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Research Article

Unsteady Free Convective Heat Generating Micropolar Fluid Flow Through Porous Medium in The Presence of Forchheimer Number with Mhd And Constant Heat And Mass Fluxes

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Abstract
The effect of heat source and Forchheimer on an unsteady MHD heat and mass transfer generated due to free convective micro-polar fluid flow over a vertical porous medium under magnetic field was investigated. The problem was investigated for both cooling and heating effects. The governing equation for unsteady one dimensional boundary layer equations of momentum, angular momentum, temperature and concentration was considered. An implicit finite difference solution was obtained for the non-dimensional Momentum, Angular Momentum, Energy and Concentration equations respectively. The computed values of fluid velocity, angular velocity, temperature and concentrations and also were analyzed for the different parameters, such as magnetic parameter M, thermal Grashof number Gr, modify Grashof's Number Gm, Prandtl Number Pr, and Schmidt Number Sc, Eckert number Ec, micro-rotational parameter d, spin gradient viscosity parameter Λ, heat source α, vortex viscosity parameter λ, Darcy's number Da and Soret Sr. It was observed that velocity profile increases with increase in parameter such as, M, and Gr and, also decreases with increase in Pr, Gm and Da. It also noticed that the temperature rises with increase magnetic parameter M, and Ec, the temperature reduces with increase in Pr number, d, and α. In angular velocity profile the velocity reduced drastically when the Λ and λ. while in concentration profile the concentration increases with increase in Sc and decreases with increase in Sr.

Nomenclature and units

y	Cartesian coordinate
u ,v	velocity components
g	local acceleration due to gravity
β	thermal expansion coefficient,
β^*	concentration expansion coefficient,
H	Humidity
RH	Relative humidity
υ	kinematic viscosity
ρ	density
χ	vortex viscosity
σ	is electrical conductivity
K	is the permeability
γ	spin-gradient viscosity
k	thermal conductivity
c_p	specific heat at constant pressure
c_s	concentration susceptibility
Q	constant heat flux per unit area
S	micro rotational constant,
D_m	. coefficient of mass diffusivity
k_T	thermal diffusion ratio

1.0 Introduction

In many applications, the micropolar fluids are fluids with microstructure physically with a rigid, randomly oriented (or spherical) particles suspended in a viscous medium, where the deformation of fluid particles is not consider with nonsymmetrical, micropolar fluids are important in Engineering and scientist working with hydrodynamic-fluid problems and phenomena. Ealrly scholars that have worked on micropolar fluid includes; Eringen (1972) studied the theory of micropolar fluid in his thermo-micropolar fluid theory. Ahmad (1976) investigated the micro inertia effect on the flow of a micropolar fluid past a semi plate. Peddision and McNitt (1970) investigated boundary layer situation for steady micropolar fluid flow past a semi-infinite flat plate.

The free convective micropolar fluid flow is of great interest in nature and in many industrial applications such as solidification of binary alloy drying process as well as in astrophysics, geophysics and oceanography. A solution for laminar free convective flow of thermo-micropolar fluid from none isothermal vertical flat plate was obtained by Jena and Mathur (1981). Abd El-Nably *et al.* (2003) carried out an investigation on magnetohydrodynamic transient natural convection radiation boundary layer flow with variable surface temperature, showing that velocity, temperature and skin friction are enhanced with a rise in radiation parameter. El-Amin (2004) also investigated the combined effect of internal heat generation and magnetic field on free convective mass transfer micropolar fluid flow over a vertical infinite surface with constant suction. Ibrahim *et al.* (2004) studied unsteady MHD micropolar flow with heat transfer through vertical porous plate in the presence of thermal and mass diffusion with a constant heat source. Baker (2011) analyzed the steady thermal convection heat and mass transfer in a micropolar fluid saturated by non-darcian porous medium in the presence of radiation and thermophoresis effect. Haque *et al.* (2011) investigated the heat and mass transfer due to a magneto micropolar fluid flow along a semi-infinite vertical plate bounded by a porous medium are investigated in presence of induced magnetic field.

However, the study on unsteady MHD heat and mass transfer by free convective micropolar fluid flow over an infinite vertical porous medium under the action of transverse magnetic field with thermal diffusion have been studied numerically in the presence of constant heat source was considered by Alam *et al. (*2015). MHD free convection boundary layer flow over a permeable shrinking sheet in the presence of thermal radiation and chemical reaction was studied by Anarudah and Priyadarshini (2016). The unsteady MHD convective flow of a viscous incompressible electrically conducting fluid past an oscillating vertical porous plate in a porous medium with oscillatory heat flux in the presence of a uniform transverse magnetic field was studied by Chebos. *et al.* (2016). Mishra *et al.* (2017) studied the heat transfer effect on MHD flow of a micropolar fluid through porous medium with uniform heat source and radiation they also consider two dimensional governing equations. They examine the effect of heat transfer on electrically conducting MHD micropolar fluid flow along a semi-in finite horizontal plate with radiation and heat source, the uniform magnetic field has applied the principal flow direction.

Thermal radiation effect on heat and mass transfer in steady laminar boundary layer flow of an incompressible viscous micropolar fluid over a vertical flat plate, with the presence of a magnetic field was studied by Alouaoui and Hanini (2017). Rosseland approximation was applied to describe the radiative heat flux in the energy equation. The resulting similarity equations were solved numerically.

Abbas *et al.,* (2022) carried out a study on the influence of the Darcy–Forchheimer relation on third-grade fluid flow and heat transfer over an angled exponentially stretching sheet embedded in a porous medium. Kovic *et al.,* (2023) considers the stationary flow of a micropolar fluid between two plates under the influence of an external magnetic field at constant and different temperatures which is perpendicular to the direction of the flow. The system of differential equations were solved analytically and the solutions for velocity, microrotation and temperature was obtained. This research is to study the effect of thermal diffusion, Forchheimer number and Soret on MHD free convective heat generating unsteady micropolar fluid flow through a porous medium with constant heat and mass fluxes using numerical solution of implicit finite difference scheme.

2.0 Mathematical Analysis

The unsteady free convective MHD heat and mass transfer flow of electrically conducting incompressible viscous micro-polar fluid through an electrically non conducting infinite vertical porous medium with constant suction velocity with Forchheimer number was considered. The flow is considered to be in the x- direction, taken along the medium in uphill direction and y-axis is assumed normal to it. The physical configuration of the flow with coordinate system is shown in Figure 1.

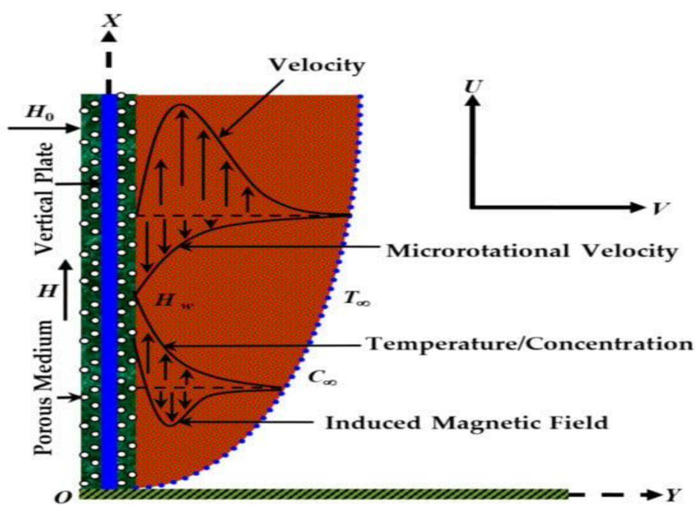

Figure 1 Physical Configuration and Coordinate System.

The temperature ($\bar{T} = T_\infty$) and concentration level ($\bar{C} = C_\infty$) of the fluid particles and the plate was assumed to be at rest at all points. Also the fluid temperature T_∞ and concentration C_∞ of uniform flow respectively.

The following assumptions was considered for the analysis;

I. In the energy equation viscous dissipation and Joule heating terms were been considered for high speed flow.

II. A constant heat source is used for heat generation.

III. The physical properties of fluid are considered to be constant.

IV. Changes in density with temperature is assumed only in the body force term which is approximated by the well-known Boussinesq's Approximation.

V. Considering unsteady fluid motion and infinite plate therefore all the flow variables will depend only on y ant time (τ).

VI. Micro-rotational vector of the form G = (0, 0, $\bar{\Gamma}$) where $\bar{\Gamma}$ is the micro-rotational component is considered.

VII. The magnetic Reynolds number of the fluid flow is assumed to the small enough and therefore the magnetic field is negligible in comparison with the applied transverse magnetic field.

Considering the assumptions above, the unsteady one-dimensional boundary layer equations of momentum, angular momentum, temperature and concentration are governed as follows;

Continuity equation $\frac{\partial v}{\partial y} = 0$ (1)

$$\frac{\partial u}{\partial \tau} + v\frac{\partial u}{\partial y} = \left(\upsilon + \frac{\chi}{\rho}\right)\frac{\partial^2 u}{\partial y^2} + \frac{\chi}{\rho}\frac{\partial \bar{\Gamma}}{\partial y} + g\beta(\bar{T} - T_\infty + g\beta^*(\bar{C} - C_\infty) - \frac{\upsilon}{K}u - \frac{\sigma\beta_0^2 u}{\rho} - \frac{\upsilon}{k}u^2 \quad (2)$$

The angular momentum

$$\frac{\partial \bar{\Gamma}}{\partial \tau} + v\frac{\partial \bar{\Gamma}}{\partial y} = \frac{\gamma}{\rho j}\frac{\partial^2 \bar{\Gamma}}{\partial y^2} - \frac{\chi}{\rho j}(2\bar{\Gamma} + \frac{\partial u}{\partial y}) \quad (3)$$

The energy equation

$$\frac{\partial \bar{T}}{\partial \tau} + v\frac{\partial \bar{T}}{\partial y} = \frac{K}{\rho c_p}\frac{\partial^2 \bar{T}}{\partial y^2} + \frac{1}{c_p}\left(\upsilon + \frac{\chi}{\rho}\right)\left(\frac{\partial u}{\partial y}\right)^2 - \frac{\delta\beta_0^2 u^2}{\rho c_p} + \frac{Q}{\rho c_p}(\bar{T} - T_\infty) \quad (4)$$

The concentration equation

$$\frac{\partial \bar{C}}{\partial \tau} + v\frac{\partial \bar{C}}{\partial y} = D_m\frac{\partial^2 \bar{C}}{\partial y^2} + \frac{D_m k_T}{c_s c_p}\frac{\partial^2 \bar{T}}{\partial y^2} \quad (5)$$

And the corresponding initial and boundary condition with constant heat and mass fluxes are given below;

$$\left.\begin{array}{l} \tau \le 0, u = 0, \bar{\Gamma} = 0, \bar{T} \to T_\infty, \bar{C} \to C_\infty \; every\ where \\ \tau > 0, u = 0, \bar{\Gamma} = -s\frac{\partial u}{\partial y}, \frac{\partial \bar{T}}{\partial y} = -\frac{Q}{k}, \frac{\partial \bar{C}}{\partial y} = -\frac{m}{D_m} at\ y = 0 \\ u = 0, \bar{\Gamma} = 0, \bar{T} \to T_\infty, \bar{C} \to C_\infty \; as\ y \to \infty \end{array}\right] \quad (6)$$

where y is Cartesian coordinate; u ,v are velocity components; g is the local acceleration due to gravity, β is thermal expansion coefficient, β^* is concentration expansion coefficient, υ kinematic viscosity, ρ is the density, χ is the vortex viscosity, σ is electrical conductivity, K is the permeability, j is micro-inertia per unit mass, γ is spin-gradient viscosity, k is thermal conductivity, c_p is the specific heat at constant pressure, c_s is a concentration susceptibility, Q is constant heat flux per unit area, s is a micro rotational constant, D_m is the coefficient of mass diffusivity, k_T is the thermal diffusion ratio.

2.1 Method of Solution

To solve the mathematical model, the governing equation (2)-(5) are transform into dimensionless form. From equation (1) we take v = constant and t = $-V_0$ (constant suction velocity).

Using the dimensionless quantities as;

$$Y=\frac{yV_0}{\upsilon}, U=\frac{u}{V_0}, t=\frac{\tau V_0^2}{\upsilon}, \Gamma=\frac{\bar{\Gamma}}{V_0^2}\upsilon, \quad T=\frac{kV_0(\bar{T}\cdot T_\infty)}{Q\upsilon}, \text{ and } C=\frac{kV_0(\bar{C}\cdot C_\infty)}{m\upsilon} \tag{7}$$

After simplifying equation (2)-(6) we obtain a system of nonlinear coupled partial differential equation in terms of dimensionless term as follows;

$$\frac{\partial U}{\partial t}-\frac{\partial U}{\partial Y}=(1+\Delta)\frac{\partial^2 U}{\partial Y^2}+\Delta\frac{\partial \Gamma}{\partial Y}+GrT+GmC-(Da+M)U-D_aU^2 \tag{8}$$

$$\frac{\partial \Gamma}{\partial t}-\frac{\partial \Gamma}{\partial Y}=\Lambda\frac{\partial^2 \Gamma}{\partial Y^2}-\lambda\left(2\Gamma+\frac{\partial U}{\partial Y}\right) \tag{9}$$

$$\frac{\partial T}{\partial t}-\frac{\partial T}{\partial Y}=\frac{1}{\Pr}\frac{\partial^2 T}{\partial Y^2}+E_c(1+\Delta)\left[\frac{\partial U}{\partial Y}\right]^2-\mathrm{ME_c}\mathrm{U}^2-\frac{\alpha}{\Pr}T \tag{10}$$

$$\frac{\partial C}{\partial t}-\frac{\partial C}{\partial Y}=\frac{1}{S_c}\frac{\partial^2 C}{\partial Y^2}+S_0\frac{\partial^2 T}{\partial Y^2} \tag{11}$$

With the initial and boundary conditions,

$$t\le 0, U=0, \Gamma=0, C=0 \ \ everywhere$$
$$t>0, U=0, \Gamma=-s\frac{\partial U}{\partial Y}, \frac{\partial T}{\partial Y}=-1, \partial C/\partial Y=-1, at\ Y=0$$
$$U=0, \Gamma=0, T=0, C=0 as\ Y\to\infty \tag{12}$$

where t stand for the dimensionless time, Y is the dimensionless Cartesian coordinate, U is the dimensionless velocity component, Γ is the dimensionless micro rotational component, T be the dimensionless temperature, C is the dimensionless concentration, where t stand for the dimensionless time, Y is the dimensionless Cartesian coordinate, U is the dimensionless velocity component, Γ is the dimensionless micro rotational component, T be the dimensionless temperature, C is the dimensionless concentration, $G_r=\frac{g\beta Q\upsilon^2}{kV_0^4}$ (Grashof number), $G_m=\frac{g\beta^* m\upsilon^2}{D_mV_0^4}$ (modify Grashof number), $\Delta=\frac{\chi}{\upsilon\rho}$ (Micro-rotational number), $D_a=\frac{\upsilon^2}{kV_0^2}$ (Darcy number), $\Lambda=\frac{\gamma}{\upsilon j\rho}$ (spin gradient viscosity number),$\lambda=\frac{\chi\upsilon}{V_0^2 j\rho}$ (vortex viscosity), $M=\frac{\sigma\beta_0^2\upsilon}{\upsilon V_0^2}$ (Magnetic force number),$P_r=\frac{\upsilon\rho C_p}{k}$ (Prandtl number), $E_c=\frac{kV_0^3}{Q\upsilon c_p}$ (Eckert number), $\alpha=\frac{Q\upsilon^2}{kV_0^2}$ (Heat source number), $S_c=\frac{\upsilon}{D_m}$ (Schmidt number), $S_r=\frac{QD_m^2k_T}{mk\upsilon c_sc_p}$ (Soret number).

2.2 Numerical Solution

The partial differential equation (8)-(11) are solved numerically by the implicit finite difference technique. Initially, the equations of velocity, angular velocity, temperature and concentration are discretized as follows;

$$\frac{U_i^{j+1}-U_i^j}{\Delta t}-\xi\frac{U_{i+1}^j-U_i^j}{\Delta Y}=(1+\Delta)\frac{U_{i-1}^{j+1}-2U_i^{j+1}+U_{i+1}^{j+1}}{(\Delta Y)^2}+\Delta\frac{\Gamma_{i+1}^j-\Gamma_i^j}{\Delta Y}+GrT_i^j+GmC_i^j-(Da+M)U_i^j-D_a{U^2}_i^j \tag{13}$$

$$\frac{\Gamma_i^{j+1}-\Gamma_i^j}{\Delta t}-\xi\frac{\Gamma_{i+1}^j-\Gamma_i^j}{\Delta Y}=\Lambda\frac{\Gamma_{i-1}^{j+1}-2\Gamma_i^{j+1}+\Gamma_{i+1}^{j+1}}{(\Delta Y)^2}-\lambda\left(2\Gamma+\frac{U_{i+1}^j-U_i^j}{\Delta Y}\right) \tag{14}$$

$$\Pr\frac{T_i^{j+1}-T_i^j}{\Delta t}-\Pr\xi\frac{T_{i+1}^j-T_i^j}{\Delta Y}=\left[\frac{T_{i-1}^{j+1}-2T_i^{j+1}+T_{i+1}^{j+1}}{(\Delta Y)^2}\right]+\Pr E_c(1+\Delta)\left(\frac{U_{i+1}^j-U_i^j}{\Delta Y}\right)^2+\Pr ME_cU_i^j-\alpha T_i^j \tag{15}$$

$$\frac{C_i^{j+1}-C_i^j}{\Delta t}-\xi\frac{C_{i+1}^j-C_i^j}{\Delta Y}=\frac{C_{i-1}^{j+1}-2C_i^{j+1}+C_{i+1}^{j+1}}{(\Delta Y)^2}+S_r\frac{T_{i-1}^j-2T_i^j+T_{i+1}^j}{(\Delta Y)^2} \tag{16}$$

After simplifying the equations above, the following solutions for velocity, angular velocity, temperature and concentration are obtained as follows;

$$-r1U_{i-1}^{j+1}+(1+2r1)U_i^{j+1}-r1U_{i+1}^{j+1}=(1-\xi r3-\Delta tDa)(U_i^j)^2+\xi r3U_{i+1}^j+r2(\Gamma_{i+1}^j-\Gamma_i^j)+\Delta tGrT_i^j+\Delta tGmC_i^j \tag{17}$$

$$-r4\Gamma_{i-1}^{j+1}+(1+2r4)\Gamma_i^{j+1}-r4\Gamma_{i+1}^{j+1}=(1-\xi r3-2\lambda\Delta t)\Gamma_i^j+\xi r3\Gamma_{i+1}^j-r5(U_{i+1}^j-U_i^j) \tag{18}$$

$$-r7T_{i-1}^{j+1}+(\Pr-2r7)_i^{j+1}-r7_{i+1}^{j+1}=(\Pr-r3\xi\Pr-\alpha\Delta t)T_i^j$$

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$$+r3\xi \text{Pr} T_{i+1}^{j} + r8\xi (U_{i+1}^{j} - U_{i}^{j})^2 + \Delta t \text{Pr} m Ec (U_{i}^{j})^2$$

(19)

$$-r7C_{i-1}^{j+1} + (Sc + 2r7)C_{i}^{j+1} - r7C_{i+1}^{j+1} = (Sc - Sc\xi r3)C_{i}^{j}$$

$$+Sc\xi r3 C_{i+1}^{j} + r6(T_{i-1}^{j} - 2T_{i}^{j} + T_{i+1}^{j}) \quad (20)$$

3.0 Results and Discussion

We have examined the MHD free convective heat generating unsteady micropolar fluid flow through a porous medium with effects of Forchhiemer's number, constant heat and mass fluxes. The system of governing equation is formulated, analyzed and solve using implicit finite difference scheme. To carry out analysis, some physical parameters namely Grashof number Gr, Mass Grashof number Gm, Prandtl number Pr, Schmidt number Sc, Time t were considered. The investigation was performed using the basic dimensionless parameters that governed the flow, to be specific the following choices where made; $\text{Pr} = 0.71$ which correspond to air $Sc = 0.26$, and $Gr > 4$.

The results for the velocity profile are obtained and presented in Figure 6 to 6. In Figure 2 **i**t is observed that the fluid velocity increases as M increases for fixed value of other parameters. It indicates that the hydro magnetic effect in the term MU^2 of the momentum equation increases the velocity in the hot channel plates. In Figure 3 it observed that the fluid velocity significantly rises as Gr increase for fixed values of other parameters. This means that the external cooling of the channel plates which result in thickening the boundary layer and assist the velocity. This shows that the flow is accelerating. It is also observed in Figure 4 that the velocity of the flow reduces as Gm increases for fixed value of other parameters. In Figure 5 the velocity also decreases as Da increase for fixed value of other parameters. This shows velocity boundary layer thickness increases with the rising in the value of Darcy parameter Da. It also observed that in Figure 6 the velocity decrease with increase in Δ micro-rotational number.

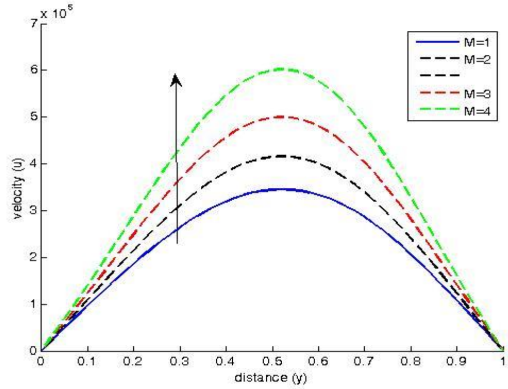

Figure 2 Velocity profile for difference value M. Effect of magnetic parameter on velocity when d =0.01, A =0.1, Pr =0.71, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, Ec = 0.001, Da = 0.02, Gr = 5, Gm = 5, and S =0.5.

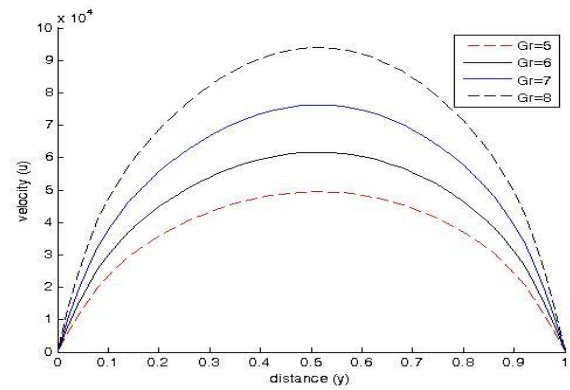

Figure 3 Velocity profile for difference value Gr. Effect of Grashof number on velocity when dd =0.01, A =0.1, Pr =0.71, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, Ec = 0.001, Da = 0.02, M = 1, Gm = 5, and S =0.5.

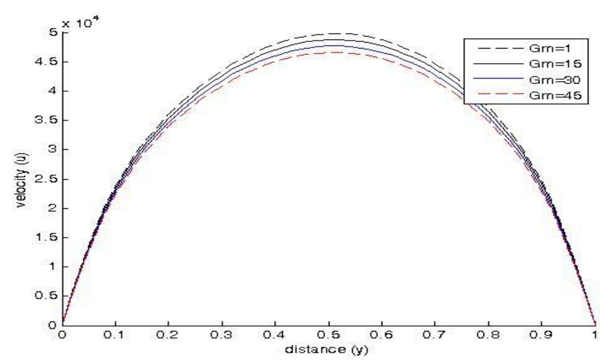

Figure 4 Velocity profile for difference value Gm. Effect of modified Grashof Number on velocity when d =0.01, A =0.1, Pr =0.71, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, Ec = 0.001, Da = 0.02, Gr = 5, M = 1, and S =0.5.

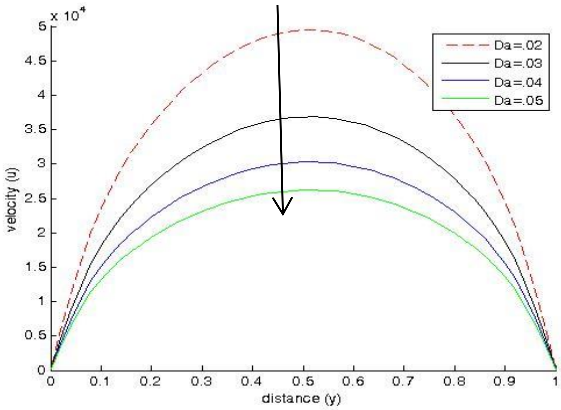

Figure 5 Velocity profile for difference value Da. Effect of Darcy Number on velocity when d =0.01, A =0.1, Pr =0.71, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, Ec = 0.001, Gm = 5, Gr = 5, M = 1, and S =0.5.

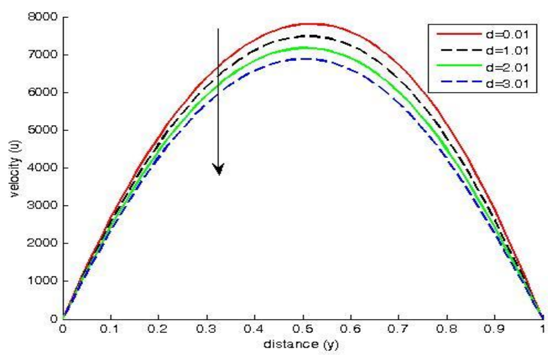

Figure 6 Velocity profile for difference value d. Effect of micro-rotational number on velocity when A =0.1, Pr =0.71, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, Ec = 0.001, Gm = 5, Gr = 5, M = 1, and S =0.5.

The result for the temperature profile were obtained and presented in Figure 7 to 11. Figure 7 illustrate the effect of M in temperature, it is observed the temperature increases as M increase for fixed value of other parameters. This implies the as the external magnetic drag increases it makes the temperature of the fluid to go higher, the increase in magnetic parameter reduce the magnitude of velocity profile in the boundary layer and the temperature of the boundary layer will rise. Figure.8 we observed that as the value of (Ec) Eckert number increased the temperature also increased. In Figure 9 increase in heat source parameter (α) make the temperature to decrease as well. In Figure 10 we observed that temperature increase as Δ = d decreases for fixed value of other parameters. Figure 11 present the effect of Prandtl number on temperature profile the fluid temperature increases with decrease in Prandtl number Pr. Prandtl number controls the relative thickness of the momentum and thermal boundary, when the thermal boundary exceed the thickness in the velocity boundary layer then the temperature will be high.

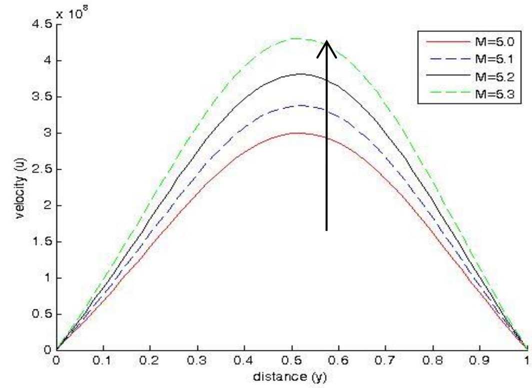

Figure 7 Temperature profile for difference value M. Effect of magnetic parameter on temperature when d =0.01, A =0.1, Pr =0.71, alp = 2, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, Ec = 0.001;, and S =0.5.

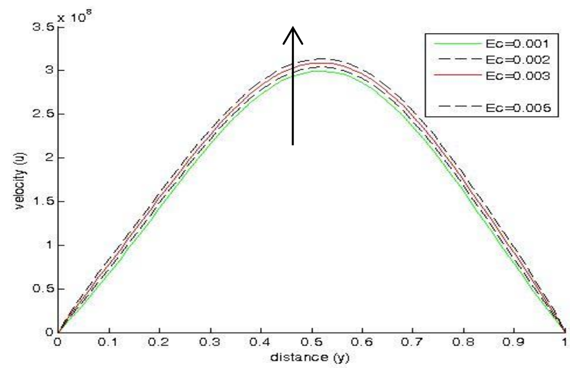

Figure 8 Temperature profile for difference value Ec. Effect of Eckert Number on temperature when d =0.01, A =0.1, Pr =0.71, alp = 2, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, M =1, and S =0.5.

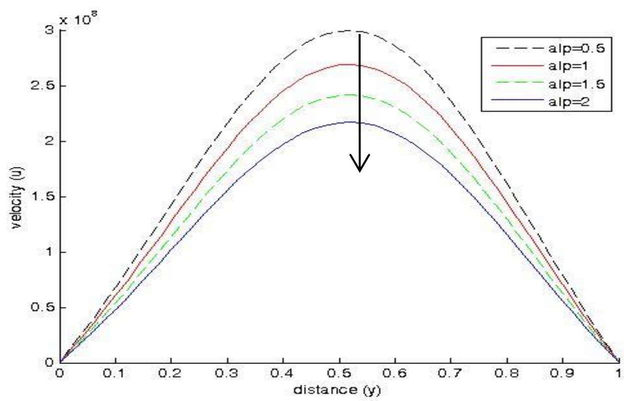

Figure 9 Temperature profile for difference value alp α. Effect of heat source number on temperature when d =0.01, A =0.1, Pr =0.71, Ec = 0.001, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, M =1, and S =0.5.

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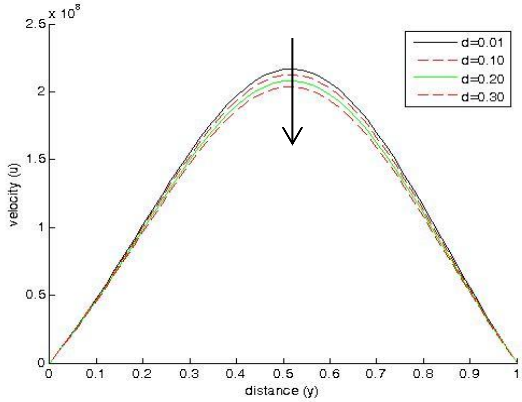

Figure 10 Temperature profile for difference value d. Effect of micro-rotational Number on temperature when alp =0.5, A =0.1, Pr =0.71, Ec = 0.001, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, M =1, and S =0.5.

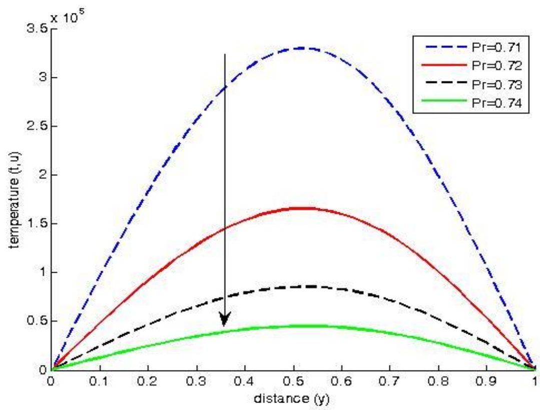

Figure 11 Temperature profile for difference value Pr. Effect of Prandtl Number on temperature when alp =0.5, A =0.1, Pr =0.71, Ec = 0.001, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, M =1, and S =0.5.

The angular velocity profile results are studied for different parameter like skin gradient viscosity number Λ and vortex viscosity number λ. It is presented in Figure 13 to 13. In Figure 12 it is observed the angular velocity decrease as the skin gradient viscosity Λ increase in for fixed value of other parameters. Figure 13 show that as the value of vortex viscosity λ increase so the angular velocity reduces for fixed value of other parameters. The boundary layer thickness increase with increase in angular velocity flow

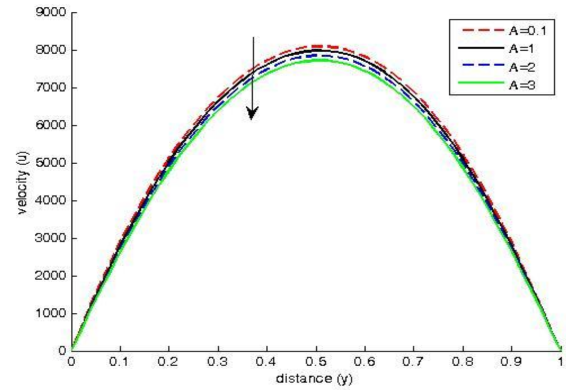

Figure 12 Angular velocity profile for difference value A. Effect of skin Gradient viscosity Number on angular velocity when alp =0.5, ld=0.1, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, and S =0.5.

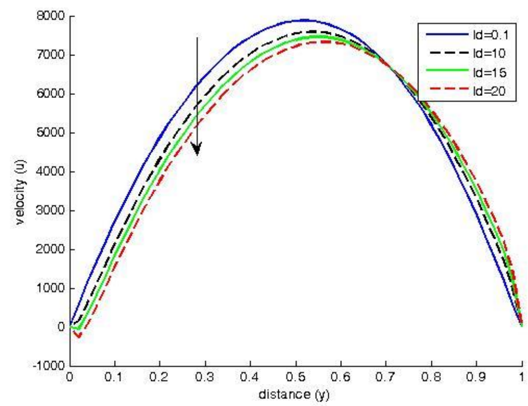

Figure 13 Angular velocity profile for difference value ld. Effect of Vortex Viscosity Number on Angular velocity when alp =0.5, A =0.1, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, and S =0.5.

The concentration profile obtained and presented for different value of Sc and Sr in Figure 14 to 17. A reverse flow is recognized due to suction as demonstrated in Figure 4.13 and 4.14 respectively when the heat source parameter S<2.and dt=0.002 however positive flow is observed when S= 2 and dt =0.02 as shown in Figure 14 and 15. In Figure 16 it is observed that concentration increases as Schmidt number Sc increase with time when other numerical values are constant. In Figure 17 it is also observed that the concentration decreases as Soret number Sr increases with time when other numerical values are treated as constant.

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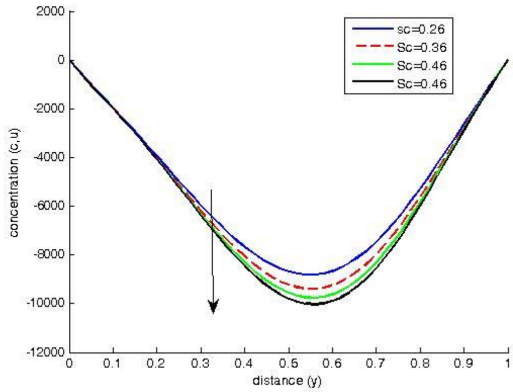

Figure 14 Concentration profile for difference value Sc. Effect of Schmidt Number on concentration when Sr =0.2, dt=0.02, dy = 1/m, y =0:dy:1, DY2=2.0*dy, and S =0.5 (reverse Flow).

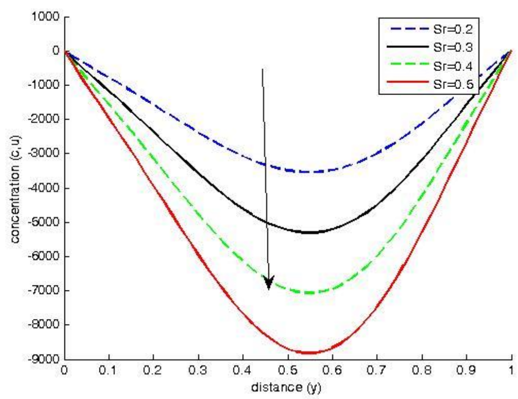

Figure 15 Concentration profile for difference value Sc. Effect of Schmidt Number on concentration when Sc =0.26, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, and S =0.5 (reverse flow).

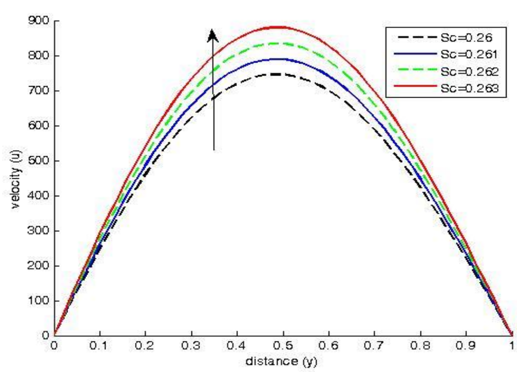

Figure 16 Concentration profile for difference value Sc. Effect of Schmidt Number on concentration when Sr =0.2, dt =0.02, dy = 1/m, y =0: dy: 1, DY2=2.0*dy, and S =2.

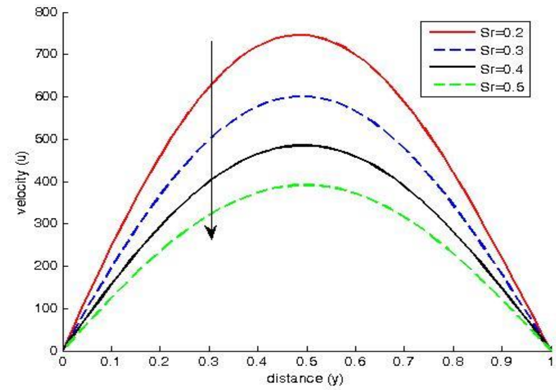

Figure 17 Concentration profile for difference value Sr. Effect of Soret Number on concentration when Sc = 0.26, dt=0.002, dy = 1/m, y =0:dy:1, DY2=2.0*dy, and S =2.

5.0 Conclusions

The study on MHD free convective micro-polar fluid flow over a vertical porous medium under magnetic field with heat and mass transfer in the presence of heat source, Forchheimer number have been studied. The investigation is performed for both cooling and heating problem. The partial differential equation of the non-dimensional form are solved numerically by the implicit finite difference technique. The flow characteristics of velocity, angular velocity, temperature and concentrations are computed and analyzed for the different parameters, such as thermal Grashof number Gr, modify Grashof Number Gm, Prandtl Number Pr, and Schmidt Number Sc. The results obtained shows that velocity profile increase with increases in parameter such as, Magnetic parameter M, and Gr and it also decreases with increase in Pr, Gm and Darcey number Da. A rises was observed in the temperature flow profiles with increase magnetic parameter M, and Eckert number Ec, and the temperature reduces with increase in Pr number, micro-rotational parameter d, and heat source α. In angular velocity profile the velocity reduced drastically when the Λ spin gradient viscosity parameter rises and vortex viscosity parameter λ. The concentration profiles was seen to increase with increase in Sc and decreases with increase in Sr.

Declaration of conflict of interest

The manuscript titled "Unsteady Free Convective Heat Generating Micropolar Fluid Flow through Porous Medium in the Presence of

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Forchheimer Number with MHD And Constant Heat and Mass Fluxes" by the authors, Yale I. D, and Sanusi I. This manuscript is a research article carried out during a study. The manuscript is an original work written by the authors and no part of it has been published before, nor is any part of it under consideration for publication at another journal and there is no conflict of interest among authors.

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