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Experimental studies on heat transfer and friction factor characteristics of CuO/water nanofluid under turbulent flow in a helically dimpled tube

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ABSTRACT

An experimental investigation on the convective heat transfer and friction factor characteristics in the plain and helically dimpled tube under turbulent flow with constant heat flux is presented in this work using CuO/water nanofluid as working fluid. The effects of the dimples and nanofluid on the Nusselt number and the friction factor are determined in a circular tube with a fully developed turbulent flow for the Reynolds number in the range between 2500 and 6000. The height of the dimple/protrusion was 0.6 mm. The effect of the inclusion of nanoparticles on heat transfer enhancement, thermal conductivity, viscosity, and pressure loss in the turbulent flow region were investigated. The experiments were performed using helically dimpled tube with CuO/water nanofluid having 0.1%, 0.2% and 0.3% volume concentrations of nanoparticles as working fluid. The experimental results reveal that the use of nanofluids in a helically dimpled tube increases the heat transfer rate with negligible increase in friction factor compared to plain tube. The experimental results showed that the Nusselt number with dimpled tube and nanofluids under turbulent flow is about 19%, 27% and 39% (for 0.1%, 0.2% and 0.3% volume concentrations respectively) higher than the Nusselt number obtained with plain tube and water. The experimental results of isothermal pressure drop for turbulent flow showed that the dimpled tube friction factors were about 2–10% higher than the plain tube. The empirical correlations developed for Nusselt number and friction factor in terms of Reynolds number, pitch ratio and volume concentration fits with the experimental data within ±15%.

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1. Introduction

Particle-laden fluids are those in which solid particles are dispersed in a carrier liquid to a particular concentration. The particles are generally in the order of micro and nanometer size, and the carrier liquid commonly used in the laboratory is either water or mineral oil. The particles are of various types, like metal, ceramic, metal oxide, etc. These particles tend to increase the thermal conductivity of the fluid by a substantial amount and hence promoting more amount of heat energy to be transferred. This phenomenon is known as heat transfer enhancement and these particles-laden fluids have been found to have better heat transfer properties as solid materials have much higher thermal conductivities than fluids.

However, large particles cause many troublesome problems like: (a) settling of large sized particles from the base fluids, especially in low speed circulation, not only losing the enhancement in thermal conductivity, but forming a sediment layer at the surface, increasing the thermal resistance and impairing the heat transfer capacity of the fluids, (b) severe clogging problems, especially with the circulation of fluids in micro channels, (c) large particles in fluid also carry too much momentum and kinetic energy, which may cause damage to the surface, (d) the erosion of the pipelines by the coarse and hard particles increases rapidly when the speed the circulation increases, (e) noticeable conductivity enhancement is based on high particle concentration, which leads to apparent increase in viscosity and hence the pressure drop in fluids goes up considerably due to the increase of viscosity [1–4].

Due to the above mentioned disadvantages associated with the liquid suspension of larger particles, the method of enhancing the thermal conductivity by adding solid particles is not preferred until the emergence of nanofluids. In general, the working fluid such as water, oil, and ethylene glycol is used for various industrial fields, namely, power generation and air conditioner. However, these fluids with low thermal conductivity suppress development of compact and higher-performance heat exchangers. Fluid including nanoparticles is referred to as nanofluid, which is a term proposed by Choi [1]. The term "nanofluid" refers to a two phase mixture with its continuous phase being generally a liquid and the dispersed phase constituted of nanoparticles, that is, extremely fine

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