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Eutectic mixtures of some fatty acids for latent heat storage: Thermal properties and thermal reliability with respect to thermal cycling

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Abstract

Accelerated thermal cycle tests have been conducted to study the change in melting temperatures and latent heats of fusion of the eutectic mixtures of lauric acid (LA)–myristic acid (MA), lauric acid (LA)–palmitic acid (PA) and myristic acid (MA)–stearic acid (SA) as latent heat storage materials. The thermal properties of these materials were determined by the differential scanning calorimetry (DSC) analysis method. The thermal reliability of the eutectic mixtures after melt/freeze cycles of 720, 1080 and 1460 was also evaluated using the DSC curves. The accelerated thermal cycle tests indicate that the melting temperatures usually tend to decrease, and the variations in the latent heats of fusion are irregular with increasing number of thermal cycles. Moreover, the probable reasons for the change in thermal properties of the eutectic mixtures after repeated thermal cycles were investigated. Fourier Transform Infrared (FT-IR) spectroscopic analysis indicates that the accelerated melt/freeze processes do not cause any degradation in the chemical structure of the mixtures. The change in thermal properties of the eutectic mixtures with increasing number of thermal cycles is only because of the presence of certain amounts of impurities in the fatty acids used in their preparation. It is concluded that the tested eutectic mixtures have reasonable thermal properties and thermal reliability as phase change materials (PCMs) for latent heat storage in any solar heating applications that include a four year utilization period.
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1. Introduction

Latent heat thermal energy storage (LHTES) systems for low temperature solar heat storage have been drawing considerable attention in recent times due to their possible application for solar residential heating and cooling systems. Depending on the rapid developments in LHTES, the surveys of phase change materials (PCMs) have gained significant interest.

The selection of suitable heat storage material plays an important role in terms of thermal efficiency, economic feasibility and utility life of LHTES systems. So, the development and improvement of PCMs with respect to the application conditions have been handled in many studies. A number of inorganic–inorganic, organic–inorganic and organic–organic eutectic PCMs have been investigated in view of their thermal energy storage characteristics [1–4]. Among these groups of PCMs, fatty acids were most promising owing to their advantages of suitable melting temperature, high latent heat of fusion, low cost, ready availability, non-toxicity, non-flammability, non-subcooling, non-corrosiveness, small volume change [5–8] and good thermal reliability after a large number of melt/freeze cycles [9,10]. An added advantage is that fatty acids are derived from common vegetable and animal oils that provide an assurance of continuous supply despite the shortage of fuel sources [7].

Based on these superior thermo-physical properties, a considerable number of binary or ternary mixtures of fatty acids that melt at desired temperatures with respect to the energy storage requirement may be prepared. Besides estimation of the thermal performance of a newly developed PCM in LHTES systems, the determination of its thermal stability for long time energy storage periods is essential to predict not only the life of the LHTES system but also the database for parametric analysis of the LHTES system. Therefore, to observe the repeatability of the thermal properties of a PCM, it should be subjected to a large number of melt/freeze processes.

There are several studies on the thermal stability of different PCMs after many heating–cooling cycles. The thermal stability of some salt hydrates as PCMs was studied by determining their latent heats of fusion and melting temperatures after subjection to repeated cycles [11,12]. Sharma et al. [13] conducted 1500 accelerated thermal cycles to study the changes in latent heat of fusion and melting temperature of commercial acetamide, stearic acid and paraffin wax. They concluded that paraffin and acetamide have shown reasonably good thermal stability for melting temperature and variations in latent heat of fusion during the cycle processes. Sharma et al. [14] also studied the thermal reliability of urea after repeated thermal cycles and recommended that urea should not be used as a latent heat storage material. The thermal characteristics and thermal stability of lauric, palmitic and stearic acid and their binary systems after 30, 50, 80 and 100 thermal cyclings were estimated by Zhang et al. [15]. Moreover, accelerated thermal cycle tests to study the thermal properties and thermal reliability of some fatty acids and their binary eutectic mixtures were performed by Sarı [16] and Sarı et al. [17].

Based on the literature survey mentioned above, it can be noted that a comprehensive knowledge of the thermal properties and thermal reliability of a PCM should be verified by thermal cycling life testing to ensure the longevity of the LHTES system in which it is used. Therefore, this

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