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Research Article

Three dimensional CuO–Water nanofluid flow considering Brownian motion in presence of radiation

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Abstract

In this investigation, three dimensional CuO–Water nanofluid flow between two horizontal parallel plates through porous medium in a rotating system is scrutinized. Micro mixing in suspensions is taken into account while calculating viscosity. The problem under consideration gives rise to set of nonlinear partial differential equations. Using proper change of variables, these give rise to set of ordinary differential equations. This cannot be solved using analytical methods, so Mathematica is employed for obtaining solution using HAM. To avail insight of the physics of the problem, the effects of pertinent parameters are discussed. Nanofluid temperature can be increased by increasing either of Radiation parameter, Magnetic parameter, Rotation parameter, Thermophoretic parameter or Brownian parameter. It is observed that skin friction can be reduced by reducing Reynolds number and rotation parameter. Also it can be established that Nusselt number and Sherwood number can be decreased by increasing values of Thermophoretic parameter, Schmidt number, Brownian parameter or rotation parameter.

Keywords: Micro mixing; MHD; Nanofluid; Heat transfer; Mass transfer

1. Introduction

Improvement of heat transfer is useful in engineering and real world problems. Oil extraction, pollution of ground water, filtering media, geothermal energy recovery and thermal energy storage are some problems involving heat transfer in porous media. This can be achieved by replacing conventional fluids with nano fluids. Thus researchers are attracted towards heat transfer properties of nanofluids. Sheikholeslami et al. [1] studied heat transfer of nanofluid MHD flow numerically. Sheikholeslami et al. [2] modeled nanofluid flow and simulated using Lattice Boltzmann Method. Sheikholeslami et al. [3] investigated forced convection heat transfer in presence of magnetic field. Sheikholeslami and Bhatti [4] revealed application of Active method in solving heat transfer problem. Sheikholeslami and Bhatti [5] analyzed nanofluid flow considering shape effects of nanoparticles. Kataria and Patel [6–10] analyzed MHD flow considering different types of fluids.

Sheikholeslami and Shehzad [11] analyzed the MHD nanofluid flow in porous enclosure. Kataria and

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Nomenclature

T	Temperature (k)
u,v,w	Velocity components along x, y, z axes, respectively (m s^{-1})
B	External uniform magnetic field (A m^{-1})
C_p	Specific heat at constant pressure (J kg^{-1} k)
g	Acceleration due to gravity (m s^{-2})
k	Thermal conductivity (W m^{-1} k^{-1})
k_1	Permeability of the fluid
M	Magnetic parameter (Ratio of Lorentz force to viscous force)
Pr	Prandtl number (ratio of momentum diffusivity to thermal diffusivity)
L	Distance between the plates (m)

Greek symbols

ρ	Density (kg m^{-3})
σ	Electrical conductivity (s/m)
$\varnothing$	Nanoparticle volume fraction
θ	Dimensionless temperature
Φ	Dimensionless concentration
μ	Dynamic viscosity (Pas)
φ	Porosity
κ	Permeability (dimensionless)
Ω	Constant Rotation velocity (rad s^{-1})
ν	Kinematic viscosity (m^2 s^{-1})
η	Dimensionless variable

Subscripts

f	Fluid phase
nf	Nano-fluid
s	Solid phase

Mittal [12] investigated velocity, mass and temperature of nanofluid flow in a porous medium. Kataria and Mittal [13] considered Casson nanofluid in their investigation. Sheikholeslami et al. [14,15] analyzed $CuO-H_2O$ nanofluid.

In real world problems, thermal radiation is evident which is reflected in study of various researchers. Kataria and Mittal [16] studied optically thick nanofluid flow past an oscillating vertical plate in presence of radiation. Many significant studies [17–38] are dedicated towards nanofluid flow recently.

Effect of magnetic field on heat and mass transfer in presence of thermal radiation between horizontal parallel is analyzed in the present investigation. System considered is a rotating system.

Novelty of the present work is the inclusion of often neglected effects such as Brownian motion, nanoparticle volume fraction and micro mixing in suspensions. Homotopy analysis method is employed to solve the resulting system of ordinary differential equations. The effects of relevant parameters on nanofluid flow are discussed in detail.

2. Problem statement

It is assumed that CuO–Water nanofluid flows between two horizontal parallel plates placed L units apart through a porous medium. A coordinate system (x, y, z) is such that origin is at the lower plate as shown in Fig. 1. The lower plate is stretched by two equal forces in opposite directions. The plates along with the fluid rotate about y axis with angular velocity Ω. A uniform magnetic flux with density B is applied along y-axis. Under these assumptions, governing equations [42] are:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

$$\rho_{nf}\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+2\Omega w\right)=\mu_{nf}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\sigma_{nf}B^2u-\frac{\mu_{nf}\varphi}{k_1}u \tag{2}$$

$$\rho_{nf}\left(v\frac{\partial v}{\partial y}\right)=\mu_{nf}\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \tag{3}$$

$$\rho_{nf}\left(u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}-2\Omega w\right)=\mu_{nf}\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}\right)-\sigma_{nf}B^2w-\frac{\mu_{nf}\varphi}{k_1}w \tag{4}$$

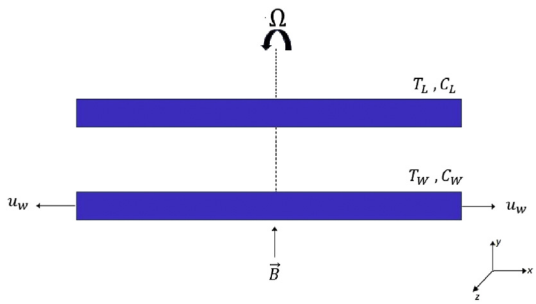

Fig. 1. Physical sketch of the problem.