Applied Thermal Engineering 59 (2013) 336–347

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Preparation, characterization and thermal properties of Lauryl alcohol/Kaolin as novel form-stable composite phase change material for thermal energy storage in buildings

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HIGHLIGHTS

- Form-stable composite PCM is prepared by incorporation of LA into Kaolin.
- Maximum mass fraction of LA retained in Kaolin without seepage was 24%.
- Composite PCM is chemically and thermally stable and reliable.
- Prepared composite PCM cement paste panel reduced the indoor temperature by 4 °C.
- The composite is a potential candidate for thermal energy storage in buildings.

ARTICLE INFO

Article history:
Received 10 December 2012
Accepted 8 May 2013
Available online 16 May 2013

Keywords:
Form-stable composite PCM
Lauryl alcohol
Kaolin
Thermal energy storage
Phase change material

ABSTRACT

This research was aimed at developing novel form-stable composite phase change material (PCM) by incorporation of Lauryl alcohol (LA) into Kaolin (KO) through vacuum impregnation. The composite PCM was characterized by using SEM and FT-IR. Thermal properties, thermal stability and reliability of the composite were determined by using DSC, TGA and thermal cycling test. Thermal performance of cement paste composite PCM panel was also evaluated. Test results showed that the maximum fraction of LA retained in KO was 24%. SEM images showed that LA was held by the porous and layered structure of KO due to the effect of capillary and surface tension forces. FT-IR results indicated that the composite PCM has good chemical stability and the interaction between LA and KO is physical. The melting temperature and latent heat of the composite PCM were measured as 19.14 °C and 48.08 J/g by DSC analysis. TGA and thermal cycling test revealed that the composite PCM is thermally stable and reliable. Thermal performance test showed that the cement paste panel with composite PCM reduced the indoor temperature by 4 °C. It can therefore be concluded that the prepared composite PCM is a potential candidate for thermal energy storage in buildings.

1. Introduction

The rapid economic growth worldwide has lead to increase in energy demand. Moreover, the conventional fossil energy sources are depleting, and their usage is related to emission of harmful gases making people worried about environment issues and shortage of energy resources. To deal with this demanding situation, energy resources should be used efficiently. The building and industrial sectors are the dominant energy consumers around the world with a total 28 percent share of the overall energy consumption [1]. For example in Hong Kong, the electricity consumption has increased by approximately 75 percent during the last 20 years [2]. Thus, improving the energy consumption of buildings would not only reduce the dependence on fossil fuel but would also have a major impact on the total green house gas emissions. Thermal energy storage is a simple and effective technique for application to building envelops to enhance the energy efficiency of buildings. This, in turn, reduces the environmental impact related to energy use [3].

Thermal energy storage can be stored and retrieved as the change in the internal energy of a material as sensible heat, latent heat and thermo-chemical or combination of these [3]. In sensible

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http://dx.doi.org/10.1016/j.applthermaleng.2013.05.015

heat storage, energy is stored by raising the temperature of material. The system utilizes the heat capacity and the change in the temperature of material during the process of charging and discharging. The amount of energy stored by the system depends on the specific heat of the medium, the temperature change and the amount of storage material [4]. However, these materials require massive mass and huge space to achieve desired degree of comfort [5]. To overcome the issues in sensible heat storage systems, the research in the field of latent heat storage systems began in 1940's. Latent heat storage is based on heat absorption or release when a storage material undergoes change in phase from solid to liquid or liquid to gas or vice versa [6]. In thermo-chemical systems, the energy is absorbed or released during breaking and reforming molecular bonds in a completely reversible chemical reaction. The energy stored in the system depends on the amount of storage material, the endothermic heat of reaction and the extent of conversion [3].

Among above thermal energy storage systems, latent heat storage system using PCM is most promising technique because of its advantages of high energy storage density and small temperature change from storage to retrieval [7]. The utilization of organic PCM as heat storage is known for long time. They are generally chemically stable, do not suffer from super cooling, non-corrosive, non-toxic and have high latent heat of fusion. However, for successful utilization of PCMs in building envelope, the phase change temperature should be in the human comfort zone [8]. Lauryl alcohol, which is an organic PCM, has attracted researchers because it has phase change temperature in the human comfort zone and also has high latent heat storage capacity.

The word Kaolin is derived from the name of the Chinese town Kao-Ling (Gaoling), located in the Jiangxi Province of southeast China [9]. Kaolin or China clay is a geological term referring to a rock that is rich is Kaolinite. Kaolinite is a hydrated aluminum silicate with 1:1 layer structure formed by one silicon–oxygen (SiO_4) tetrahydral sheet linked to one alumina [Al (O, $OH)_6$] octahedral sheet through sharing of apical oxygens [10,11]. The chemical composition of Kaolinite is $Al_2Si_2O_5(OH)_4$. Kaolin has wide range of industrial application mostly dominated by paper and ceramic industry followed by specialty applications such as fillers in paints, rubber etc. [12]. It has also been used extensively in mortar and concrete to improve its strength and durability [13]. Moreover, China is a significant producer of Kaolin with 2.1 million tonnes in 2002 representing 8.4% of the world's total of 24.9 million tonnes [9]. Fig. 1 shows the deposits of Kaolin in China. According to the British Geological Survey, the world total Kaolin production in 2008 was around 27.4 million tonnes with China having 10.94 percent share (Table 1) [14]. Therefore, successful utilization of PCM in Kaolin for the purpose of thermal energy storage in buildings will open a new venture for Kaolin industry of the world in general and China in particular. The use of thermal energy storage systems would not only result in efficient utilization of energy resources by reducing the dependency on fossil fuels but they will reduce energy cost and scale of air-conditioning systems, flatten the fluctuation of indoor temperature and improve the indoor thermal environment [15]. It is worth mentioning here that the combination of building materials and PCM is an efficient way to increase the thermal energy storage capacity of building components for the purpose of direct thermal energy storage in buildings [16].

This research developed novel form-stable composite PCM having excellent heat transfer control in terms of thermal storage, thermal stability and reliability, physical and chemical compatibility. LA would be incorporated in KO using vacuum impregnation method. The possible chemical and physical interaction between KO and LA would be evaluated through FT-IR analysis while the thermal properties, thermal stability and reliability of the composite would be determined by using DSC, TGA and thermal cycling

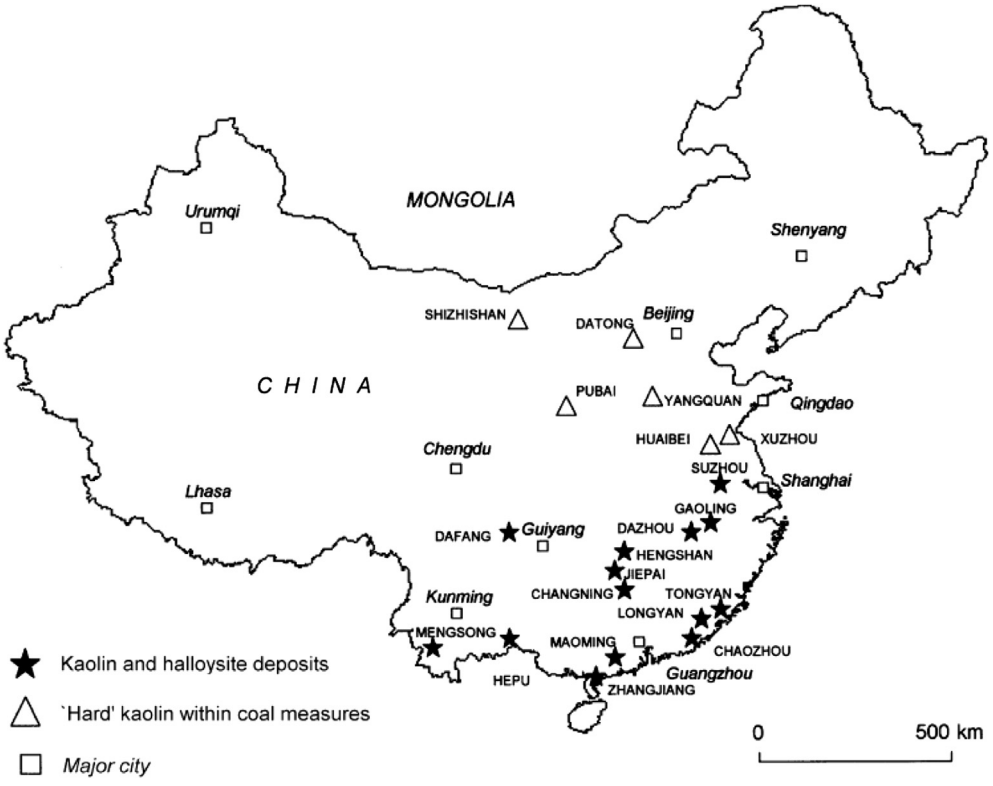

Fig. 1. KO deposits in China [9].