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Experimental heat transfer of nanofluid through an annular duct ☆

M. Nasiri, S.Gh. Etemad *, R. Bagheri

Department of Chemical Engineering, Isfahan University of Technology, Isfahan 84154–83111, Iran

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ABSTRACT

This paper is related to heat transfer performance of Al_2O_3/H_2O and TiO_2/H_2O nonofluids through an annular channel with constant wall temperature boundary condition under turbulent flow regime. The constant temperature is applied on the outer wall of the channel. Experimental investigation was done for a wide range of Al_2O_3 and TiO_2 nanoparticle concentrations and Reynolds number. Based on the experimental results, for specific Peclet number, Nusselt number of nanofluids is higher than that of the base fluid. The enhancement increases with increase of nanparticle concentration for both employed nanofluids. Based on the results of this investigation there is no significant difference on the heat transfer enhancement associated with two employed nanofluids.

1. Introduction

Heat exchangers have wide applications in various industries. Energy saving management and idea of downsizing and under-weighting the heat exchangers motivate researchers to pay much attention to enhance heat transfer per unit area of these equipments. The efforts to increase the heat transfer efficiency in heat exchangers have been focused in two ways: making changes in heat exchangers' structure and the behavior of fluids flowing in the heat exchangers. Using extended surfaces are among the techniques based on changing of the heat exchangers' structure while adding materials to fluid to make changes in its rheological and thermophysical properties is an example of efforts of enhancing the heat transfer efficiency in heat exchangers via changing the fluid behavior.

One of the most effective properties of a fluid in heat transfer is its thermal conductivity. Adding metal and/or metal oxide solid particles to a fluid increases the fluid's thermal conductivity. It should be noted that the size of solid particles plays an important role in the enhancement of thermal conductivity of fluid. Practically, using large sized particles is unfeasible, since they cause some problems such as sedimentation of particles, erosion, and pressure depreciation which make the fluid's movement impossible. Adding particles with nanometric size usually is free of such problems. Nanofluid is prepared by adding metals, metal oxides, carbon nanotubes or any other solid nanomaterials to a base fluid like water, ethylene glycol or engine oil. Solid nanoparticles can be directly produced in a base fluid through chemical techniques. This way which is known as single-step method is a complex and difficult method, while there is a simpler method called double-step method. In this method prepared nanoparticles are added into a base fluid. Nanofluid has some advantages such as large specific surface area, high thermal conductivity, low erosion and proper stability [1].

Generally, there is a remarkable difference between thermal conductivity of nanoparticles used in preparing nanofulid and thermal conductivity of the base fluids. For this reason, adding nanoparticles to a base fluid is expected to make reasonable changes in the fluid's thermal conductivity. This subject has been reflected in the following published papers. Masuda et al. [2] employed Al_2O_3 nanoparticle with a size of 13 nm and with a concentration of 4.3 vol.% and water as a base fluid and obtained about 30% increase in thermal conductivity of prepared nanofluid in comparison with water. Type of nanoparticle and base fluid, and conditions such as temperature or pH affect the final value of thermal conductivity. Lee et al. [3] reported an increase about 10% for the Al_2O_3 /water nanofluid with nanoparticle size of 40 nm and concentration of 4 vol.%.

Xie et al. [4] showed lower thermal conductivity of nanofluid for elevated pH of the fluid. Researchers believe that in addition to mentioned parameters, the thermal conductivity of nanofluid is influenced by Brownian motion of nanoparticles [5]. Adding carbon nanotubes usually causes higher thermal conductivity than metal and metal oxide nanoparticles. Ding et al. [6] reported about 80% enhancement for carbon nanotube/water nanofluid containing 1%wt nanotube concentration for the base fluid of water with 0.25%wt of Arabic gum.

One of the other advantages of using nanofluid is higher heat transfer coefficient in comparison with that of the base fluid. Xuan and Li [7] demonstrated the enhancement up to 35% for the turbulent forced convective heat transfer of Cu/H_2O nanofluid with nanoparticle concentration of 25 vol.%. According to their report the enhancement is lower for lower concentrations. For example, for concentration of 0.3 vol.% the relative increase in heat transfer coefficient is less than 5%. Ding et al. [8] investigated about the heat transfer of CNT (carbon

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* Corresponding author at: Department of Chemical and Biological Engineering, University of Ottawa, Ottawa, Ontario, K1N 6N5, Canada.
E-mail addresses: etemad@cc.iut.ac.ir, sgetemad@uottawa.ca (S.G. Etemad).

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