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Convective heat transfer of non-Newtonian nanofluids through a uniformly heated circular tube

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ABSTRACT

Three kinds of nanofluids were prepared by dispersing γ-Al_2O_3, CuO, and TiO_2 nanoparticles in an aqueous solution of carboxymethyl cellulose (CMC). The forced convective heat transfer of these nanofluids through a uniformly heated circular tube under turbulent flow conditions was investigated experimentally. The base fluid and all nanofluids show pseudoplastic (shear-thinning) rheological behavior. Results reveal that the local and average heat transfer coefficients of nanofluids are larger than that of the base fluid. Heat transfer enhancement of nanofluids increases with an increase in nanoparticle concentration. Similar trend are demonstrated for Nusselt number of nanofluids. For a given nanoparticle concentration and Peclet number, the local heat transfer coefficient of the base fluid and that of the nanofluids decreases with the axial distance from the tube inlet. A new correlation is proposed to predict successfully the Nusselt number of non-Newtonian nanofluids as a function of the Reynolds and the Prandtl numbers.

1. Introduction

The tendency to greater miniaturization of modern devices and process intensification driven by recent technological advancements are facing the technological challenge of the efficient cooling of these devices. Indeed, it is required to develop cooling or heating systems that are able to provide very high heat fluxes. Many heat transfer enhancement techniques have been proposed to increase the efficiency of heat transfer equipments. In the past decade, attention has been focused on the improvement of heat transfer by adding solid particles to heat transfer fluids. When the size of particles is less than 100 nm, the liquid/solid dispersion is referred to as a nanofluid. Nanofluids are stable and uniform suspension of nano-sized particles in a conventional heat transfer base fluid. Recent investigations show that presence of nanoparticles enhances significantly the thermal characteristics of the nanofluid compared to the base fluid.

Some review articles [1–3] discussed the results obtained in numerous investigations performed to evaluate the thermophysical properties of nanofluids and their ability to improve the heat transfer occurring in industrial equipments. Many researchers have studied the convective heat transfer of nanofluids in both the laminar [4–17] and the turbulent [8,16,18–27] flow regimes. Numerous types of nanoparticles such as oxide nanoparticles [4,7–11,13–15,17,18,20–22,26–30], carbon nanotubes [6,12,16] and different other nanoparticles [5,19,23,25] were used in the preparation of nanofluids. Water, ethylene glycol and transformer oil were often used as the base fluid. Gherasim et al. [29], Nguyen et al. [20], and Jwo et al. [30] have used a radial flow cooling system, a closed system designed for cooling microprocessors or other electronic components, and a multi-channel heat exchanger for cooling of electronic chips. All other investigators have studied the convective heat transfer of nanofluids in circular tubes. Results of these investigations showed that the inclusion of nanoparticles improves the convective heat transfer compared to the base fluid and the enhancement of heat transfer coefficient increases with the nanoparticle concentration. Predicted values of the heat transfer coefficient of nanofluids using conventional correlations for the heat transfer of single-phase fluids are generally much smaller than the values observed experimentally. It was believed that the enhancement in the thermal conductivity of nanofluids would be mostly responsible for the improvement in the convective heat transfer coefficient of nanofluids. However, in most investigations, results show that the improvement of the convective heat transfer coefficient of nanofluids is much higher than the expected contribution of the thermal conductivity to the enhancement in the convective heat transfer coefficient of nanofluids. Thus, it is clear that other factors have also an effect on the convective heat transfer

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