Technical note

Eutectic mixtures of capric acid and lauric acid applied in building wallboards for heat energy storage

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Abstract

Capric acid (CA) and lauric acid (LA), as phase change materials (PCM), can be applied for energy storage in low temperature. The phase transition temperature and values of latent heat of eutectic mixtures of CA and LA are suitable for being incorporated with building materials to form phase change wallboards used for building energy storage. 120, 240 and 360 accelerated thermal cycle tests were conducted to study the changes in latent heat of fusion and melting temperature of phase change wallboards combined with the eutectic mixtures of CA and LA. Differential scanning calorimetry (DSC) tested the transition temperature and latent heat. The results showed that the melting temperature and latent heat of these phase change wallboards with eutectic mixtures have not obvious variations after repeated 360 thermal cycles, which proved that these phase change wallboards have good thermal stability for melting temperature and variations in latent heat of fusion for long time application. Therefore, they can be used for latent heat storage in the field of building energy conservation.

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1. Introduction

Fatty acids, as PCM for the energy storage, are preferred due to their large latent heat, the characteristic of constant temperature in the course of absorbing or releasing energy and low cost. The combination of PCM and building materials to form phase change wallboards can shift redundant heat in summer and supply insufficient energy in winter through latent heat storage of PCM, an effective way to reduce energy consumption and the cost of HVAC system. The application of latent heat storage material in phase change wallboard for energy storage depends on the life, invariable phase transition temperature and values of latent heat of PCM during the time of phase transition cycles [1–4].

Fatty acids have superior properties over many PCM such as melting congruency, good chemical stability and non-toxicity. More important characteristics are their smaller volume change during phase transition and high latent heat of fusion per unit mass and suitable melting temperature range. On the other hand, the compatibility of construction material over a long period application is very important criteria for successful heat storage applications. CA and LA, as PCM for low temperature latent heat storage with their low carbon chains, can be applied in building wallboards for energy storage [5–9].

PCM in the phase change wallboards undergoes at least one phase transition cycle in a day. Repeated melt/freeze cycles test conducted with a hot plate or similar system is called the accelerated thermal cycle test. Sharma et al. [10] conducted accelerated thermal cycle tests of acetamide, stearic acid and paraffin wax for solar thermal latent heat storage applications. The results showed that no regular degradation happened in their melting points during repeated 1500 thermal cycles. Sari and Kaygusuz [11] analyzed the thermal characters of stearic acid, palmitic acid, myristic acid and lauric acid after 40, 410, 700 and 910 phase transition cycles. A noticeable deviation was detected during the solidification with increasing phase transition number. Sari et al. [12] measured the melting temperatures and the latent heats of fusion of the some fatty acids’ eutectic mixtures after 0, 90, 180 and 360 accelerated test cycles. The changes in the melting temperatures of the tested PCM after 360 melt/freeze cycles were in a reasonable level for a PCM, which will be used in a latent heat energy storage system.
2. Materials and methods

2.1. PCM

CA and LA were the production of Shanghai Chemical Reagent Corporation, China Medicine Group. Thermal characteristics of CA, LA and the mixtures of different proportion were tested by DSC in Changchun Institute of Applied Chemistry of Chinese Academy Sciences. The testing instrument was DSC7 series of Thermal Analysis System produces by U.S.A. PERKIN ELMER Company. Figs. 1 and 2 showed the DSC curves of CA and LA.

The melting temperature of CA and LA were 30.638 °C and 42.906 °C, respectively. The latent heat were 155.457 J/g and 175.832 J/g, which proved that both had large latent heat and were adapt to being applied for energy storage. After mixing CA and LA with certain proportion, if the mixture had large latent heat and suitable transition temperature in the range of indoor comfortable temperature, it could be applied for heat storage as PCM in phase change wallboards.

2.2. Phase change wallboards

There are some building materials such as gypsum, plasterboard, cements board which can be combined with PCM. After analyzing and comparing, it is found that gypsum is porous, in which the 40% volume is the air vent and has good absorbing ability to make PCM absorbed easily. Additionally, gypsum is light, cheap, conveniently and simply constructed and can insulate against sound and heat. Thus, Mount Tai gypsum incorporated with PCM served as phase change wallboards in this work. Phase change wallboards samples with the dimensions of 150 mm × 150 mm × 9.5 mm were formed by soaking the gypsum in the mixtures of CA and LA liquids for about 6–10 min. The mixtures absorbed in the gypsum were about the 26% of total weight. The density of phase change wallboards is 1007 ± 26 kg/m³.

2.3. Accelerated thermal cycle test

Accelerated thermal cycle experiments had been conducted to study the changes in melting temperature and latent heat of fusion of phase change wallboards after repeated numbers of phase transition cycles. The experimental equipment consisted of an electric hot plate with a temperature controller. Phase change wallboards were put in a stainless steel container with a lid [10]. Wallboards were heated above the melting temperature and then cooled in a refrigeration plant. The procedure was performed consecutively until the number of thermal cycles would be 120, 240 and 360. DSC analysis after the number of melt/freeze test cycles was used to measure the melting temperatures and the latent heat of fusion of phase change wallboards.

3. Results and discussions

3.1. Eutectic model

The transition temperature of both CA and LA exceed the indoor comfortable temperature. Therefore, only after mixing them, the transition temperature of mixtures can possibly be in the range we require. The mixing process is regarded as the ideal solution model and the transition temperature of mixture is always lower than that of any of the pure compounds. According to Schroder’s equation: Eq. (1), eutectic transition temperature of mixtures of CA and LA can be calculated.

\[
\ln x_A = -\frac{\Delta H_A}{R} \left( \frac{1}{T} - \frac{1}{T_f} \right)
\]

(1)

where \(x_A\) and \(\Delta H_A\) are the molar fraction and latent heat of fusion of compound A, respectively. \(T\) and \(T_f\) are the melting
temperature values of the mixture and compound A, respectively. \( R \) is the gas factor.

By calculation, the eutectic transition temperature of mixtures of CA and LA was 19.6 °C. The ratio of CA to LA was 65% to 35% approximately.

Fig. 3 showed the melting temperature of the binary systems of CA and LA, which were obtained by DSC. The melting temperature of CA was decreased by the addition of LA to CA. In the same way, the melting point of LA was decreased by the addition of CA to LA. By DSC analysis, when the proportion of CA to LA in the mixture was about 65.12% to 34.88%, both components melted simultaneously at a constant temperature of 19.67 °C known as the eutectic transition temperature. It was consistent with the calculation value. Such behavior may result from a molecular rearrangement in the solid phase at the eutectic mixture ratio. Fig. 4 summarized the latent heat of fusion and phase transition temperature measured by DSC for the solid and liquid phases of the CA–LA eutectic mixture.

The eutectic transition temperature of CA and LA was 19.67 °C, approximately equal to the calculation value. The latent heat was 126.562 J/g. The eutectic transition temperature of CA and LA was in the range of indoor comfortable temperature, which proved that the eutectic mixtures could be applied in the building materials for heat and cold storage in winter and summer to decrease the load of HVAC system.

3.2. Thermal properties of phase change wallboards incorporated in eutectic mixtures

The specific heat values of phase change wallboards and gypsum were tested by DSC. Fig. 5 shows the variation of specific heat in the course of solid–liquid phase transition. When the phase transition happened, \( C_p \) of phase change wallboards increased greatly. But, the value of gypsum kept constant. Therefore, compared with specific heat value of gypsum, phase change wallboards have higher heat storage ability. The thermal conductivity of these phase change wallboards is 0.21 W/m²·°C, higher than the 0.17 W/m²·°C of gypsum.
These phase change wallboards decreased about 0.8°C after 360 cycles. The results proved that the melting temperature of 120 cycles, \( C_0 \) of CA–LA eutectic mixtures, the variation of latent heat was from 0.755% (after 120 cycles) to 0.822% (after 360 cycles). The results meant that the latent heat variation of latent heat was from 0.49% (after 360 cycles) to 0.868% (after 240 cycles) and 0.822% (after 360 cycles). Therefore, the application of eutectic mixtures of CA and LA in the indoor comfort temperature range. The melting latent heat was 35.239 J/g. Compared with the eutectic transition temperature of CA and LA, the variation of melting temperature was little.

Phase change wallboards incorporated in eutectic mixtures of CA and LA after 120, 240, 360 phase transition cycles were tested by DSC. Figs. 7–9 showed the DSC curves, respectively.

The measured melting temperatures and the latent heats of fusion of the phase change wallboards incorporated in CA–LA eutectic mixtures after 0, 120, 240 and 360 accelerated test cycles were given in Table 1.

As shown in Table 1 and in Figs. 7–9, the melting temperature of phase change wallboards varied \(-0.822^\circ \text{C}\) after 120 cycles, \(-0.868^\circ \text{C}\) after 240 cycles and \(-0.755^\circ \text{C}\) after 360 cycles. The results proved that the melting temperature of these phase change wallboards decreased about 0.8 °C after 120 repeated cycles. Further, these results indicated that the change in the melting temperatures of phase change wallboards did not regularly vary with increasing numbers of thermal cycles and vary little during 360 transition cycles. Also, it can be observed from Table 1 and in Figs. 7–9 that, for the phase change wallboards incorporated in CA–LA eutectic mixtures, the variation of latent heat was from \(-0.49\%\) (after 360 cycles) to 2.26% (after 120 cycles). The results meant that the latent heat of fusion of the phase change wallboards did not decrease with increasing numbers of thermal cycles. Moreover, the fluctuation of latent heat values was not obvious. Therefore, it could be understood that the ability of energy storage of these phase change wallboards was stable after 360 transition cycles.

### 3.3. Thermal reliability of phase change wallboards incorporated in eutectic mixtures

Phase change wallboards uncycled incorporated in CA–LA eutectic mixtures were tested by DSC. Fig. 6 showed the test results. The melting temperature was 19.108 °C, in the indoor comfort temperature range. The melting latent heat was 35.239 J/g. Compared with the eutectic transition temperature of CA and LA, the variation of melting temperature was little.

Phase change wallboards incorporated in eutectic mixtures of CA and LA after 120, 240, 360 phase transition cycles were tested by DSC. Figs. 7–9 showed the DSC curves, respectively.

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### 4. Conclusion

Known in this study, the phase transition temperature and latent heat value of eutectic mixtures of 65.12% CA and 34.88% LA was suitable for application in building envelopes. Further, it could be noted that the changes in the melting temperatures and latent heat of the phase change wallboards with eutectic mixtures after 360 phase transition cycles, approximately one year utility period, were in a reasonable level, no regular degradation during repeated 360 thermal cycles. These phase change wallboards can be used for latent heat storage in HVAC system to reduce its scales and cost. Therefore, the application of eutectic mixtures of CA and LA in phase change wallboards will surely bring more benefits to the field of heat energy storage.

### References