Performance characteristics of microencapsulated phase change material slurry in a helically coiled tube

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Abstract

Flow and heat transfer characteristics of microencapsulated phase change material (MPCM) slurry as a heat transfer fluid (HTF) in a heated helically coiled tube have been investigated experimentally. Thermophysical properties of MPCM slurry were determined experimentally. A fully instrumented helical coil system was designed, built, and characterized to conduct pressure drop and heat transfer experiments at different mass fractions of MPCM slurries under turbulent flow conditions. Pressure drop and friction factor of MPCM slurry in the coiled tube were measured and correlated using the Dean number. Local convective heat transfer of MPCM slurry flowing through the coiled tube was characterized under turbulent flow and constant heat flux conditions. In addition, useful correlations have been postulated to predict Nusselt number of MPCM slurry. Furthermore, overall thermal performance analyses have been conducted to determine the benefits of using MPCM slurry in terms of heat transfer and heat capacity, respectively. The results showed that the enhancement in heat transfer performance is restricted due to the high viscosity and low latent heat of fusion of phase change material (PCM), but MPCM slurry still exhibits enhanced heat capacity when compared to water. Also, it was found that a helically coiled tube is more appropriate for convection of MPCM slurry than a straight tube.

1. Introduction

The use of microencapsulated phase change material (MPCM) slurry has received considerable attention as an enhanced heat transfer fluid (HTF) in heating and cooling applications due to the high heat carrying capacity of MPCM slurry. Generally, MPCM particles in the slurry contain phase change material (PCM) with high latent heat of fusion (LHF). The PCM absorbs or releases heat equivalent to its LHF with no significant change of temperature during the phase change process, which leads to greater heat transfer performance. Due to the high heat capacity, however, MPCM slurries usually need heat exchangers with relatively high surface area for adequate heat transfer to ensure complete phase change of PCM. Therefore, appropriate heat exchanger configurations should be used to harness the potential of MPCM slurries. Coil heat exchangers (CHX) are used widely in many heat transfer applications due to the superior heat transfer performance and compactness. A typical CHX can accommodate a large heat transfer area in a small space, which ensures high heat transfer rate partly due to the secondary flows induced by its configuration. Therefore, understanding how MPCM may exhibit enhanced heat transfer performance in a CHX is very important and necessary for the implementation of MPCM slurries in heat transfer applications.

1.1. MPCM slurry

1.1.1. Thermophysical properties of MPCM slurry

Alvarado et al. [1] used and characterized MPCM consisting of n-tetradecane as phase change material. The MPCM particles in their study had a size range of 2-10 μm, and contained tetradecanol as nucleating agent to reduce the supercooling effect. The viscosity of MPCM slurry exhibited a Newtonian-like behavior when the mass fraction was kept below 18%, and that the MPCM’s relative viscosity was found to be independent of temperature. Alvarado et al. [2] also studied how to reduce subcooling (or supercooling) of microencapsulated n-tetradecane by adding tetradecanol (2 and 4 wt%) to the PCM. Taherian et al. [3] used and characterized methyl stearate as a PCM and the MPCM particle size...