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Magneto-convection of water-based nanofluids inside an enclosure having uniform heat generation and various thermal boundaries

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Abstract

Investigation of two-dimensional steady laminar magneto-convection heat transfer of (Ag, TiO_2) water based nanofluids with variable properties inside a heat generating square enclosure having different thermal boundaries is done numerically in this paper. The governing equations are solved utilizing the finite volume method with power-law scheme and SIMPLE algorithm is used for handling the pressure-velocity coupling. The algorithm and the computer code have been also compared with numerical results in order to verify and validate the model. By using the developed fortran code, the effects of Hartmann number, heat generation (or absorption), Reyleigh number and solid volume fraction on the flow and thermal fields and heat transfer inside the enclosure are studied. Results are demonstrated in the form of streamlines, isotherms and average Nusselt number.

Keywords: Magneto-convection; Sinusoidal heating; Finite volume method; Heat generation; Nanofluids

1. Introduction

Natural Convection is the main heat transfer mechanism used in numerous engineering and technological applications. Heat transfer within enclosures has many engineering applications such as solar collectors, thermal storage systems and cooling of electrical and electronic equipments, heat exchangers, energy systems and mechanical components. The first work on the numerical simulation of free convection heat transfer inside enclosures was done by Davis [1].

Commonly used fluids, such as water, mineral oil, etc., have very low thermal conductivity. Taking into account, there is a necessity to emerge new kind of fluids that will be more efficacious in heat transfer. Nanofluids were introduced in order to get past the above requirement. Fluids with nano-meter sized particles suspended into them was called nanofluids. The use of nanoparticles in the base fluid enhances heat transfer. Convection heat transfer of nanofluids in enclosure was investigated by some researchers by considering different models of nanofluid properties. It aims at manipulating the structure of the matter at the molecular level with the goal for innovation

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Nomenclature

Alphabets

B_0	Magnetic field strength (N/A m^2)
C_p	Specific heat (J kg^{-1} K^{-1})
g	Acceleration due to gravity (m s^{-2})
Ha	Hartmann number ($B_0 L\sqrt{\sigma_f/\rho_f\nu_f}$)
K	Thermal conductivity (W m^{-1} K^{-1})
L	Length of the enclosure (m)
Nu_m	Average nusselt number (h L/K)
P	Non-dimensional pressure
Pr	Prandtl number (ν_f/α_f)
q_0	Heat generation (absorption) (W/m^3 K)
Q	Non-dimensional heat generation (absorption) ($q_0 L^2/((\rho C_p)_{nf}\alpha_{nf})$)
Ra	Rayleigh number ($g\beta_f(T_h - T_c)L^3)/\nu_f\alpha_f$
T	Temperature (K)
U, V	Non-dimensional velocity components
W	Width of the solid body
X, Y	Non-dimensional co-ordinates

Greek symbols

α	Thermal diffusivity (m^2 s^{-1})
α	Thermal diffusivity (m^2 s^{-1})
θ	Non-dimensional temperature
ϕ	Solid volume fraction
μ	Dynamic viscosity (N s m^{-2})
ν	Kinematic viscosity (m^2 s^{-1})
ρ	Density (kg m^{-3})
σ	Electrical conductivity (A m/V)
Ψ	Non-dimensional stream function

Subscripts

c	Cold wall
f	Pure fluid
h	Hot wall
nf	Nanofluid
p	Particle
s	Solid

in virtually every industry and public endeavor including biological sciences, physical sciences, electronics cooling, transportation, the environment and national security. Choi and Eastman [2] were the first authors proposed the fluids with suspended nanoparticles to enhance the thermal conductivity of pure fluids. Several researchers used so many models to calculate the physical properties of nanofluid. Lee et al. [3] experimentally investigated the viscosities and thermal conductivities of water-based nanofluids having nanoparticles of low concentration. Abu-Nada and Chamkha [4] performed a numerical study of natural convection heat transfer in a differentially heated enclosure filled with CuO–*EG*–water nanofluid. Their results were compared with Brinkman model and MG models for nanofluid viscosity and thermal conductivity. Natural convection of SiO_2–water nanofluid using two different models has been studied by Jahanshahi et al. [5]. In the first model they employed a set of experimental data for thermal conductivity of nanofluid and in the second model they calculated the thermal conductivity from the equation