Research on proportion and thermal storage property of the shape stabilized fatty acid

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Abstract. In the paper, four kinds of fatty acid binary mixtures and liquid paraffin and lauric acid binary mixture were prepared. Fatty acid binary mixtures were made of capric acid and myristic acid, lauric acid, palmitic acid and stearic acid. High-density polyethylene was used as supporting material to prepare the shape-stabilized phase change materials. The 25 kinds of shape stabilized phase change material samples were prepared by adding fatty acid mixtures to high density polyethylene according to the mass addition ratios of 50%, 60%, 70%, 80% and 90%. The phase change temperatures, the phase change latent heats, the uniformity and stability of the 25 kinds of shape-stabilized phase change materials were studied experimentally by using differential scanning calorimeter (DSC), the aim was to find suitable phase change materials for phase change wall energy storage. The results showed that the phase change temperatures and the phase change latent heats were related to the components and contents of fatty acids. The optimum content of fatty acid in the shape stabilized phase change materials was 70%. The homogeneity and stability of the shape stabilized fatty acid phase change materials were better, and they are suitable for use in phase change wall. The results in this paper can provide references and basis for the application of fatty acid phase change materials in the wall.

1. Introduction
In order to prevent liquid leakage, the solid-liquid phase change material needs to be encapsulated by the container in the application. Therefore, the thermal resistance between the phase change material (PCM) and the heat transfer medium is increased, the packaging cost is increased, and the heat transfer efficiency is reduced. The shape stabilized phase change materials can be prepared by mixing the solid-liquid phase change material and the supporting material. In the shape stabilized phase change materials, the proportion of PCM and supporting material is of great significance for the application of shape stabilized phase change materials in the field of practical energy storage. Fatty acids have been widely used in the field of energy storage. They have large phase change latent heat, small volume change during the phase change process, low price, and no supercooling during the solidification. They are easy fusion with building materials. According to a certain proportion, the stereotyped phase change fatty acids are made by mixing binary or multiple mixtures with polymer support materials, and then fill them in the wall by the appropriate way. It is the ideal choice for fatty acid in the application field of wall energy storage.

Ahmet et al. studied the heat transfer process of PCM, such as fatty acid and applied them to solar energy storage [1]. Sari, Py.X and Min.X et al. studied the thermal storage properties of shape...
stabilized fatty acids and their additives materials [2]. Fu Lujun et al. studied the physical properties of silica as a shape stabilized material and binary eutectic fatty acids mixture [3]. Zhang Lin et al. studied the thermal storage properties of the binary mixture of fatty acids and prepared the shape stabilized fatty acids to study their thermal and mechanical properties [4]. Liang Chen et al. mixed the paraffin with high density polyethylene to study its application in the phase change wall [5]. Professor Zhang Yinping of Tsinghua University studied the application of phase change and chemical reaction in building energy efficiency and comfort [6]. Song Xiulong et al. used the diatomite to adsorb n-octadecane, and prepared diatomite/n-octadecane composite PCM with high latent heat and stable morphology [7]. Huang Xue et al. prepared and studied the composite PCM mixed by myristic acid, capric acid, stearic acid ternary mixtures and organic modified montmorillonite (OMMT) [8]; Wang Gang et al. prepared and studied the composite PCMs of KNO₃, LiNO₃, Ca(NO₃)₂ eutectic salt and expanded graphite powder [9].

In this paper, five kinds of fatty acid phase change materials were selected, and the phase change temperature, phase change latent heat, uniformity and stability of the phase change materials prepared with high density polyethylene and the five kinds of fatty acid PCMs were studied. The feasibility of applying them to the wall is verified, which provides the basis for the preparation, experimental study of the phase change wall, and the application of the fatty acid PCM in the wall.

2. Experimental method

2.1. Experimental equipment

The experimental equipments and instruments include differential scanning calorimetry (DSC), analytical balance, beaker, infrared thermometer (model HT6885), warm air blower (model HP2009), stirrer, electric furnace, etc..

DSC is the 200PC type calorimeter of NETZSCH. Liquid nitrogen is used for cooling. Both the protective gas and the purge gas are of high purity nitrogen. The protective gas velocity is 60ml/min, and the purge gas velocity is 20ml/min. The control range of temperature in the process of experiments is between -90°C to 150 °C. The sample is cooled to a lower temperature by liquid nitrogen, and then heat up to observe the melting process of the materials. The heating rate is 15 °C/min.

2.2. Experimental materials and samples

The experimental materials are capric acid (CA), stearic acid(SA), palmitic acid(PA), lauric acid(LA), myristic acid(MA), liquid paraffin(LP), and high density polyethylene(HDPE). All of them are Beijing reagent company.

In the experiment, according to the mass ratio of fatty acid mixture preparation: CA-MA (30% - 70%), CA-LA (20% -80%), CA-PA (80% -20%), CA-SA(70% -30%), LP-LA (60% -40%), 25 kinds of PCM samples were prepared by mixing each phase change material with 50%, 60%, 70%, 80%, 90% mass addition ratio and high density polyethylene. The samples number and mass percent content of the phase change fatty acid materials in the sample are shown in table 1.

| Number | Content of CA-MA | Number | Content of CA-LA | Number | Content of CA-PA | Number | Content of CA-SA | Number | Content of LP-LA |
|--------|------------------|--------|------------------|--------|------------------|--------|------------------|--------|------------------|
| 1      | 50%              | 6      | 50%              | 11     | 50%              | 16     | 50%              | 21     | 50%              |
| 2      | 60%              | 7      | 60%              | 12     | 60%              | 17     | 60%              | 22     | 60%              |
| 3      | 70%              | 8      | 70%              | 13     | 70%              | 18     | 70%              | 23     | 70%              |
| 4      | 80%              | 9      | 80%              | 14     | 80%              | 19     | 80%              | 24     | 80%              |
| 5      | 90%              | 10     | 90%              | 15     | 90%              | 20     | 90%              | 25     | 90%              |
3. Experimental results and analysis

3.1. Thermal properties of shape stabilized phase change materials

The phase change temperature and phase change latent heat of 25 kinds of shape stabilized phase change materials were measured by DSC. The reasonable ratio of phase change materials with suitable phase change temperature and phase change large latent heat was found. Each sample was sampled 3 times and averaged, and the test results were shown in figure 1 and figure 2.

![Figure 1. Phase change temperature of shape-stabilized PCM.](image1)

![Figure 2. Phase change latent heat of shape-stabilized PCM.](image2)

It can be seen from figure 1 that the phase change temperature of the shape stabilized phase change materials is slightly increased with the increase of the proportion of phase change material. When the content of fatty acid increased from 50% to 90%, the phase change temperature of the shape stabilized phase change fatty acid increased to about 10%.

It can be seen from figure 2 that phase change the latent heat of the shape stabilized phase change fatty acid increases approximately and linearly with the increase of fatty acid content. When the content of fatty acid decreased from 90% to 50%, the phase change latent heat of the shape stabilized phase change fatty acid decreased to about 50%.

3.2. The optimum ratio of shape stabilized phase change fatty acid

The higher the content of fatty acids in the shape stabilized phase change materials, the greater the phase change latent heat of the materials and the better the heat storage effect. But if the fatty acids content is too much, the high density polyethylene will not be able to support the encapsulation, which makes it easy to appear leaking the phase change materials. Therefore, it is particularly important to study the optimum proportion of phase change materials in shape stabilized phase change materials, which can ensure the best thermal storage effect and ensure there is no leakage.

In this experiment, each type of shape stabilized phase change material was heated by warm air blower, and the surface temperature change of shape stabilized phase change materials was measured by infrared thermometer. When the surface temperature reached or exceed the phase change temperature, the change of the shape stabilized phase change material needs to be observed. The experimental results shown that the content of fatty acids in the shape stabilized phase change materials was between 50% to 70%. When the temperature increased to the phase change temperature, the surface of the shape stabilized phase change materials has no liquid precipitation, and the PCMs has good encapsulation effect. When the content of fatty acid reached 80%, the fine liquid is precipitated but not obvious, and the encapsulation effect was better. When the content of fatty acid reached 90%, obvious liquid exudation was found, and the encapsulation effect of PCMs was not good. The morphology of shape stablied phase change materials with different fatty acids content after heating is shown in figure 3.
3.3. Sample uniformity
Two kinds of shape stabilized phase change material samples were selected including CA-MA(30% - 70%) and LP-LA (60% - 40%). The mass ratio of PCM and supporting material is 7:3 in order to ensure the best sealing effect. A small amount of material was taken from 4 different parts of the two samples. And the phase change temperature and phase change latent heat were measured by DSC. The experimental results are shown in figure 4 and figure 5.

3.4. Stability of sample
Take above 2 kinds of samples, and heat them in the furnace at 40°C. Then take them out and put them in the environment of 20 °C. Repeated absorption and exothermic experiments were carried out for 10 times, 20 times, 30 times, 50 times and 100 times, and studied the stability of the material thermal properties. The experimental results are shown in figure 6 and figure 7.
The results show that the phase change temperature of the 2 kinds of shape stabilized materials was basically unchanged after many times of absorption and release heating, the phase change latent heat is very small after repeated absorption and release heating. The stability of the shape stabilized phase change material is better.

4. Conclusions

(1) According to the figure of the phase change temperature and latent heat of the PCM with different content, we can see that the phase change latent heat of the shape stabilized fatty acids change approximately and linearly with the content of fatty acids. When the fatty acids content was decreased from 90% to 50%, the phase change latent heat of the fatty acids was reduced about 50%. The phase change temperature of the shape stabilized fatty acids increased with the increase of the fatty acids content. When the fatty acids content increased from 50% to 90%, the phase change temperature of the shape stabilized fatty acids increased by about 10%.

(2) It can be obtained from the packaging effect experiment of shape-stabilized phase change materials. When the content of fatty acids in the phase change material is 50%~70%, the phase change material encapsulation effect is very good. At the same time, the optimum content of phase change materials in the setting fatty acid is 70% considering the heat storage requirement.

(3) The phase change materials are uniformly distributed in the shape stabilized fatty acid. After the 100 endothermic exothermic cycle, the change of phase change temperature and phase change latent heat of phase change is small, and shape stabilized fatty acid is good.

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