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Computational analysis of non-isothermal temperature distribution on natural convection in nanofluid filled enclosures

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ABSTRACT

In this study, the problem of steady state natural convection in an enclosure filled with a nanofluid has been analyzed numerically by using heating and cooling by sinusoidal temperature profiles on one side. The governing partial differential equations, in terms of the dimensionless stream function–vorticity and temperature, are solved numerically using the finite volume method for various inclination angles $0^\circ \leq \phi \leq 90^\circ$, different types of nanoparticles (TiO_2 and Al_2O_3) and fractions of nanoparticles $0 \leq \varphi \leq 0.1$, whereas the range of the Rayleigh number Ra is 10^3–10^5. It is found that the addition of nanoparticles into water affects the fluid flow and temperature distribution especially for higher Rayleigh numbers. An enhancement in heat transfer rate was registered for the whole range of Rayleigh numbers. However, low Rayleigh numbers show more enhancement compared to high Rayleigh numbers.

1. Introduction

Buoyancy induced heat transfer in enclosures filled with a clear fluid has been studied extensively in recent years [1,2]. It is used in many engineering applications such as furnaces, double pane

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Nomenclature

A	Aspect ratio (W/H)
C_p	Specific heat at constant pressure (kJ kg^{-1} K^{-1})
g	Gravitational acceleration (m s^{-2})
H	Height of the enclosure (m)
h	Local heat transfer coefficient (W m^{-2} K^{-1})
k	Thermal conductivity (W m^{-1} K^{-1})
Nu	Nusselt number, Nu = hH/k
Pr	Prandtl number
q_w	Heat flux, (W m^{-2})
Ra	Rayleigh number
T	Dimensional temperature (K)
u, v	Dimensional x and y components of velocity (m s^{-1})
U, V	Dimensionless x and y components of velocity
W	Width of the enclosure (m)
x, y	Dimensionless coordinates

Greek symbols

λ	Frequency
α	Fluid thermal diffusivity (m^2 s^{-1})
β	Thermal expansion coefficient (K^{-1})
ε	Numerical tolerance
θ	Dimensionless temperature
μ	Dynamic viscosity (N s m^{-2})
ν	Kinematic viscosity (m^2 s^{-1})
ρ	Density (kg m^{-3})
φ	Nanoparticle volume fraction
Ψ	Dimensionless stream function
ψ	Dimensional stream function (m^2 s^{-1})
Ω	Dimensionless vorticity
ω	Dimensional vorticity (s^{-1})

Subscripts

avg	Average
nf	Nanofluid
f	Fluid
H	Hot
C	Cold
w	Wall
p	Particle

windows, building heating, automotive technology, solar technology and cooling of electronic equipments. These applications are reviewed by Vahl Davis [3], Fusegi et al. [4], Barakos and Mitsoulis [5]. The efforts have been focused on the enhancement of natural convection heat transfer while using a minimum energy input. With this aim, an innovative technique to enhance heat transfer rate by using nanoscale particles (smaller than 100 nm) suspended in the base fluid, known as nanofluids, has been used extensively in recent years. The resulting mixture possesses a substantially larger thermal conductivity compared to that of base fluids [6,7].

Natural convection heat transfer in nanofluid filled enclosures has drawn attraction of many researchers in recent years. In this context, Oztop and Abu-Nada [8] studied the effects of a partial