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Study on Phase Change Energy Storage Materials in Building Energy Saving

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In order to prepare porous matrix phase change energy storage materials suitable for building energy saving, the fatty acids, such as stearic acid, lauric acid and capric acid, which are easy to be obtained, are selected as raw materials for the experiment. Three eutectic composite phase change materials with different melting points are prepared to meet the needs of different summer temperatures. The latent heat of capric acid/stearic acid composite is 149.3J/g, and the latent heat of capric acid/lauric acid composite is 126.7J/g, and the latent heat of lauric acid / stearic acid is 161.9J/g. In order to test the stability of phase change process of phase change materials, the experiment of heat storage and release is carried out at 15°C to 40°C. The results show that the stability of phase change materials is good. The expanded perlite with porous media is used as carrier and is combined with the phase change material by direct immersion method. The scanning electron microscope shows that the phase change material could be filled with the pores of expanded perlite. The test shows that latent heat of expanded perlite incorporated with three phase change materials is 105.5J/g, 74.41J/g and 96.2J/g.

1. Introduction

With the development of the world economy, the contradiction between supply and demand of energy is becoming more and more prominent. It is very necessary to study the energy saving technology while the conventional energy sources and new alternative energy sources are developed (Manish and Jyotirmay, 2013). As a part of energy saving technology, energy storage technology has great potential in the rational allocation and utilization of energy resources. There are two kinds of energy storage methods: sensible heat storage and latent heat storage. The energy storage technology using material phase change latent heat has attracted much attention due to its advantages of large energy storage density and stable energy storage temperature (Pradyumna et al., 2014). At present, the commonly used phase change energy storage materials mainly include two categories: inorganic and organic (Min, 2013). Most inorganic phase change energy storage materials are corrosive. Moreover, in the process of phase transition, it has the defects of supercooling and phase separation, which affects its energy storage capacity. However, the corrosion resistance of organic phase change energy storage materials is small, and there is almost no phase separation in the phase transition process (Sharma et al., 2015). The chemical properties of the material are stable, and it is also cheap. (Zhang et al., 2013). Organic phase change energy storage materials generally have the disadvantage of low thermal conductivity, resulting in poor heat transfer performance and low energy storage efficiency in the application of energy storage systems, thereby reducing the efficiency of the system (Ji et al., 2014). Therefore, the development of composite phase change energy storage materials with high energy storage density and stable performance has become a hot and difficult area in this field.

Phase change materials are the key to phase change energy storage technology. Therefore, the selection and preparation of phase change materials is the key part of the research. Many organic and inorganic compounds can undergo phase transitions in the required temperature range, giving off heat. However, not all of these materials can be used as phase change energy storage materials, and phase change materials must have good thermal, dynamic, economic and chemical properties (Jamekhorshid et al., 2014). Single compound or phase change material is difficult to meet all of the above requirements, and the actual application requires a certain choice of the above requirements. Phase change materials need to be improved, such as adding a

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certain number of additives in phase change materials to improve their thermal conductivity and reduce undercooling. In addition, two or more materials can be compounded to prepare the phase change energy storage materials meeting the requirements of the phase transition temperature (Kinga and Krzysztof, 2014). Combined with different research methods, the application value of lightweight building materials and phase change materials is analyzed. From the viewpoint of economy, practicability and environmental protection, a variety of phase change thermal storage materials with phase transition temperature range were developed to meet the requirements of temperature in different regions

2. Method

2.1 Experimental raw materials selection and instrument

Organic fatty acid is selected as raw materials. The phenomena of supercooling and phase segregation are not observed in organic phase change materials. The material has very little corrosive and stable chemical properties without toxicity (Rakesh et al., 2014). Fatty acids can be extracted directly from animals and plants. It is a renewable material with a wide range of sources and cheaper prices (Tumirah et al., 2014).

The expanded perlite is formed by the vaporization of the internal moisture of perlite ore at high temperature. It expands the ore particles in the molten state and forms a porous white substance with honeycomb like surface (Ronald et al., 2014). As lightweight building materials, expanded perlite is commonly used in thermal insulation. The raw material is rich and easy to prepare, and the price is low. However, one of the disadvantages of expanded perlite is its strong water absorption, and it is easy to absorb water when used, which makes the insulation performance greatly reduced. The composite building material made of porous structure and phase change material can not only have the effect of energy storage and heat insulation, but also be economical and easy to obtain (Abdelwaheb et al., 2014). Based on these advantages, the expanded perlite is used as matrix to prepare composite materials with energy storage function.

Capric acid, purity≥98.5%, Sinopharm Chemical Reagent Co., Ltd.; Lauric acid, purity≥98.5%, Sinopharm Chemical Reagent Co., Ltd.; Stearic acid, purity≥98.5%, Chongqing Maoye Chemical Reagent Co., Ltd.; Expanded perlite, particle equivalent diameter dp=1.1mm, permeability k=97.5×10-9; Differential scanning calorimeter, NETZSCH Gerätebau GmbH; DSC special lamination machine, NETZSCH Gerätebau GmbH.

2.2 Experiment process

First, the binary material is matched. The raw materials A and B are respectively weighed by electronic balance, and the samples were made according to the proportion of 10 percentage points (Sayanthan et al., 2015). Samples of different proportions were melted and mixed in different beaker. About 10 mg liquid mixed material is placed in a DSC crucible and a sample is prepared by a lamination machine (Lee et al., 2015). The samples are then placed in DSC for measurement, and each sample is prepared for three measurements. If the difference between the first two test results is small, then the third can be unexpected, if the difference is larger, then the third measurement needs to be increased. It is necessary to find the matching interval of the eutectic melting point of the two materials, and then reduce the proportion to 2 percentage points in this interval (Qi et al., 2014). The test is carried out according to the above method until the ratio of the two materials to the eutectic point was found, that is, the mass percentage.

The direct immersion method is used in the experiment of phase change material and expanded perlite. First of all, the phase change material melted into liquid is placed in a big beaker, then the expanded perlite which has been dried for 24 hours (Dan et al., 2014) has been put into it and stirred evenly. Experiments should not only ensure that liquid phase change materials can submerge perlite, but also ensure that the immersion time is 72 hours (He et al., 2014). This ensures that porous expanded perlite absorbs liquid phase change materials sufficiently.

2.3 Sample detection method

DSC thermal analysis test. Main technical parameters of DSC equipment: The test range of temperature is -150°C ~+600°C; Equipment sensitivity is 3μV/mW; The linearity of the baseline is 0.5mW; Heat range is ±700mW; Heating rate is 0.1 ~99.9K/min; Cooling mode adopts liquid nitrogen; The flow of sweeping gas is 20ml/min; The flow of protective gas is 60ml/min; Heating rate is 5K/min; Temperature setting range is 0°C ~90°C.

Field emission scanning electron microscopy (SEM) is used to observe and analyze the morphology of porous expanded perlite samples prepared under different conditions. The lithium electrode is selected as the counter electrode for charge-discharge test of constant current. The charge discharge interval is 0.01~3.0V, and the time interval is 5min. The current density of the constant current test is 100mAg-1, and the current density is 100~2000mAg-1 (Xu and Li, 2013). The scan voltage range of cyclic voltammetry is 0.0~3.0V, the scanning rate is 0.1mV/s, and the test temperature is 30°C

3. Analysis of experimental results

3.1 Experimental test of phase change materials for energy storage

Figure 1, Figure 2 and Figure 3 are the DSC curves when the composite material reaches the eutectic point. As shown in the figure, the latent heat of the capric acid / lauric acid eutectic composite is 126.7J/g, and the phase change temperature is 17.7°C. The latent heat of the capric acid /stearic acid eutectic composite is 149.3J/g, and the phase change temperature is 18.6°C The latent heat of the lauric acid / stearic acid eutectic composite is 161.9J/g, and the phase change temperature is 30°C The first two kinds of phase change materials are more suitable for areas with larger diurnal temperature difference. The latter phase transition material is suitable for regions with higher temperature in summer because of its relatively high phase transition temperature (Adeel, et al., 2013). Compared with single material, the latent heat of phase change of eutectic materials composed of the above two materials is reduced.

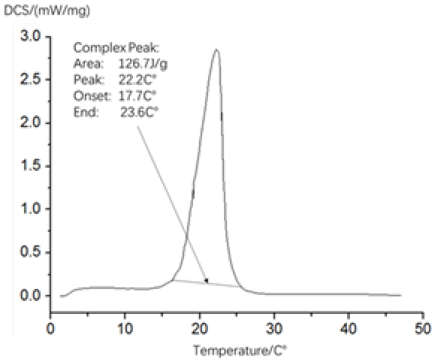

Figure 1: The DSC curve of CA/LA cotectic mixture

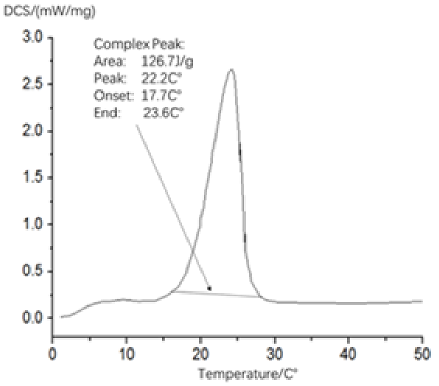

Figure 2: The DSC curve of CA/SA eutectic mixture

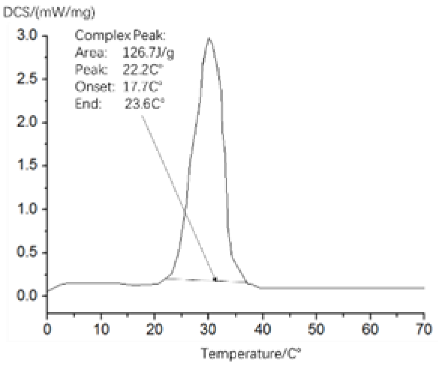

Figure 3: The DSC curve of LA/SA eutectic mixture

3.2 Experimental study on the combination of phase change material and expanded perlite

The results of scanning electron microscope are shown in figure 4. Figure 4(a) is the SEM photograph before the fusion of expanded perlite and phase change material. Figure (b)-(d) are the SEM photograph after the fusion of expanded perlite and phase change material. It can be seen from the figure(a) that the expanded perlite has obvious porous structure. After 72 hours immersion in the phase change material, figure (b), (c), and (d) show that the pores of expanded perlite have been filled with phase change material, and there is no leakage of phase change material.

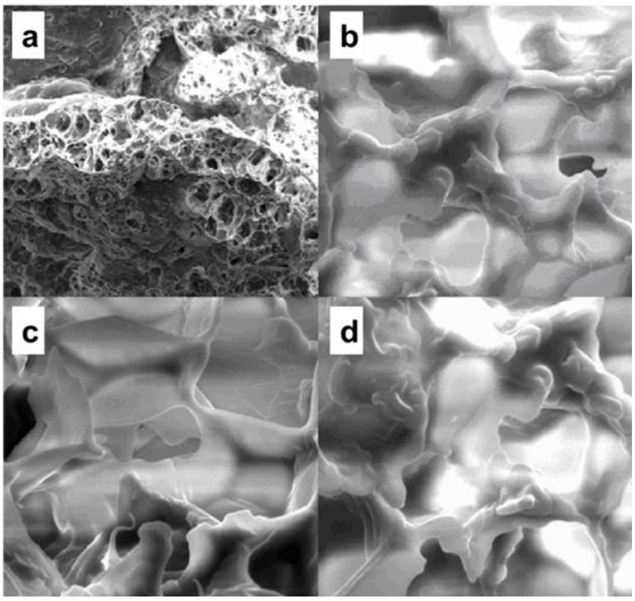

Figure 4: The SEM images of EP(a) and EP/PCM (b, c, d)

Differential scanning calorimeter (DSC) is used to test expanded perlite and three kinds of expanded perlite with phase change materials. As shown in figure 5, it shows that the heat capacity of pure expanded perlite is 1.1J/g.K (40 C). As shown in table 1, compared with pure eutectic phase change materials, the phase change temperature of expanded perlite incorporating phase change materials increases slightly. Compared with pure expanded perlite, it can be known that the specific heat of the three materials is increased by about 80%. When the phase change material in expanded perlite melts, the vapor pressure increases, causing the melting point and phase transition temperature to rise (Yeliz, et al., 2014). The latent heat of phase transformation is about 60% of that of eutectic phase change material.

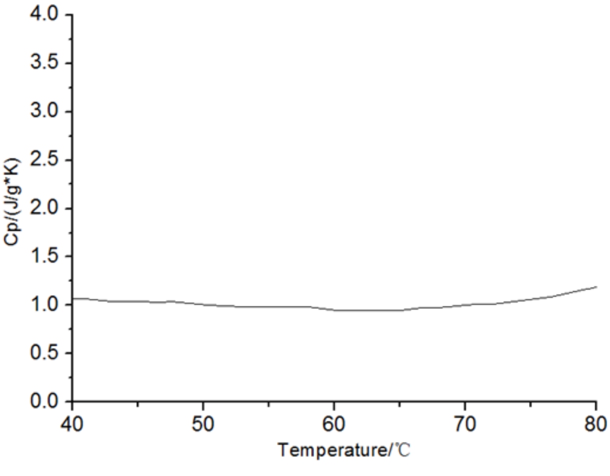

Figure 5: The specific heat curve of EP

Table 1: Comparison result between PCM and PCM/EP

PCM	Latent heat(J/g)	Melting point(°C)	PCM/EP phase change latent heat(J/g)	PCM/EP phase change temperature (°C)	PCM/EP constant pressure specific heat (J/gK, 40°C)
CA/LA	126.7	17.7	74.41	17.9	1.7
LA/SA	161.9	30.9	105.5	31	2.1
CA/SA	149.3	18.6	96.2	19.1	1.8

4. Conclusion

Firstly, the screening methods of phase change materials are described in this paper, and then the selected materials are compounded. The fatty acids, such as capric acid, lauric acid and stearic acid, are chosen as raw materials. The samples are tested by differential scanning calorimetry (DSC), and the eutectic point of the 3 composites is found. The mass fraction is the eutectic materials with 65% capric acid and 35% lauric acid, the eutectic materials with 80% capric acid and 20% stearic acid, the eutectic materials with 80% capric acid and 20% stearic acid. At the same time, the phase transition temperature and latent heat of phase change are tested. Then, several lightweight composite materials are prepared by choosing lightweight building materials and expanded perlite as the carrier of phase change materials. The properties of lightweight materials are tested respectively, while the latent heat, phase transition temperature and specific heat of constant pressure of porous materials with phase change materials are obtained. The test results show that the thermal storage capacity of the energy storage material is larger.

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