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Effects of uncertainties of viscosity models for Al_2O_3–water nanofluid on mixed convection numerical simulations

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ABSTRACT

The effects of uncertainties in the effective dynamic viscosity of Al_2O_3–water nanofluid in the laminar mixed convection fluid flow and heat transfer in a square cavity are investigated. The left and the right vertical walls of the enclosure as well as its horizontal top wall are maintained at a constant temperature T_c. The horizontal bottom wall of the cavity, which moves in its own plane from left to right with a constant speed u_b, is kept at a constant temperature T_h, with $T_h > T_c$. The governing equations written in terms of the primitive variables are solved numerically using the finite volume method. Two different models proposed in the literature are considered for the effective dynamic viscosity of the nanofluid. Using the developed code, a parametric study is performed incorporating the two viscosity formulas, and the effects of the Richardson number and the volume fraction of the nanoparticles on the fluid flow and heat transfer inside the enclosure are investigated in each case. The results show that significant differences exist between the magnitudes of heat transfer enhancement in the cavity for the two viscosity models employed. Moreover, in general, the average Nusselt number of the hot wall increases with increasing the volume fraction of the nanoparticles for both of the viscosity models.

1. Introduction

Mixed convection fluid flow and heat transfer are encountered in a number of engineering and industrial applications such as cooling of electronic equipment, chemical processing equipment, float glass manufacturing, food processing, and lubrication technologies. There are a number of early studies on the mixed convection flow and heat transfer inside enclosures. As early as in 1972, Torrance et al. conducted a numerical investigation of the mixed convection heat transfer in rectangular enclosures [1]. They showed that the Richardson number was a governing parameter of the problem. Among experimental studies on the mixed convection heat transfer inside a lid-driven cavity, is the work of Prasad and Koseff [2] in which they investigated heat transfer inside a cavity, filled with water for various Reynolds and Grashof numbers. Moallemi and Jang [3] used the finite volume method and the SIMPLER algorithm to investigate the effects of the Prandtl number on the fluid flow and heat transfer induced by the motion of the upper lid, and by the buoyancy force due to heating from the bottom wall of a square cavity. They concluded that for fixed values of Reynolds and Grashof numbers, the effect of buoyancy on the flow and heat transfer was more pronounced at higher values of the Prandtl number. Mohammad and viskanta [4] carried out a three-dimensional numerical simulation of heat transfer in a shallow driven cavity heated from the top moving wall, and cooled from below for a range of Rayleigh and Richardson numbers. Prasad and Koseff [5] reported experimental results for the mixed convection flow and heat transfer in a deep, lid-driven cavity heated from below. Their results indicated that the heat transfer was a weak function of the Richardson number. In another numerical investigation, Lee and Chen [6] employed the finite element method to simulate laminar as well as turbulent mixed convection heat transfer in a driven cavity heated from below.

More recently, Guo and Sharif [7] used the finite volume method and the SIMPLER algorithm to study the mixed convection heat transfer in a rectangular enclosure with a constant heat flux, partially heated bottom wall, and isothermal sidewalls which were moving in the vertical direction. They investigated the effects of the Richardson number, the heat source length, and the aspect ratio of the cavity on the heat transfer. Their results indicated that the average Nusselt number increased by moving the heat source towards the sidewalls. Oztop and Dagtekin [8] conducted a numerical study of mixed convection fluid flow and heat transfer in a vertical, two-sided, lid-driven square cavity. The moving left and right walls of the cavity were maintained at different constant temperatures; while, the top and the bottom walls were kept

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