatty acids according to the predetermined proportion, tested the phase change temperature and latent heat of mixtures by differential scanning calorimetry (DSC). In order to find the fatty acid mixture which has suitable phase change temperature, the larger phase change latent heat and can be used for phase change wall. The results showed that the phase change temperature and latent heats of the binary mixtures of fatty acids decreased compared with the single component; The phase change temperature of the binary mixtures of fatty acids containing capric acid were lower, the range was roughly 20~30°C, and latent heat is large, which are ideal phase change materials for phase change wall energy storage; The phase change temperature of the binary mixtures consisting of other fatty acids were still high, didn’t meet the temperature requirements of the wall energy storage.

1. Introduction

The phase change material is added to the enclosure structure such as wall, roof or ground by proper method to form phase change enclosure structure. When the outside temperature rises, the temperature of the phase change material rises and melts after reaching the phase change point, then they can store the heat outside. When the external temperature is rised, the temperature of the phase change material rises to the freezing point, that is, releasing stored heat. Phase change material combines with ventilation, which can greatly reduce the air conditioning cooling load [1] in summer. In order to realize the energy storage and energy release of phase change in the appropriate condition and time, the phase change point of the phase change material is very important. According to the characteristics of summer climate in most cities, the phase change temperature of phase change material is 20~30°C at reasonable temperature [2].

The commonly used medium low temperature phase change materials mainly include fatty acids and paraffin. The advantage of fatty acids is that their latent heat of phase change is large, the volume change in phase change process is small, and it is easy to be fused with building materials. No supercooling phenomenon occurs during solidification, and the price is low. The phase change temperature of single fatty acid is above 30°C, mainly for medium and high temperature [3, 4] solar energy storage field. The phase change temperature range of single fatty acid does not accord with the temperature requirement of wall energy storage, but preparation of binary fatty acid mixture can reduce the phase change temperature. By adjusting the ratio, binary mixture systems of fatty acid with different phase change temperature were obtained. Zhang Xuelai et al. studied the mass ratio of lauric
acid (LA), capric acid (CA), tetradecyl alcohol (TA) and dodecane (DD) which was suitable for phase change material at 5-15 °C and the mass ratio is 27.1:28.5: 9.6:14.8[5] . Huang Xue et al. used ultrasonic method to prepare three fatty acid phase change materials which included capric acid, stearic acid and palmitic acid as raw materials and studied their thermal properties. They have analyzed the problems of low thermal conductivity and leakage in phase change materials at home and abroad, and put forward some feasible methods[6,7]. Wu Zimin et al. prepared microcapsules by situ polymerization, in which capric acid-palmitic acid was used as the core material and the urea formaldehyde resin as the wall material and characterized the thermal properties and chemical structure of the microcapsules [8]. Shang Jianli et al. prepared fatty acid /SiO2 composite phase change materials by sol-gel method and studied their thermal properties. They take fatty acids as phase change material, SiO2 as carrier material, deionized water and anhydrous alcohol as solvent[9]. Meng Duo et al. prepared the nano crystalline phase change materials by sol-gel method and measured its structure, property and thermal conductivity. They used capric acid-lauric acid as phase change material, and industrial water glass as the precursor of nano SiO2[10].

This paper made binary mixture by five kinds of fatty acids, tested the heat storage properties of them by using differential scanning calorimetry(DSC) and studied the change law of phase change temperature and latent heat of phase change in order to find the suitable binary mixture with suitable phase change temperature , large latent heat of phase change, and it is suitable for the wall.

2. Experimental process

2.1. Equipment and instruments

The experimental equipment and instruments include DSC (200PC) belongs to NETZSCH company, analytical balance, beaker, infrared lamp etc..

In the DSC test, liquid nitrogen was used to cool the gas, and the shielding gas and the purge gas were all pure nitrogen. The gas flow rates were respectively 65ml/min and 15ml/min . The range of temperature control in the process of experiments is -100°C to 150°C and it takes 8 °C/min heating rate to rise. DSC test results show that the starting point is the phase change temperature, and the area is latent heat of phase change.

2.2. Material properties

The materials used in the experiment were capric acid, stearic acid, palmitic acid, lauric acid and myristic acid from Beijing Reagent company. The heat storage properties of five kinds of fatty acids were tested by DSC, and the results were shown in Table 1.

| Experimental materials | phase change temperature (°C) | Latent heat of phase change (J/g) |
|------------------------|-------------------------------|----------------------------------|
| stearic acid           | 67.4                          | 239.9                            |
| lauric acid            | 42.8                          | 222.3                            |
| myristic acid          | 52.7                          | 217.6                            |
| palmitic acid          | 61.0                          | 241                              |
| capric acid            | 30.5                          | 151.1                            |

2.3. Sample preparation method

Advance to set the proportion of the quality ,weigh with analytical balance, and put into the container ,then heat by infrared irradiation. After melting, the mixture can be mixed evenly by stirring and shaking. The binary mixture is cooled and solidified in the air. Then the sample number is made. It
needs to take a small amount of sample which is placed in the aluminum crucible, and then put it down with capping machine to wait for use when the test experiment was carried out by using DSC.

2.4. Error analysis
The heating rate of DSC had an effect on the test results. Before the use of the instrument, the standard sample had been calibrated. The heating rate of the calibration experiment was 8℃/min, so the heating rate of the test was also 8℃/min, in order to improve the accuracy of the measurement.

3. Experimental results and analysis
The DSC test results for the binary mixture containing fatty acids are shown in figure 1~8.

Figure 1 shows that the regulation of phase change temperature of binary mixture containing capric acid changes with quality content of capric acid. The figure shows: after adding capric acid with low phase change temperature into myristic acid, palmitic acid, lauric acid, stearic acid, , the phase change temperature of the mixtures obviously fell, then changed to be gently, and finally rose slightly. When the mass ratio of capric acid accounts for 20% ~ 90% in the mixture, phase change temperature of binary mixture containing capric acid / myristic acid and capric acid / lauric acid does not change significantly between 20 to 30 ℃ and below the transition temperature of each single fatty acid. When the mass ratio of capric acid in the mixture is 30% - 90%, the phase change temperature of capric acid / palmitic acid and capric acid / stearic acid is between 20 and 30 ℃. The phase change temperature of the binary mixture of the above ratio meets the requirements of the wall.

Figure 2 shows that the regulation of the latent heat of phase change of binary mixture containing capric acid with the content of capric acid. The diagram shows that the latent heat of the binary mixture containing fatty acid is lower than that of the single component. With the increase of the content of capric acid, the latent heat of the phase change of the mixture tends to decrease. And the latent heat of the mixture is above 140J/g. The latent heat of the phase change is still large.

Figure 3 is the regulation of the phase change temperature of binary mixture containing lauric acid, palmitic acid, stearic acid and myristic acid with quality content of lauric acid. It is shown in the diagram that the phase change temperature of the mixture falls obviously first, then changes slightly, and then rises slightly. The phase change temperature of binary mixture of lauric acid and other three kinds of fatty acids is above 30℃. When the quality content of lauric acid is between 35%~85%, the
phase change temperature of the fatty acid binary mixture is relatively low. Its temperature range is between 30°C and 40°C and it can be used in the phase change floor energy storage.

Figure 4 is the regulation of the latent heat of phase change of binary mixture containing lauric acid and palmitic acid, stearic acid and myristic acid with the quality content of lauric acid. The figure shows: the latent heat of phase change of binary fatty acid mixture is lower than the latent heat of two kinds of single component. The latent heat of phase change of the mixture is above 160J/g. The latent heat of phase change has no obvious regulation with the change of component.

**Figure 3.** Phase change temperature of lauric acid mixture.

**Figure 4.** Latent heat of phase change of lauric acid mixture.

**Figure 5.** Phase change temperature of stearic acid mixture.

**Figure 6.** Latent heat of phase change of stearic acid mixture.
Figure 5 to figure 8 is the change regulation of the phase change temperature and the latent heat of the binary mixture with the component mass ratio. They are composed of three mixtures of stearic acid, myristic acid and palmitic acid. The phase change temperature of three mixtures containing stearic acid/palmitic acid, stearic acid/myristic acid and palmitic acid/myristic acid is between the change temperature of each component. The phase change temperature is higher, and they are all above 42°C. The latent heat of the mixture has no obvious change, and the latent heat of the phase change is lower than the latent heat of the single component.

In order to decrease the change temperature of fatty acids and meet the requirements of the use of phase change wall, we prepared binary fatty acid mixture to achieve the purpose of reducing the phase change temperature, but at the same time, mixing different fatty acids also reduced the latent heat of phase change.

4. Conclusions
(1) The phase change temperature of single component fatty acid is higher, which cannot meet the energy storage requirements of phase change wall. By mixing different kinds of fatty acids, the phase change temperature can be decreased, and the binary mixture with different phase change temperature can be obtained to meet the application requirements.

(2) The latent heat of phase change of binary fatty acid mixture is lower than that of single component fatty acid, but a large latent heat can still be attained at some mixing ratios.

(3) The phase change temperature of binary fatty acid mixture containing capric acid is mostly between 20°C and 30°C. And the latent heat value of phase change is larger. They can be used for wall energy storage.

(4) The phase change temperature of binary mixture containing lauric acid/stearic acid, lauric acid/palmitic acid and lauric acid/myristic acid mixture is mostly at 30°C to 40°C. The phase change temperature of binary mixture prepared from stearic acid, myristic acid and palmitic acid is above 42°C. The latent heat value of the phase change is higher. They do not meet the requirements of the wall energy storage, but they can be used for the energy storage of the phase change floor.
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