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Modeling of convective heat transfer of a nanofluid in the developing region of tube flow with computational fluid dynamics ☆

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ABSTRACT

In this article, convective heat transfer effect on the nanofluid flow in the developing region of a tube with constant heat flux was investigated using computational fluid dynamics (CFD). For this purpose, nanofluid containing Al_2O_3 and water as a liquid single phase with two average particle sizes of 45 and 150 nm and four particle concentrations of 1, 2, 4 and 6 wt.% were used. Effect of particle size on convective heat transfer coefficient was investigated in different Reynolds numbers (500<Re<2500) for various axial locations of tube. According to the modeling results, an equation was obtained for Nusselt number prediction using the dimensionless numbers. The results showed that the predicted data were in very good agreement with experimental data obtained from the literature. The maximum error was around 10%.

1. Introduction

A fluid with good heat execution is an effective parameter to increase heat transfer rate in the heat exchangers [1]. Recent researches on nanofluid showed that nanoparticles changed the fluid characteristics because thermal conductivity of the particles was higher than ordinary fluids [2,3]. Nanofluids are produced by solid nanoparticles dispersion in a base fluid (such as water, oil and ethylene glycol) [4–7]. Alumina and copper oxide are the most ordinary and cheap nanoparticles which are used in the experimental investigations [4].

Xuan and Li experimentally studied the convection heat transfer and friction coefficient of nanofluid in both laminar and turbulent flows. Their results showed that the flow velocity and volume fraction of nanoparticles affected on the coefficients [8,9].

Wen and Ding investigated the convective heat transfer characteristics in Al_2O_3–water nanofluid along a copper tube. It was observed that heat transfer coefficient enhanced with increasing the Reynolds number and volumetric ratio of particles [10]. Heris et al. measured the heat transfer coefficient in Al_2O_3–water nanofluid flow through a duct with constant wall temperature. Also, they investigated numerically laminar-flow convective heat transfer in a circular tube for different particles in different sizes. They found that heat transfer coefficient increased with increasing the volume fraction of nanoparticles [11,12].

Mirmasoumi et al. numerically studied a fully developed mixed convection in Al_2O_3–water nanofluid. They used two-phase mixture model. The results showed that the convection heat transfer coefficient significantly increases with decreasing the nanoparticles means diameter [13]. He et al. numerically studied the convective heat transfer in TiO_2 nanofluid flow through a straight tube under the laminar conditions by using both single phase method and combined Euler and Lagrange method [14]. Izadi et al. numerically investigated laminar forced convection in Al_2O_3–water nanofluid in an annulus by the single phase approach [15].

Abu-Nada investigated effects of variable viscosity and thermal conductivity of (Al_2O_3–water) nanofluid in horizontal annuli on heat transfer in natural convection [16].

Sharma et al. experimentally studied the convective heat transfer coefficient and pressure drop in the transition Reynolds number range for Al_2O_3 and water nanofluid under constant heat flux. They found that convective heat transfer increased by using Al_2O_3 nanoparticles in water and increasing Reynolds number [17].

Khoddamrezaee et al. simulated ethylene glycol and Al_2O_3 nanofluid through a shell and tube heat exchanger with constant heat flux. They compared the stagnation point, separation point, heat transfer coefficient and shear stress of nanofluid with pure fluid [1].

In the present investigation, modeling of convective heat transfer in the developed region of tube flow containing water and Al_2O_3 nanofluid with constant heat flux was carried out using computational fluid dynamics (CFD) tools. Two average particle sizes of 45 nm and 150 nm and four particle concentrations of 1, 2, 4 and 6 wt. % were used. Further, effect of nanoparticle size on convective heat transfer coefficient was investigated and the results were compared with the reference [18] experimental. Although from the modeling results, a prediction equation based on the dimensionless numbers for Nusselt number was obtained.

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