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Viscosity and thermal conductivity of nanofluids containing multi-walled carbon nanotubes stabilized by chitosan

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A B S T R A C T

Thermal conductivity, viscosity, and stability of nanofluids containing multi-walled carbon nanotubes (MWCNTs) stabilized by cationic chitosan were studied. Chitosan with weight fraction of 0.1%, 0.2 wt%, and 0.5 wt% was used to disperse stably MWCNTs in water. The measured thermal conductivity showed an enhancement from 2.3% to 13% for nanofluids that contained from 0.5 wt% to 3 wt% MWCNTs (0.24 to 1.43 vol %). These values are significantly higher than those predicted using the Maxwell's theory. We also observed that the enhancements were independent of the base fluid viscosity. Thus, use of microconvection effect to explain the anomalous thermal conductivity enhancement should be reconsidered. MWCNTs can be used either to enhance or reduce the fluid base viscosity depending on the weight fractions. In the viscosity-reduction case, a reduction up to 20% was measured by this work. In the viscosity-enhancement case, the fluid behaved as a non-Newtonian shear-thinning fluid. By assuming that MWCNT nanofluids behave as a generalized second grade fluid where the viscosity coefficient depends upon the rate of deformation, a theoretical model has been developed. The model was found to describe the fluid behavior very well.

1. Introduction

Carbon nanotubes (CNTs) are relatively new materials that possess some unique properties including high moduli of elasticity, high aspect ratios, and high thermal conductivity. Thus, by dispersing CNTs into a liquid phase such as water, ethylene glycol, or engine oil, its thermal and transport properties could be enhanced. This work, therefore, will focus on nanofluids prepared by dispersing multi-walled carbon nanotubes (MWCNTs) in deionized water (DW) and we will look at their potential, in terms of their thermal conductivity, stability, and viscosity in heat transfer applications.

Stability study is motivated by the fact that CNTs can bundle together easily because of their high van der Waals interaction forces [1,2], non-reactive surface properties, very large specific surface areas and aspect ratios [3]. Therefore, to prepare a stable nanofluid containing CNTs, their surface properties need to be modified either physically or chemically. Physical methods such as ultrasonication and high shear mixing have been used [4,5]. However, such approaches are not very effective and can fragment nanotubes causing a decrease in their aspect ratios. Chemical methods use either hydrophilic functional groups or surfactants to attach onto CNTs to stabilize them. For this approach, hydrophilic functional groups such as nitric/sulfuric acid mixture, potassium hydroxide group [6,7] and a wide range of surfactants such as sodium dodecylbenzene sulphonate (SDBS), sodium dodecyl sulfate (SDS), gum Arabic (GA) [4,8] have been used. For the chemical methods to be effective either aggressive chemical functionalization or high concentrations of surfactant need to be used. For example, Jiang et al. [8] reported that the optimum amounts of SDS used to obtain a stable homogeneous suspension of 0.5 wt% CNTs was 2 wt%. Aggressive chemical functionalization can cause defects on CNTs altering their thermal and physical properties. High surfactant concentrations can significantly increase the base fluid viscosity and the interface thermal resistance between the carbon nanotubes, thus, limiting the thermal transport in the nanotube-matrix [9]. In this work, we explore the use of chitosan to stabilize MWCNTS dispersed in deionized water. Chitosan is a cationic surfactant having a positive charge on the polar portion of a solution. Cationic surfactants such as hexadecyltrimethylammonium bromide (CTAB), gemini surfactant [10], and cationic-onionic mixed surfactant [11] have been found to be effective in stabilizing CNTs and various metal particles [12] with low surfactant concentrations. We use chitosan because it is biocompatible and is a natural polymer isolable from crustacean cell.

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