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Parametric study on natural convection of nanofluids in a heated chamber

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Abstract

In this work, we conducted a numerical study of laminar natural convection in a closed cavity. The top and the bottom of the cavity are adiabatic, the upper part of the left wall is subjected to a hot temperature T_H, and the lower part of the right wall is subjected to a cold temperature T_C. The governing equations were discretized by the finite volume method using the power law schema. The dynamic viscosity and the effective thermal conductivity of the nanofluid are approximated respectively by the model of Brinkman and Maxwell Garnetts. Numerical simulations are performed using pure water and a mixture of water and nanoparticules (Al_2O_3, Cu and TiO_2) for a Rayleigh Number from 10^3 to 10^6 and a fraction of nanoparticules between 0 and 0.1. The results obtained shows that the heat transfer improves if we increase the volume fraction of the nanoparticules and the Rayleight Number.

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Keywords: Nanofluid; Heat transfert; Natural convection; Numerical staudy; Finite volume

1. Introduction

Heat transfer by natural convection is used in various industrial processes such as cooling of electronic equipment, solar technology, safety of nuclear reactors, biology, medical diagnostics, water treatment... etc.

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Regarding the applications in the field of heat transfer, studies conducted over the past ten years have shown that under certain conditions, the addition of nanoscale particles in a fluid (called then nanofluid) such as Aluminum oxide particles (Al_2O_3), copper oxide (CuO), copper (Cu) or carbon nanotubes in water could increase the heat transfer compared to the case of the pure substance (water), by modifying significantly the thermal conductivity of the carrier fluid. Several recent studies have been conducted on the natural convection of nanofluids, for example, Khanafar and al [1], Jou and Tzeng [2], Hwang and al [3], Ho and al [4], Abu Nada and Oztop [5], M . Elhatab and al [6], Ghasemi and al [7], Mahmoodi [8], Putra and al [9], Li and Peterson [10], Wen and Ding [11], Ho and al [12], Santra and al [13], and Esmail [14] .All these studies demonstrated that the increase of the volume fraction improves heat transfer. A numerical study of natural convection in rectangular enclosures partially heated was carried out by Hwang et al. [3], and also Ho et al. [4], Abu-Nada and Oztop [5], Mohamed El Hatab [6] and Ghasemi et al. [7]. In the present work, we study numerically the stationary laminar natural convection of water-Al_2O_3, water-Ti_2O_3 and water-Cu mixture into a squared enclosure.

Nomenclature

C_P	Specific heat, $J.(Kg.K)^{-1}$	α	Thermal diffusivity, $m^2.s^{-1}$
u, v	Dimensinal velocity componenents,$m.s^{-1}$	θ	Dimensionless temperature
p	Dimensionless pressure	Ψ	Dimensionless streamline
Pr	Prandelt number	β	coefficient of thermal expansion, K^{-1}
Ra	Rayleigh number	Φ	Particle volume fraction
Nu_a	Average Nusselt number	ρ	Density, $Kg.m^{-3}$
H	Enclosure lengh, m	μ	Dynamic viscosity, $N.m^{-2}.s$
x, y	coordinates, m	υ	Kinetic viscosity, $m^2.s$
P	Dimensional pression, Pa	Subscripts	
T	Dimensional temperature, K	H	Hot
k	Thermal conductivity, $W.(m.K)^{-1}$	C	Cold
g	Gravity acceleration, $m.s^2$	f	Fluid(pur water)
X, Y	Dimensionless coordinates	nf	Nanofluid
U, V	Dimensionless vilocity components	np	Nanoparticle

2. formulation and solving method

The geometry of the studied case is shown in Figure 1. It is mainly based on a squared enclosure of length H, filled with a homogeneous mixture of water and the nanoparticle Al_2O_3. The upper 1/3 of the left wall is maintained at a constant temperature T_H, and the lower 1/3 of the right wall is maintained at a constant temperature T_C. The other surfaces are all adiabatic. The base fluid used is Newtonian; the flow is two-dimensional, laminar and stationary. The viscous dissipation is negligible and the thermo-physical properties of the nanofluid are constant, except for the change of density, which is estimated by the Boussinesq approximation. The thermophysical properties of pure fluid and nanoparticles are summarized in Table 1.

Table 1. Thermophysical properties of water and the other nanoparticle.

An example of a column heading	Pr	$\rho(Kg/m^3)$	$C_P(J/Kg.K)$	k(W/m.K)	$\beta\times10^{-5}(K^{-1})$	$\alpha\times10^{-7}(m^2/s)$
Pur water	6.2	997.1	4179	0.613	21	1.47
Al_2O_3	-	3790	765	40	0.85	131.7
Cu	-	8933	385	400	1.67	1163.1
TiO_2	-	4250	686.2	8.9538	0.9	30.7