Solar Energy Materials and Solar Cells 188 (2018) 6–17

Contents lists available at ScienceDirect

Solar Energy Materials and Solar Cells

journal homepage: www.elsevier.com/locate/solmat

Experimental study on thermal properties and thermal performance of eutectic hydrated salts/expanded perlite form-stable phase change materials for passive solar energy utilization

Zhonghao Rao[a,*], Taotao Xu[a], Chenzhen Liu[a], Zhangjing Zheng[a], Lin Liang[a], Kun Hong[b]

[a] School of Electrical and Power Engineering, China University of Mining and Technology, Xuzhou 21116, PR China
[b] Jiangsu Provincial Engineering Laboratory for Advanced Materials of Salt Chemical Industry, Huaiyin Institute of Technology, Huainan 223003, PR China

ARTICLE INFO

Keywords:
Thermal performance
Passive solar energy utilization
Phase change materials
Hydrated salts

ABSTRACT

A novel composite phase change material (PCM) used as exterior and interior envelop materials for passive solar energy utilization was synthesized and investigated in this paper. Eutectic hydrated salt (EHS) consisted sodium carbonate decahydrate (SCD) and disodium hydrogen phosphate dodecahydrate (DHPD) with a mass ratio of 5:5 was prepared as the PCM with its phase change temperature of 26.94 °C and phase change enthalpy of 198.44 J/g while three different kinds of expanded perlites (EPs) were pretreated as supporting materials. According to the results of leakage tests and volume enthalpy, 70%EHS/EP2 was chosen as the form-stable phase change materials (FSPCM) to fabricate phase change insulation panels. The thermal conductivity with different temperature of 70%EHS/EP2 was measured and the maximum was 0.44 W/(m K) when the testing temperature was 25 °C. In addition, the heat storage and release results of 70%EHS/EP2 indicated that there was no supercooling. The thermogravimetric analysis and thermal cycling tests were performed and the results indicated that 70%EHS/EP2 had a good thermal stability and reliability. The heat transfer properties of EP panel and 70%EHS/EP2 phase change panel were tested and the results showed 70%EHS/EP2 phase change panel could remarkably decrease the maximum temperature during the melting process and obviously prolong the time of heat preservation in the cooling process which contributed to its good thermal control performance.

1. Introduction

Latent heat thermal energy storage (LHTES) has been attracted considerable attention in passive solar energy utilization owing to its high energy storage density and phase change at a nearly constant temperature. Phase change materials (PCM) could be divided into four types: solid-solid PCM, solid-fluid PCM, solid-gas PCM and liquid-gas PCM. And the solid-liquid PCM has been extensively investigated and applied. Solid-liquid PCM included organic and inorganic PCM, such as fatty acid [1,2], paraffin waxes [3,4] and inorganic hydrated salt [5], which used their phase transition to store thermal energy. However, the supercooling phenomenon and ease of leakage of melting PCM during the phase transition limited their further application.

To solve the problems mentioned above, encapsulating PCM into micro/nano capsules to form the shell-core composite materials [6,7] and preparing form-stable PCM (FSPCM) via an impregnation of pure PCM into porous materials [8–13] were considering as two effective method. Liu et al. [14] reviewed the research progress of nano encapsulated in recent years including four parts: preparation and characterization of nano PCM, application of nano PCM in latent functional thermal fluid, heat transfer enhancement of nano PCM and dynamics simulation study of nano PCM. Also, the limitation of current research and the further prospective research of nano PCM were analyzed and discussed. In comparison with encapsulation technique, the manufacturing process of FSPCM was simple and widely used. Right now, porous carbons (such as expanded graphite, graphene and carbon nanotube), porous inorganic materials and silicate minerals (such as expanded perlite (EP), diatomite), porous silicon dioxide and porous polymers have been used as supporting materials for FSPCM. And, nine kinds of silicate mineral materials including kaolin, diatomite, sepiolite,

Abbreviations: BHS, Binary hydrated salt; DHPD, Disodium hydrogen phosphate dodecahydrate; DSC, Differential scanning calorimetry; EHS, Eutectic hydrated salt; EP, Expanded perlite; FSPCM, Form-stable phase change materials; FT-IR, Fourier transformation infrared spectroscope; LEG, Leakage evaluation grade; LHTES, Latent heat thermal energy storage; SCD, Sodium carbonate decahydrate; SEM, Scanning electron microscopy; PCM, Phase change materials; TGA, Thermogravimetric analysis; T_p, Peak temperature in DSC curve; XRF, X-ray fluorescence spectrometer

* Corresponding author.
E-mail address: raozhonghao@cumt.edu.cn (Z. Rao).

https://doi.org/10.1016/j.solmat.2018.08.012
Received 29 May 2018; Received in revised form 10 August 2018; Accepted 19 August 2018
0927-0248/

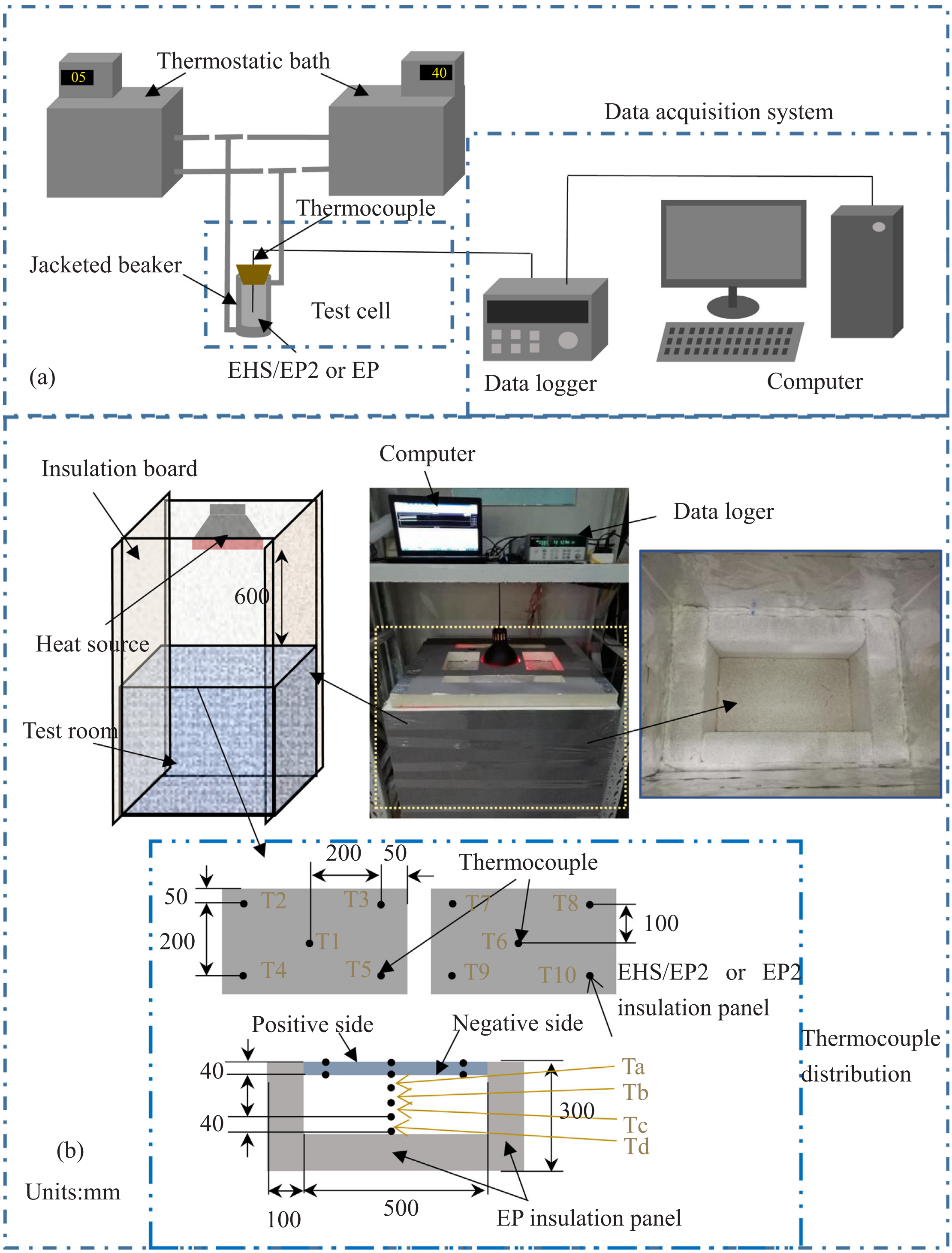

Fig. 1. Test system for (a) heating storage/release70%EHS/EP2, (b) thermal performance of 70%EHS/EP2 insulation panel.

montmorillonite, perlite, SiO_2, attapulgite, vermiculite and fly ash used for supporting matrix were reviewed in the reference by Lv et al. [15].

Research on the application of PCM in passive solar energy utilization has been widely investigated. Recently, some organic PCM incorporated into EP used for passive solar energy utilization have been reported [13,16–26]. For examples, Karaipekli et al. [27] prepared a novel FSPCM by using a eutectic mixture of capric acid and myristic acid as PCM and EP as supporting materials. And the maximum absorption of EP was 55 wt% without melted PCM seepage from the composite. The thermal cycling test was performed which indicated that the FSPCM had good thermal reliability in terms of changes in thermal properties after 5000 thermal cycling. To realize the objective to improve the thermal insulation and thermal storage capacity of magnesium oxychloride cement with satisfied mechanical properties, the paraffin/EP composites was prepared and applied [28]. Kong et al. [25] focused on a building energy storage panel prepared in two steps: vacuum absorption and surface film coating. Firstly, paraffin was incorporated into expanded perlite; secondly, the FSPCM was immersed into the mixture of colloidal silica and acrylate, and then it was taken out and dried naturally. The results showed that the optimum adsorption ratio for paraffin and EP was 52.5:47.5 in mass fraction; the building energy storage panel had low temperature variation,