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Effect of water-based Al_2O_3 nanofluids on heat transfer and pressure drop in periodic mixed convection inside a square ventilated cavity ☆

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ABSTRACT

A numerical study of unsteady mixed convection flows through an alumina-water nanofluid in a square cavity with inlet and outlet ports due to incoming flow oscillation is performed. It is found that an oscillating velocity at the inlet port cased to creating a periodic variation in the fluid flow and temperature field in the cavity after a certain time duration. The influence of the nanoparticle on the flow and temperature fields has been plotted and discussed. The effect of the oscillation frequency is concealed in a dimensionless number which is the Strouhal number. It is observed that the heat transfer is enhanced for all the Strouhal and Richardson numbers investigated by adding the nanoparticle to the base fluid. It is also found that the performance of the nanoparticle on the enhancement of the heat transfer at higher Richardson numbers is less than that of lower Richardson numbers.

1. Introduction

The conventional fluids such as water, oil and ethylene glycol (EG) have low thermal conductivity for heat transfer so it is a primary problem in places where need to exchange high thermal flux for example microchannels and heat exchangers. One of the ways to overcome this problem is to adding some solid nanoparticles with high thermal conductivity into the fluid. The resulting fluid is a suspension of the solid nanoparticle in the base fluid which is called nanofluid. The thermal conductivity of the nanofluids is more than the base fluid due to the high thermal conductivity of the nanoparticles [1]. There are some mechanisms which explain the enhancement of thermal conductivity in nanofluids such as interfacial layer at the particle/liquid interface [2–4], Brownian motion of nanoparticles in the base fluid [5,6], clustering of nanoparticles [7,8], temperature and nanoparticle's size and shape [9]. These parameters must be considered to predict the effective thermal conductivity of nanofluids using theoretical models. Recently Murshed et al. [4] presented theoretical and experimental results on the enhanced thermal conductivity of three nanofluids containing aluminum oxide, copper oxide and titanium oxide nanoparticles dispersed in base fluid of ethylene glycol and water. They proposed their models (one for spherical nanoparticles and the other for cylindrical nanoparticles) by considering the effects of the interfacial nanolayer, particle's size and shape, volume fraction of nanoparticles and thermophysical properties of the base fluids and nanoparticles. The proposed models show good agreement with the experimental results and give better predictions of the effective thermal conductivity of nanofluids compared to existing models [10,11] in the literature.

In the recent years many research have investigated numerically and experimentally the enhancement of heat transfer utilizing nanofluids [12–14]. Khanafer et al. [15] performed a numerical study of laminar natural convection in a square cavity. They have used three theoretical models for prediction of viscosity and thermal conductivity of nanofluids and deduced that the variances within different models have substantial effects on the results. Tiwari and Das [16] studied numerically combined convection heat transfer and fluid flow inside a two-sided lid-driven differentially heated square cavity for various Richardson number and the direction of the moving walls. Sharma et al. [17] investigated experimentally to evaluate heat transfer coefficient and friction factor for flow in a tube and with twisted tape inserts in the transition range of flow with alumina (Al_2O_3) nanofluid and observed considerable enhancement of convective heat transfer with Al_2O_3 nanofluids compared to flow with water.

The aim of this study is to simulate numerically the unsteady laminar mixed convection heat transfer of alumina (Al_2O_3)-water nanofluid in a square cavity with inlet and outlet ports due to oscillation of incoming flow. The buoyancy force has been induced by higher temperature on the four walls of the cavity and lower temperature of the incoming flow. The effective thermal conductivity and the viscosity of nanofluid have been determined by the models which presented by Murshed [4] and Nguyen et al. [18] respectively. The consequence of varying the Reynolds number, Richardson number, the oscillating velocity frequency and the nanoparticle concentration on the flow and heat transfer will be presented and discussed.

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