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Review

A review on thermophysical properties of nanoparticle dispersed phase change materials

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ABSTRACT

A review of current experimental studies on variations in thermophysical properties of phase change material (PCM) due to dispersion of nanoparticles is presented in this article. Dispersed carbon nanotubes/fiber and different metal/metal oxide nano particles in paraffin and fatty acids might be a solution to improve latent heat thermal storage performance. Thermophysical properties such as thermal conductivity, latent heat, viscosity and super cooling of phase change materials (PCM) could be changed for different physical properties of dispersed nanoparticle such as size, shape, concentration and surface properties. Among the nano particles, comparatively carbon nanotubes and carbon nano fiber have shown better performance in enhancing the thermal properties of PCM for their unique properties. The present review will focus on the studies that describe how the surface, chemical and physical properties of nanoparticle could affect the thermal properties of PCM with the help of available explanations in the literature.

Contents

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Nomenclature

D	diameter (nm)
ΔH	phase change enthalpy (J/kg)
K	thermal conductivity (W/m K)
L	length (μm)
L	latent heat (J/kg)
M	mass of PCM (g)
T	temperature (°C)
Greek Symbols	
A	thermal diffusivity (m^2/s)
B	coefficient of volumetric expansion (1/K)
P	density (kg/m^3)
Subscript	
F	fluid
L	liquid
M	melting
S	solid
Abbreviations	
Ag NWs	Ag nanowires
CNF	carbon nanofiber
CNT	carbon nanotubes
CTAB	cetyltrimethylam-monium bromide
LHTES	latent heat thermal energy storage
MWCNT	multi walled carbon nanotubes
NePCM	nanoparticle-enhanced phase change materials
PA	Palmitic acid
PANI	Polyaniline
PCM	phase change material
PEG	polyethylene glycol
PVA	polyvinylalcohol
PW	paraffin wax
SDS	sodium dodecyl sulfate
SW	Soy Wax
SWCNTs	single walled carbon nanotubes
TD	1-Tetradecanol
TEA	Triethylamine
TEMED	Tetramethylethylenediamine
TES	Thermal Energy Storage

1. Introduction

The needs of energy for a wide variety of applications in different forms and stages are time dependent with the limitation of available energy sources. This indicates that the available sources of energy and applications should be complemented strongly with an efficient energy storage system. On the subject of renewable energy technologies, thermal energy storage system is an expanding field of innovation. In recent years, the Thermal Energy Storage (TES) technologies have been grabbed the attention of researchers for its exceptional behavior, storing energy for usage in a later period, which would lead to a reduction in the overall energy demand. Among the various TES methods, LHTS has been investigated in last two decades, LHTS system's using PCMs were the most favorable for their high-energy storage density with small temperature variations [1]. In spite of these great advantages, most PCM's have a limitation of their own i.e., very low thermal conductivity [2]. To reduce the thermal energy charging/discharging time of TES system and temperature difference, enhancing the thermal conductivity of PCM is one of the ways to improve the effectiveness of the PCM-based TES systems. As a result, from the previous findings, to increase the performance of TES, PCM has been the major research priority topic recently [3]. Many researches have been conducted on this topic introducing high conductive metal fins and fibers in various forms such as fins, honeycomb, wool, and brush, to enhance the thermal conductivity of PCM [4]. However, the metal fillers/fins/fibers increase the weight and cost of the storage systems. In addition, determining the proper configurations of these fixed enhancers and their interactions with conduction or convection heat transfer involved in solid-liquid phase poses challenges. On the other hand, rapid pioneer advancement in the nanotechnology field, an innovative concept of using ultrafine nano sized particles which usually possess a nominal diameter of the order of 10–50 nm, have become commercially available in various metals and metal oxides. These highly conductive nanoparticles have been used to develop advanced heat transfer fluids called nano fluids with considerably enhanced thermal conductivity compared to the base liquids [5]. Accordingly, utilization of fabricated nano particles opens a great number of opportunities for new technological innovations in materials synthesis, discovering functionality-tested NEPCM (Nano particle enhanced phase change materials). Introducing nano particles in PCM, the thermo physical properties i.e., thermal conductivity, latent heat, viscosity, super cooling, etc. of the base PCM could be changed intensively. Recently Khodadadi et al. [6] and Ramm Dheep and Sreekumar [7] presents a review article showing the suitability of nano particles in enhancing the thermal conductivity of phase change materials for thermal energy storage.

In literature, various works have been accompanied to investigate the thermo physical properties of PCM with the dispersion of nanoparticles in which different studies focus on different properties of NePCM. In this context, an extensive literature review has been performed to demonstrate the effects on thermo physical properties of PCM due to dispersion of different nano particles. Furthermore, nonmoving high conductive fixed inserts and metal foam based insert that is not in nano scale is not included in the study.

2. Nano particle enhanced PCMs

Most of the research works in literature were conducted on improvement of thermal properties of PCMs such as paraffin's and fatty acids. Paraffin draws a great attraction to researchers for its desirable characteristics i.e., good heat storage density, melting or solidification compatibly with little or no sub cooling, non-reactiveness with most common chemical reagents and low cost [8]. Fatty acids shows the similar properties as paraffin [9]. However, the main drawback of these PCM's is their low thermal conductivity [10]. Dispersing high conductive nano particles could be a solution to enhance the thermal conductivity of these PCM's. Few research works presented in Table 1 are focused to investigate the thermal properties of these PCM's with different nano particles.

3. Effects on thermophysical properties due to nano particle dispersion in PCMs

3.1. Effects on thermal conductivity

The rate of energy stored and released are highly dependent on the thermal conductivity of the PCMs at both solid and liquid state.