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Investigation of turbulent convective heat transfer and pressure drop of TiO_2/water nanofluid in circular tube ☆

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ABSTRACT

Turbulent heat transfer behavior of titanium dioxide/water nanofluid in a circular pipe was investigated experimentally where the volume fraction of nanoparticles in the base fluid was less than 0.25%. The experimental measurements have been carried out in the fully-developed turbulent regime for various volumetric concentrations. The results indicated that addition of small amounts of nanoparticles to the base fluid augmented heat transfer remarkably. There was no much effect on heat transfer enhancement with increasing the volume fraction of nanoparticles. The measurements also showed that the pressure drop of nanofluid was slightly higher than that of the base fluid and increased with increasing the volume concentration. In this paper, experimental results have been compared with the existing correlations for nanofluid convective heat transfer coefficient in turbulent regime. Finally, a new correlation of the Nusselt number will be presented using the results of the experiments with titanium dioxide nanoparticles dispersed in water.

1. Introduction

The poor thermal properties of fluids act as a main barrier to the growth of energy-efficient heat exchanger. During the past decades, many efforts have been devoted to the enhancement of heat transfer. One of the possible techniques for improving heat transfer is adding millimeter- or micrometer-sized particles in fluids. In recent years, nanofluids have been introduced as an ideal candidate for enhancing heat transfer [1,2]. As a result of the small size of nanoparticles, a little pressure drop is observed in the fluid. In this situation the fluid behaves like a pure fluid or single phase liquid [1].

Various studies have been conducted on the performances of nanofluids convective heat transfer in laminar flow [3–5]. They concluded that nanofluids provide heat transfer enhancement in comparison with their corresponding base fluids. Mansour et al. [6] experimentally studied the mixed convection of water–Al_2O_3 mixture inside an inclined tube. Their results indicated that a higher particle volume concentration clearly induced a decrease of the Nusselt number for the horizontal inclination. On the other hand, they showed that for the vertical one, the Nusselt number remains nearly constant with an increase of particle volume concentration from 0 to 4%.

Nanofluids have valuable industrial applications including heating systems through the hydronic coils, cooling automotive engines through the radiators and in heat exchangers. In all of these applications, the regime of fluid flow is generally turbulent in which higher heat transfer is achievable. Based on numerical or experimental analyses of previous studies, with increasing the particle volume concentration of nanofluids the turbolant heat transfer improved [7–10]. On the other hand, Fotukian and Nasr [8] studied turbulent convective heat transfer performance of very dilute (less than 0.24% volume) CuO/water nanofluid. In their study, increasing the volume fraction of CuO particles in nanofluid had negligible effect on the heat transfer enhancement.

A few studies have reported the influence of TiO_2 on the heat transfer of nanofluids. Duangthongsuck and Wongwises [12,13] showed that using different predictive thermophysical models for nanofluid has no effect on the predicted values of the convective heat transfer coefficient of TiO_2/water nanofluids. Murshed et al. [14] measured the thermal conductivity of suspended TiO_2 nanoparticles in deionized water. The results showed that the thermal conductivity of nanofluid increased remarkably with increasing the volume fraction of nanoparticles. He et al. [15] studied static thermal conductivity, heat transfer and flow behavior of stable aqueous TiO_2 nanofluid with different particle sizes and concentrations. They found that the convective heat transfer coefficient increased with increasing nanoparticle concentration. They showed that the heat transfer improvement was more significant in turbulent flow regime.

The previous work of the authors did not examine the effect of the dilute particle concentration on heat transfer and pressure drop of TiO_2/water based nanofluids. Since this behavior has not been already reported, experiments with very dilute TiO_2 nanoparticles were planned to see if the same behavior was observed. As a result, this

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