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Natural convection in a square cavity containing a nanofluid and an adiabatic square block at the center

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ABSTRACT

The problem of free convection fluid flow and heat transfer of Cu–water nanofluid inside a square cavity having adiabatic square bodies at its center has been investigated numerically. The governing equations have been discretized using the finite volume method. The SIMPLER algorithm was employed to couple velocity and pressure fields. Using the developed code, a parametric study was conducted and the effects of pertinent parameters such as Rayleigh number, size of the adiabatic square body, and volume fraction of the Cu nanoparticles on the fluid flow and thermal fields and heat transfer inside the cavity were investigated. The obtained results show that for all Rayleigh numbers with the exception of $Ra = 10^4$ the average Nusselt number increases with increase in the volume fraction of the nanoparticles. At $Ra = 10^4$ the average Nusselt number is a decreasing function of the nanoparticles volume fraction. Moreover at low Rayleigh numbers (10^3 and 10^4) the rate of heat transfer decreases when the size of the adiabatic square body increases while at high Rayleigh numbers (10^5 and 10^6) it increases.

1. Introduction

In recent years nanofluids, which are a suspension of nano-sized solid particles in a base fluid, with thermal conductivity higher than the based fluid, are used to enhance the rate of heat transfer in many practical engineering applications [1]. Free convection heat transfer inside nanofluid filled rectangular cavities with different boundary conditions on the side walls has been studied by many

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Nomenclature

c_p	specific heat, J kg^{-1} K^{-1}
g	gravitational acceleration, m s^{-2}
h	heat transfer coefficient, W m^{-2} K
H	enclosure height, m
k	thermal conductivity, W m^{-1} K^{-1}
l	width of the adiabatic square body, m
Nu	Nusselt number
p	pressure, N m^{-2}
P	dimensionless pressure
Pr	Prandtl number
q	heat flux, W m^{-2}
Ra	Rayleigh number
T	dimensional temperature, K
u,v	dimensional velocities components in x and y direction, m s^{-1}
U,V	dimensionless velocities components in X and Y direction
x,y	dimensional Cartesian coordinates, m
X,Y	dimensionless Cartesian coordinates
Greek symbols	
α	thermal diffusivity, m^2 s
β	thermal expansion coefficient, K^{-1}
θ	dimensionless temperature
μ	dynamic viscosity, kg m^{-1} s
ν	kinematic viscosity, m^2 s
ρ	density, kg m^{-3}
φ	volume fraction of the nanoparticles
Subscripts	
c	cold
f	fluid
h	hot
nf	nanofluid
s	solid particles
w	wall

researchers. Khanafer et al. [2] conducted a numerical study on free convection inside nanofluid filled rectangular cavities with cold right wall, hot left wall and insulated horizontal walls. Their results showed that rate of heat transfer increased with increase in nanoparticles volume fraction for entire range of Grashof number considered. Similar results were found in work of Jou and Tzeng [3] on numerical study of free convection in differentially heated rectangular cavities filled with a nanofluid. Santra et al. [4] studied free convection of Cu–water nanofluid in a differentially heated square cavity with consideration of Ostwald–de Waele non-Newtonian behavior of the nanofluid. They found that heat transfer decreased with increase in the nanoparticles volume fraction for a particular Rayleigh number. Effects due to uncertainties in effective dynamic viscosity and thermal conductivity of alumina-water nanofluid on free convection heat transfer in a differentially heated square cavity were investigated by Ho et al. [5]. Their results demonstrated that heat transfer across the cavity can be found to be enhanced or mitigated with respect to the base fluid via the used dynamic viscosity formula. Oztop and Abu-nada [6] carried out a numerical study on free convection of nanofluid in partially heated rectangular cavities. The cavities had a cold vertical wall, a localized heater on the other vertical wall and insulated horizontal walls. They considered effects of Rayleigh number,