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Nanofluid Mixed-Convection Heat Transfer in a Ventilated Cavity with a Baffle

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ABSTRACT

The present paper reports numerical results of mixed-convection heat transfer with nanofluid in a horizontal ventilated cavity heated from below and provided with a thin partition on the heated surface. Free flow at low temperature enters the cavity and takes heat from the heat source. Discretization of governing equations are achieved through a finite volume method and solved with the SIMPLE method. Effects of governing parameters, such as Richardson number, $0.01 \le Ri \le 10$, the baffle position from the inlet, $0.25 \le L_b \le 1.75$, solid volume fraction, $0 \le \phi \le 0.05$, and nanoparticle type on the fluid flow and heat transfer characteristics are studied in detail. The results show that increase in Richardson number results in reduction of average Nusselt number and increase in solid concentration leads to enhancement of the average Nusselt number. In addition, the results predict an optimal position for the baffle.

KEYWORDS:

Mixed Convection, Nanofluid, Ventilated Cavity, Baffle

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1- Introduction

Heat transfer by mixed convection has attracted considerable interest in various industrial and engineering applications such as heat exchangers, electronics industry, solar collectors and nuclear reactors. A rapid survey of the literature indicates that a two-dimensional enclosure has been extensively used by a number of researchers to simulate mixed convection of pure fluid in different practical situations [1-4]. In these studies, base fluid in the enclosure has a low thermal conductivity, which in turn limits enhancement of heat transfer. An innovative technique, is using a mixture of nanoparticles and the base fluid which is called as nanofluid. It is expected that the nanoparticles in the nanofluid increase the thermal conductivity and therefore substantially enhance the heat transfer characteristics of the nanofluid [5,6].

Although nanofluids convection heat transfer in cavities has also been the subject of some studies in the recent years [7,8], to the best knowledge of the authors, no studies have been reported in the literature, which investigate the effect of nanofluids on mixed convection in baffled cavity. This problem may be encountered in a number of electronic cooling devices.

2- Methodology

Figure 1 displays the schematic diagram of the two-dimensional cavity with a baffle at the bottom wall which is considered in this study. The ventilated cavity is heated from below and provided with a thin partition on the heated surface. Free flow of nanofluid at low temperature enters the cavity from the left wall, taking heat from the heat source and exits from the right wall.

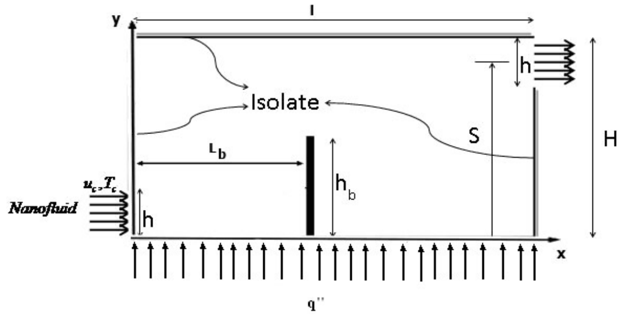

Figure 1. A schematic diagram of the physical model

The non-dimensional continuity, momentum and energy equations along with the boundary conditions were discretised using a control volume formulation.The SIMPLE algorithm was utilized to handle the pressure-velocity coupling. The convection-diffusion terms were treated with a power-law scheme. The numerical method was implemented in a FORTRAN program.

3- Discussion and Results

In this paper, the effects of the governing parameters, such as the Richardson number, $0.01 \leq Ri \leq 10$, the baffle position from the inlet, $0.25 \leq L_b \leq 1.75$, the solid volume fraction, $0 \leq \phi \leq 0.05$, and the nanoparticle type on the fluid flow and heat transfer characteristics are studied in detail. Figure 2 shows the effect of Richardson number on streamlines (left) and isothermal lines (right) of pure water and Cu-water nanofluid.

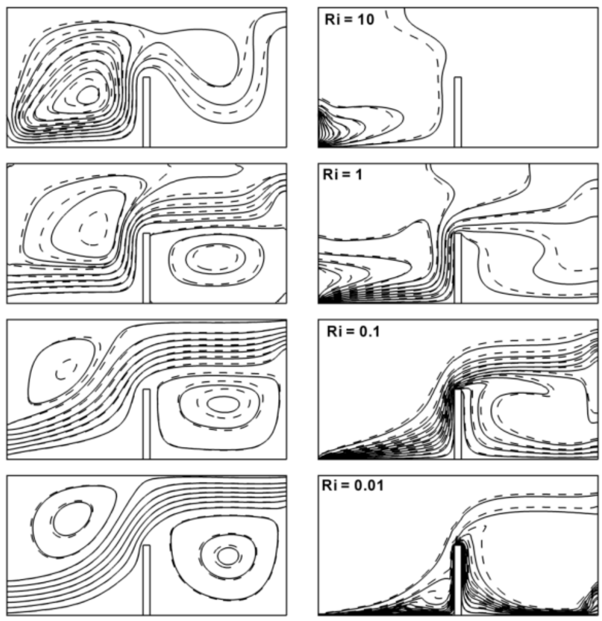

Figure 2. Streamlines (left) and isothermal lines (right) for different Richardson numbers (dash line: nanofluid(ϕ=0.03) and filled line: water) (L_b=1)

Figure 3 shows the effects of Richardson number and baffle location on average Nusselt number for Cu-water nanofluid (ϕ=0.03). This figure shows that for all baffle locations, the average Nusselt number is reduced by increasing the Richardson number. Figure 3 also shows that for all Richardson numbers, there is a baffle location that maximizes the Nusselt number and the heat transfer, consequently.

Figure 4 shows the effects of nanoparticles volume fraction for various types of nanoparticles at Ri=0.1. This figure shows that for all types of nanoparticles, the average Nusselt number is enhanced by increasing the nanoparticles volume fraction. This enhancement is more sensible for Cu and Ag with high thermal conductivities.

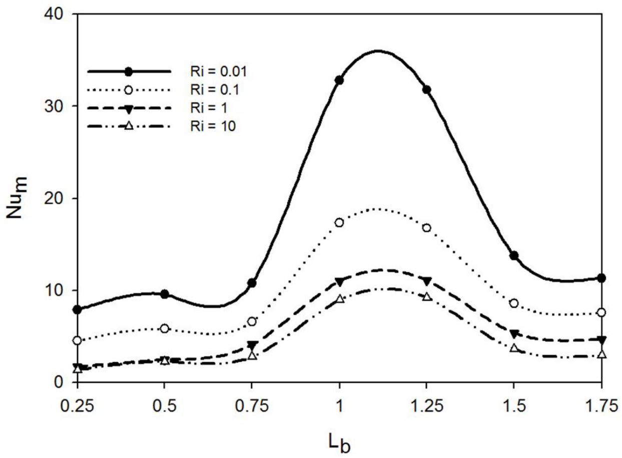

Figure 3. Variation of average Nusselt number with baffle location at various Richardson numbers (Cu-Water, ϕ=0.03)

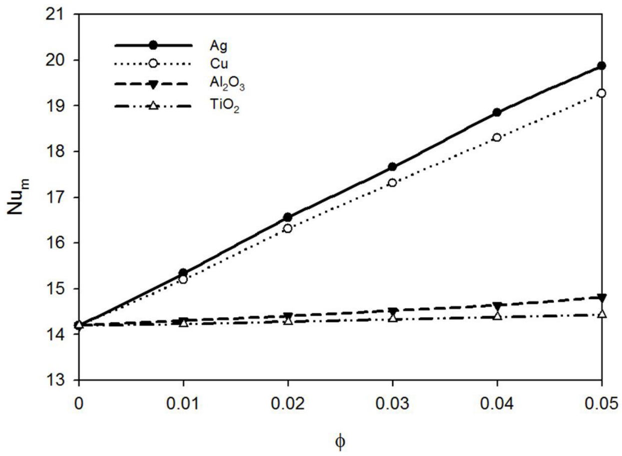

Figure 4. Variation of average Nusselt number with nanoparticles volume fraction for various types of nanoparticles (*Ri*=0.1)

4- Conclusions

Nanofluid mixed convection in a horizontal ventilated cavity heated from below and provided with a thin baffle on the heated surface has been numerically investigated. The effects of Richardson number, nanoparticles volume fraction, the baffle location and the nanoparticles type on the cavity cooling performance are studied. The important concluding remarks are presented below:

● For all baffle locations, the average Nusselt number is reduced by increasing the Richardson number.

● For all Richardson numbers, there is a baffle location that maximizes the heat transfer.

● For all type of nanoparticles , the average Nusselt number is increased by increasing the nanoparticles volume fraction. This enhancement is more sensible for Cu and Ag with high thermal conductivities in comparison with Al_2O_3 and TiO_2.

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