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Natural Convection of Water-Based Nanofluids in a Square Cavity with partially heated of the Bottom Wall

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Abstract

Numerical study of natural convection of water-based nanofluids in a square cavity with partially heated at the bottom wall and filled with nanofluids is carried out using different types of nanoparticles. The remaining wall of this enclosure is kept at cold temperature. The numerical procedure used in this work is based on the Galerkin weighted residual method of finite element formulation. Calculation are performed for Rayleigh numbers in the range 10^3 -10^6 and different solid volume fraction of nanoparticles $0 \le \phi \le 0.2$. An enhancement in heat transfer rate is observed with the increase of nanoparticles volume fraction for the whole range of Rayleigh numbers. It is observed that the heat transfer enhancement strongly depends on the type of nanofluids.

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Keywords: Natural Convection; Nanofluids; Solid volume Fraction;Finite Element Method

1. Introduction

Free convection as the key heat transfer mechanism used in numerous applications. The trend of convection plays an important role in the nature and in engineering fields because of its various applications in solar energy collectors, industries, electronic, thermal storage systems, and cooling of electrical and mechanical components etc. These applications are well described by Ho et al. [1] studied numerically the effects of dynamic viscosity and thermal conductivity of nanofluid in a square enclosure filled with Al_2O_3-water nanofluid. Enhancements in the thermal conductivity and dynamic viscosity estimated from the two adopted formulas leaded to the heat transfer enhanced or mitigated. Abu- Nada and Chamkha [2] performed a numerical study of natural convection heat transfer in a differentially heated enclosure filled with CuO-EG-Water nanofluid. The results were compared with Brinkman model and MG models for nanofluid viscosity and thermal conductivity. Either enhancement or decline was reported for the average Nusselt number as the volume fraction of nanoparticles increased. Teja et al. [3] have reported that the thermal conductivity of 2 nm titania nanoparticles is smaller than the thermal conductivity of the base fluid at the same temperature. They show this behavior is unlike that of other nanofluids, which have been shown to exhibit positive thermal conductivity enhancements. A critical synthesis of thermo physical characteristics of nanofluids is presented by Khanafer and Vafai [4]. Another study has been done by Sheikhzadeh et al. [5]. They have investigated the effects of Prandtl number on the steady magneto-convection around a centrally located adiabatic body inside a

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square cavity. Elif Buyuk Ogut [6] performed natural convection of water-based nanofluids in an inclined enclosure with a heat source. He concluded that the results show the average heat transfer rate increases significantly as particle volume fraction and Rayleigh number increase. The results further show that the length of the heater is also an important parameter affecting the flow and temperature fields. The average heat transfer decreases with an increase in the length of the heater. As the heater length is increased, the average heat transfer rate starts to decrease for a smaller inclination angle. Nader et al. [7] developed that natural convection of water-based nanofluids in a square enclosure with non-uniform heating of the bottom wall. Ternik and Rudolf [8] studied that heat transfer enhancement of natural convection flow of water based nanofluid in a square enclosure. They found that the effect of high conductive nanoparticles on heat transfer enhancement is more significant at low values Rayleigh number. Triveni and Panua [9] Studied Numerically that laminar natural convection in an arch enclosure filled with aluminum oxide-water based nanofluid. They observed that the enhancement in heat transfer is observed for both water and nanofluid with the increase of curve ratio.

From the above literature review contains many investigations into the heat transfer performance and heat generation/absorption rate of natural convection in cavities. Accordingly, the present study performs a numerical investigation into the natural convection heat transfer characteristics and heat transfer rate within the cavity containing water-based nanofluids. The results are shown in terms of parametric study of various dimensionless parameters such as Rayleigh number and nanoparticles volume fraction for the temperature, velocity component, local Nusselt number and average Nusselt number.

Nomenclature

h	heat transfer coefficient (Wm^2K^{-1})
L	Length of the cavity (m)
Pr	Prandtl number
T	Dimensional temperature (K)
U, V	Dimensionless velocities
K	Thermal conductivity ($Wm^{-1}K^{-1}$)
C_p	Specific heat at constant pressure ($JKg^{-1}K^{-1}$)
Nu	Average Nusselt number
Ra	Rayleigh number
u,v	Dimensional x and y components of velocity ($m\ s^{-1}$)
X,Y	Dimensionless coordinates
x,y	Dimensional coordinates (m)

Greek Symbols

α	Fluid thermal diffusivity (m^2s^{-1})
β	Thermal expansion coefficient (K^{-1})
ϕ	Nanoparticles volume fraction
ν	Kinematic viscosity (m^2s^{-1})
θ	Dimensionless temperature
ρ	Density(Kgm^{-3})
μ	Dynamic viscosity (Nsm^{-2})

Subscripts

c	cold
h	hot
f	fluid
nf	nanofluid