Thermal performance of a novel heat transfer fluid containing multiwalled carbon nanotubes and microencapsulated phase change materials

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Three new heat transfer fluids consisting of combinations of multi-walled carbon nanotubes (MWCNT) and microencapsulated phase change materials (MPCMs) were formulated, and tested in a turbulent flow heat transfer loop. Stable nanofluids have been prepared using different sizes of multi-walled carbon nanotubes and their thermal properties like thermal conductivity, viscosity and heat transfer coefficient have been measured. Microencapsulated phase change material slurries containing octadecane as phase change material have been tested to determine their durability and viscosity. A blend of MPCM slurry with MWCNT nanofluid has also been prepared to form a new heat transfer fluid that exhibits unique thermophysical properties including non-Newtonian viscous behavior. Heat transfer experiments have also been conducted to determine heat transfer coefficient and pressure drop values of the MWCNT nanofluids, MPCM slurries, and blends of MWCNT with MPCM under turbulent flow and constant heat flux conditions. The heat transfer results of the MPCM slurry containing octadecane was in good agreement with the published results. A maximum thermal conductivity enhancement of 8.1% was obtained for MWCNTs with diameter of 60–100 nm and length 0.5–40 μm. Heat transfer results indicate that MWCNT nanofluid exhibits a convective heat transfer enhancement in the range of 20–25% in turbulent flow conditions. The blend of MPCMs and MWCNTs was highly viscous and displayed a non-Newtonian shear thinning behavior. Due to its high viscosity, the blend exhibited laminar behavior and lower heat transfer rate, though the maximum local heat transfer coefficient achieved by the blend was comparable to that obtained with MPCM slurry alone. The pressure drop of the blend was also lower than that of the MWCNT nanofluid.

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1. Introduction

Heat transfer processes play a vital role in many industrial, biological and natural systems. Convective heat transfer is very important in the power generation industry, and in district cooling, HVAC, refrigeration and microelectronics cooling applications. The main objective in all the above applications is to maximize heat transfer while minimizing input power (i.e. pressure drop) and keeping the size and weight of heat transfer equipment as small as possible. Heat transfer fluid selection and system design are the key important factors that determine the realization of the above goal. Heat transfer enhancement can be obtained either by using an enhanced heat transfer fluid or by using enhanced surfaces in heat exchangers.

Enhanced or modified surfaces such as fins, micro channels, tube inserts and rough surfaces have been found to increase heat transfer rates significantly [1,2]. Enhanced surfaces increase the effective heat transfer area without increasing the overall volume of the equipment significantly. Though an enhancement in the heat transfer coefficient is obtained using the above mentioned techniques, it is usually obtained at the expense of increasing pressure drop which implies higher input pumping power and thus higher operational costs. Thus the other alternative of using improved heat transfer fluids to obtain enhanced heat transfer rates has gained more importance in recent years.

Commonly used heat transfer fluids include water, glycol–water mixtures, poly alkylene glycols, hydrocarbon oils, refrigerants (phase change fluids) and silicones. Though a variety of heat transfer fluids are available today that can cater to the needs of industry, problems like limited heat transfer rates, high pressure drop, limited temperature range, safety and suitability for specific applications still persist. This forms the motivating factor for research in...