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Hall Current and Ion-Slip Effects on Unsteady MHD Fluid Flow past a Vertical Porous Plate in a Porous Medium with Rotation

M. R. Islam[1] and S. Nasrin[2]

[1] *Department of Mathematics, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalganj, Bangladesh.*
[2] *Department of Mathematics, Jagannath University, Dhaka, Bangladesh.*

Corresponding e-mail: mribsmrstu@yahoo.com

ABSTRACT

The unsteady MHD viscous incompressible flow of electrically conducting fluid along an infinite vertical porous plate under a strong transverse magnetic field with a rotational system has been studied with the consideration of both Hall and Ion slip currents. Similarity transformations have been applied to transform the given governing nonlinear coupled PDE into non dimensional forms of ODE. The Perturbation technique has been used to find the solution of obtaining non dimensional equations analytically and their graphical representations are plotted by using MatlabR2010a tools. The effects of the pertinent parameters on the velocity, temperature, and concentration distributions have been discussed in detail.

KeyWords: MHD fluid, Heat and Mass transfer, Porous plate, Porous medium, Rotation, Hall and Ion slip current

Nomenclature

g : acceleration due to the gravity
$\mathbf{B}$: magnetic field vector
$\mathbf{q}$: fluid velocity vector
$\mathbf{J}$: current density vector
u : velocity components along x-axis
v : velocity components along y - axis
w : velocity components along z - axis
t : dimensional time
β : volumetric coefficient of thermal expansion
β^* : volumetric coefficient of mass expansion
U_0 : uniform velocity
T : temperature of the fluid
T_w : constant temperature near the plate
T_∞ : temperature outside of the boundary layer
C : concentration in the fluid
C_w : constant concentration near the plate
C_∞ : concentration outside of the boundary layer
θ : dimensionless temperature
ϕ : dimensionless concentration
β_e : hall parameter
β_i : ion-slip parameter
V_0 : suction velocity parameter

Ω : angular velocity
ρ : density of the fluid
σ : conductivity of the fluid
ω_e : cyclotron frequency
τ_e : electron collision time
υ : kinematic viscosity
κ : permeability of the porous medium
D : coefficient of mass diffusivity
D_T : coefficient of thermal diffusivity
K_c : chemical reaction parameter
K' : permeability parameter
R : rotational parameter
M : magnetic parameter
G_r : thermal Grashof number
G_m : mass Grashof number
P_r : prandtl number
S_c : Schmidt number
S_0 : Soret number

1. Introduction

The physical problems of magneto-hydrodynamic (MHD) flow have gained acceptance among researchers because of its practical applications such as electromagnetic flow meters, electromagnetic pumps, and MHD power generator cooling of clear reactors, aerodynamic heating, etc. MHD fluid flow systems, including Hall current and ion-slip, are extremely important in geophysics, astrophysics, and many engineering and industrial processes because most of the universe is filled with vastly charged particles and surrounded by a magnetic field, and so the concept of continuity becomes applicable. From the point of view, several authors have explained the effect of the magnetic field applied transversely with the hall and ion-slip current on the heat and mass flow of the electrically conducting fluid.

Singh and Dikshit [1] investigated an electrically conducting incompressible viscous fluid flow over a semi-infinite porous plate with the influence of a strong magnetic field and large suction. Basant and Apere [2] investigated the unsteady MHD Couette flows of an incompressible electrically conducting viscous fluid in the presence of combined hall and ion slip currents with rotation. Aboeldahab and Elbarbary [3] investigated the hall effect on the heat and mass transfer along the vertical plates under the influence of combined buoyancy force of heat and species propagation in the presence of a transversed applied uniform magnetic field. Attia [4]-[6] inspected the effect of hall and ion-slip current on the dusty fluid, viscoelastic fluid past between two parallel non-conducting porous plates and also in a circular pipe. Seddeek [7] has explained the effect of Hall and ion-slip currents of an incompressible, steady electrically conducting magneto micropolar fluid, where the heat transfer flow is induced by stretching sheet with suction and blowing. Ghara et al. [8] carried out an investigation of the effect of hall and ion-slip current on an unsteady viscous incompressible electrically conducting fluid flow over two infinite electrically non-conducting horizontal porous plates. Anika et al. [9] explained the numerical solution of a heat transferable unsteady laminar fluid flow past an infinite vertical rotating porous plate with hall effect. Ram [10] studied the effect of the hall and ion-slip currents on the free convection heat-generating flow in a rotating system with a strong magnetic field which is perpendicular to the plate. Debnath et al. [11] analyzed the hydromagnetic unsteady flow of electrically conducting fluid along the porous plate in a rotating system with hall current. Narayana et al. [12] examined the heat and mass transfer fluid flow with the influence of hall current effect along a vertical porous plate under the combined buoyancy force effects of thermal and species diffusion in the presence of the applied transverse uniform magnetic field. Dulal and Babulal [13] analyzed the thermal radiation and first-order chemical reaction effects on the oscillatory convective heat and mass transfer flow with suction, injection, and Hall current in a rotating vertical porous channel. Seddeek and Aboeldahab [14] investigated an unsteady free convection and electrically conducting fluid flow with the influence of Hall currents and radiation of a gray gas along an infinite vertical porous plate. The effects of Hall current and ion slip on the rate of entropy generation of the couple stress strad fluid with velocity slip and temperature wall were investigated analytically by Opanga et al [15]. Analytical explanation of the MHD heat and mass transferable viscoelastic fluid flow along an infinite oscillating porous plate in the presence of hall current investigated by Nasrin et al [16]. Also, Nasrin et al. [17] investigated the effect of the hall and ion-slip current on an incompressible, steady flow of electromagnetic fluid along a vertical porous plate in a rotating system.

Hence our aim is to study, “Hall current and ion-slip effect on unsteady MHD fluid flow past a vertical porous plate in a rotating system”, comparably which is the unsteady case of the work of Sonia Nasrin et al. [17]. The system of nonlinear coupled equations have investigated and solved analytically by using the perturbation technique. The obtained results have been shown graphically with reference to different flow parameters by using Matlab and its behavior discussed in detail.

2. Mathematical Model of the Flow

The heat and mass transfer flow model of an unsteady incompressible viscous electrically conducting fluid embedded in an electrically non-conducting vertical porous plate in a rotating system taking with Hall and Ion-slip current into account. Let the porous plate be fixed in an upward direction, which is along the x-axis and the direction of flow parallel to the plate, y-axis is normal to it and the system rotated about y-axis. Let the velocity components are u, v and w relative to the frame of reference. At time $t \le 0$ the plate and fluid are at rest and thereafter i.e. at time $t > 0$, the plate is oscillated in its own plane with a velocity $u = U_0 \cos pt + L\dfrac{\partial u}{\partial y}$ along x-axis and $w = U_0 \sin pt + L\dfrac{\partial w}{\partial y}$ along z-axis the temperature of the plate. The temperature of the plate and the concentration is varies from T_w to T_∞ and C_w to C_∞. The geometry of the model is shown in Fig.1.

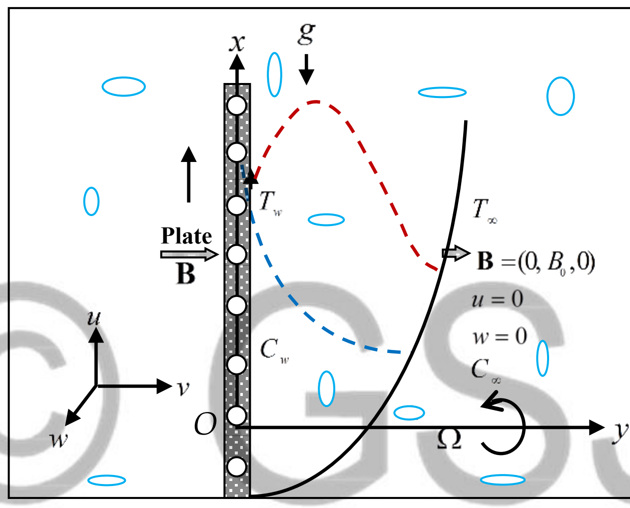

Fig.1: Physical Configuration and Coordinate System

Taking with the effect of Hall and Ion-slip current, the generalized Ohm's law may be put in the form:

$$\mathbf{J} + \frac{\beta_e}{B_0}(\mathbf{J}\wedge\mathbf{B}) = \sigma(\mathbf{q}\wedge\mathbf{B}) + \frac{\beta_e\beta_i}{B_0^2}(\mathbf{J}\wedge\mathbf{B})\wedge\mathbf{B} \quad ; \text{ where } \beta_e = \omega_e\tau_e$$

A uniform magnetic field $\mathbf{B}$ is applied perpendicular to the plate and acting along the y-axis so that $\mathbf{B} = (0, B_0, 0)$. Since the plate is extended to infinite length, then all the physical variables in the problem are a function of y and t alone. Then the continuity equation gives $v = -v_0$ everywhere in the flow, where v_0 is the suction velocity at the plates. It is assumed that the magnetic Reynolds number as a small quantity so that the induced magnetic field can be neglected. Thus accordance with the above assumptions the basic equations relevant to the problem are as follows:

$$\frac{\partial u}{\partial t} - v_0\frac{\partial u}{\partial y} = g\beta(T - T_\infty) + g\beta^*(C - C_\infty) + \upsilon\left(\frac{\partial^2 u}{\partial y^2}\right) - \frac{\upsilon}{\kappa}u - \frac{1}{\rho}\sigma B_0^{\,2}\left[\frac{\beta_e w + (1+\beta_e\beta_i)u}{(1+\beta_e\beta_i)^2 + \beta_e^{\,2}}\right] - 2\Omega_0 w \tag{1}$$

$$\frac{\partial w}{\partial t} - v_0\frac{\partial w}{\partial y} = \upsilon\left(\frac{\partial^2 w}{\partial y^2}\right) - \frac{\upsilon}{\kappa}w + \frac{1}{\rho}\sigma B_0^{\,2}\left[\frac{\beta_e u - (1+\beta_e\beta_i)w}{(1+\beta_e\beta_i)^2 + \beta_e^{\,2}}\right] + 2\Omega_0 u \tag{2}$$

$$\frac{\partial T}{\partial t} - v_0\frac{\partial T}{\partial y} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} \tag{3}$$

$$\frac{\partial C}{\partial t} - v_0\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} + D_T\frac{\partial^2 T}{\partial y^2} - K_1(C - C_\infty) \tag{4}$$

with boundary conditions

$$\left.\begin{array}{l} u = U_0 \cos pt + L\dfrac{\partial u}{\partial y} \;,\;\; w = U_0 \sin pt + L\dfrac{\partial w}{\partial y} \;,\;\; T = T_w \;,\; C = C_w \;\text{ at } y = 0 \\ u = 0, \;\; w = 0 \;,\;\; T \to T_\infty \;,\; C \to C_\infty \;\text{ at } y \to \infty \end{array}\right\} \tag{5}$$

It is assumed that $q = u + iw$; $(i^2 = -1)$, a velocity component as complex form. Then the above equations can be written as in the following form:

$$\frac{\partial q}{\partial t} - v_0 \frac{\partial q}{\partial y} = g\beta(T - T_\infty) + g\beta^*(C - C_\infty) + \upsilon\frac{\partial^2 q}{\partial y^2} - \frac{\upsilon}{\kappa}q + \frac{\sigma B_0^{\,2}\left[i\beta_e q - (1+\beta_e\beta_i)q\right]}{\rho\left[(1+\beta_e\beta_i)^2 + \beta_e^{\,2}\right]} + 2\Omega_0 iq \tag{6}$$

$$\frac{\partial T}{\partial t} - v_0 \frac{\partial T}{\partial y} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} \tag{7}$$

$$\frac{\partial C}{\partial t} - v_0 \frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} + D_T\frac{\partial^2 T}{\partial y^2} - K_1(C - C_\infty) \tag{8}$$

with boundary conditions:

$$\left.\begin{array}{l} q = U_0 e^{ipt} + L\dfrac{\partial q}{\partial y} \;,\;\; T = T_w \;,\; C = C_w \;\text{ at } y = 0 \\ q = 0, \;\; T \to T_\infty \;,\; C \to C_\infty \;\text{ at } y \to \infty \end{array}\right\} \tag{9}$$

3. Mathematical Formulation

To make the non-dimensional form of the above governing equations, introducing the following non-dimensional variables:

$$q^* = \frac{q}{U_0},\; y^* = \frac{yU_0}{\upsilon},\; t^* = \frac{tU_0^{\,2}}{\upsilon},\; \theta = \frac{T - T_\infty}{T_w - T_\infty},\; \varphi = \frac{C - C_\infty}{C_w - C_\infty}$$

By using these non-dimensional variables into the equations (6)-(9), dropping the asterisk sign the non-dimensional form of the governing equations are as follows:

$$\frac{\partial q}{\partial t} - V_0\frac{\partial q}{\partial y} = G_r\theta + G_m\phi + \frac{\partial^2 q}{\partial y^2} - \frac{q}{K'} + M^2\left\{\frac{1+\beta_e\beta_i}{(1+\beta_e\beta_i)^2 + \beta_e^2} + \frac{i\beta_e}{(1+\beta_e\beta_i)^2 + \beta_e^2}\right\}q + iRq \tag{10}$$

$$P_r\frac{\partial\theta}{\partial t} - V_0 P_r\frac{\partial\theta}{\partial y} = \frac{\partial^2\theta}{\partial y^2} \tag{11}$$

$$S_c\frac{\partial\varphi}{\partial t} - V_0 S_c\frac{\partial\varphi}{\partial y} = \frac{\partial^2\varphi}{\partial y^2} + S_0 S_c\frac{\partial^2\theta}{\partial y^2} - S_c K_c\varphi \tag{12}$$

with boundary conditions:

$$\left.\begin{array}{l} q = e^{ipt} + L_1\dfrac{\partial q}{\partial y} \;,\;\; \theta = 1 \;,\; \phi = 1 \;\text{ at } y = 0 \\ q = 0, \;\; \theta = 0 \;,\; \phi = 0 \;\text{ at } y \to \infty \end{array}\right\} \tag{13}$$

Where the dimensionless parameters are

$V_0 = \frac{v_0}{U_0}$ is the Suction Parameter, $G_r = \frac{\upsilon g\beta}{U_0^3}(T_w - T_\infty)$ is the Grashof number, $G_m = \frac{\upsilon g\beta^*}{U_0^3}(C_w - C_\infty)$ is the Mass Grashof Number, $K' = \frac{\kappa U_0^2}{\upsilon^2}$ is the Permeability parameter, $R = \frac{2\Omega_0\upsilon}{U_0^2}$ is the Rotational parameter, $M = \sqrt{\frac{\sigma\upsilon B_0^2}{\rho U_0^2}}$ is the Magnetic parameter, $P_r = \frac{\upsilon\rho C_p}{\kappa}$ is the Prandtl Number, $S_c = \frac{\upsilon}{D}$ is the Schmidt number, $L_1 = \frac{LU_0}{\upsilon}$ is the coefficient of the flux, $S_0 = \frac{D_T}{\upsilon}\frac{T_w - T_\infty}{C_w - C_\infty}$ is the Sorret number and $K_c = \frac{K_1\upsilon}{U_0^{\,2}}$ is the Chemical reaction parameter.

To solve the above equations we introduce a perturbation method that has been applied with $R_c \ll 1$ as the perturbation parameter. This assumption is quite consistent as the model under consideration is valid only for slightly elastic fluid. From Umanaheswar et.al (2013), we have considered the following transformation

$$q = q_0 + R_c q_1 + O(R_c)^2 \;;\quad \theta = \theta_0 + R_c\theta_1 + O(R_c)^2 \;;\quad \varphi = \varphi_0 + R_c\varphi_1 + O(R_c)^2$$

Substituting the value of q , θ and φ in the above equations, the following equations have been obtained:

Zeros order equations

$$\frac{\partial q_0}{\partial t} - V_0\frac{\partial q_0}{\partial y} = G_r\theta_0 + G_m\phi_0 + \frac{\partial^2 q_0}{\partial y^2} - \frac{q_0}{K'} + M^2\left\{\frac{1+\beta_e\beta_i}{(1+\beta_e\beta_i)^2+\beta_e^2} + \frac{i\beta_e}{(1+\beta_e\beta_i)^2+\beta_e^2}\right\}q_0 + iRq_0$$

$$\frac{\partial \theta_0}{\partial t} - V_0\frac{\partial \theta_0}{\partial y} = \frac{1}{P_r}\frac{\partial^2\theta_0}{\partial y^2}$$

$$S_c\frac{\partial \varphi_0}{\partial t} - V_0 S_c\frac{\partial \varphi_0}{\partial y} = \frac{\partial^2\varphi_0}{\partial y^2} + S_0 S_c\frac{\partial^2\theta_0}{\partial y^2} - K_c S_c\varphi_0$$

First order equations

$$\frac{\partial q_1}{\partial t} - V_0\frac{\partial q_1}{\partial y} = G_r\theta_1 + G_m\phi_1 + \frac{\partial^2 q_1}{\partial y^2} - \frac{q_1}{K'} + M^2\left\{\frac{1+\beta_e\beta_i}{(1+\beta_e\beta_i)^2+\beta_e^2} + \frac{i\beta_e}{(1+\beta_e\beta_i)^2+\beta_e^2}\right\}q_1 + iRq_1$$

$$\frac{\partial \theta_1}{\partial t} - V_0\frac{\partial \theta_1}{\partial y} = \frac{1}{P_r}\frac{\partial^2\theta_1}{\partial y^2}$$

$$S_c\frac{\partial \varphi_1}{\partial t} - V_0 S_c\frac{\partial \varphi_1}{\partial y} = \frac{\partial^2\varphi_1}{\partial y^2} + S_0 S_c\frac{\partial^2\theta_1}{\partial y^2} - K_c S_c\varphi_1$$

Corresponding boundary conditions are

$$\left.\begin{array}{l} q_0 = 0,\ q_1 = 0\ ,\theta_0 = 1\ ,\ \theta_1 = 0\ ,\ \varphi_0 = 1 \text{ and } \varphi_1 = 0 \quad \text{at} \quad y = 0 \\ q_0 = 0,\ q_1 = 0\ ,\theta_0 = 0\ ,\ \theta_1 = 0\ ,\ \varphi_0 = 0 \text{ and } \varphi_1 = 0 \text{ at} \quad y \to \infty \end{array}\right\}$$

In order to reduce the system of partial differential equation to a system of ordinary differential equation, it is assumed that

$$q_0(y,t) = q_{00}(y) + q_{01}(y)e^{ipt};\quad q_1(y,t) = q_{10}(y) + q_{11}(y)e^{ipt};\quad \theta_0(y,t) = \theta_{00}(y) + \theta_{01}(y)e^{ipt}$$
$$\theta_1(y,t) = \theta_{10}(y) + \theta_{11}(y)e^{ipt};\quad \varphi_0(y,t) = \varphi_{00}(y) + \varphi_{01}(y)e^{ipt}\;;\quad \varphi_1(y,t) = \varphi_{10}(y) + \varphi_{11}(y)e^{ipt}$$

Substituting this value in the above equations, it is found that

$$q_{00}'' + V_0 q_{00}' + \left(iR + M^2(A+iB) - \frac{1}{K'}\right)q_{00} = -G_r\theta_{00}'' - G_m\varphi_{00}''$$

$$q_{01}'' + V_0 q_{01}' + \left(iR + M^2(A+iB) - \frac{1}{K'} - ip\right)q_{01} = -G_r\theta_{01}'' - G_m\phi_{01}''$$

$$q_{10}'' + V_0 q_{10}' + \left(iR + M^2(A+iB) - \frac{1}{K'}\right)q_{10} = -G_r\theta_{10}'' - G_m\varphi_{10}''$$

$$q_{11}'' + V_0 q_{11}' + \left(iR + M^2(A+iB) - \frac{1}{K'} - ip\right)q_{11} = -G_r\theta_{11}'' - G_m\phi_{11}''$$

$$\theta_{00}'' + P_rV_0\theta_{00}' = 0 \;;\quad \theta_{01}'' + P_rV_0\theta_{01}' - ip\theta_{01} = 0 \;;\quad \theta_{10}'' + P_rV_0\theta_{10}' = 0 \;;\quad \theta_{11}'' + P_rV_0\theta_{11}' - ip\theta_{11} = 0$$

$$\varphi_{00}'' + V_0S_c\varphi_{00}' - K_cS_c\varphi_{00} = -S_0S_c\theta_{00}'' \;;\quad \varphi_{01}'' + V_0S_c\varphi_{01}' - (K_c + ip)S_c\varphi_{01} = -S_0S_c\theta_{01}$$

$$\varphi_{10}'' + V_0S_c\varphi_{01}' - K_cS_c\varphi_{10} = -S_0S_c\theta_{10}'' \;;\quad \varphi_{11}'' + V_0S_c\varphi_{11}' - (K_c + ip)S_c\varphi_{11} = -S_0S_c\theta_{11}''$$

Corresponding boundary conditions are as follows:

$$\left.\begin{array}{l} q_{00} = L_1\dfrac{\partial q_{00}}{\partial y},\ q_{01} = 1 + L_1\dfrac{\partial q_{01}}{\partial y},\ q_{10} = L_1\dfrac{\partial q_{10}}{\partial y},\ q_{11} = L_1\dfrac{\partial q_{11}}{\partial y}, \\ \theta_{00} = 1,\ \theta_{01} = 0\ ,\ \theta_{10} = 0,\ \theta_{11} = 0\ ,\ \phi_{00} = 1\ ,\ \phi_{01} = 0\ ,\ \phi_{10} = 0 \text{ and } \phi_{11} = 0 \end{array}\right\} \text{ at } y = 0$$

$$\left.\begin{array}{l} q_{00} = 0,\ q_{01} = 0,\ q_{10} = 0,\ q_{11} = 0\ , \\ \theta_{00} = 1,\ \theta_{01} = 0\ ,\ \theta_{10} = 0,\ \theta_{11} = 0\ ,\ \varphi_{00} = 1\ ,\ \varphi_{01} = 0\ ,\ \varphi_{10} = 0 \text{ and } \varphi_{11} = 0 \end{array}\right\} \text{ at } y \to \infty$$

where, $A=(1+\beta_e\beta_i)\left[(1+\beta_e\beta_i)^2+\beta_e^2\right]^{-1}$ and $B=\beta_e\left[(1+\beta_e\beta_i)^2+\beta_e^2\right]^{-1}$

The above equations shows that the couple ordinary linear differential equations, which can be solved easily by analytically.

$\theta_{00}=e^{-m_2 y}$; $\theta_{01}=0$; $\theta_{10}=0$; $\theta_{11}=0$; $\varphi_{00}=a_1e^{-m_2 y}+a_2e^{-m_{10}y}$; $\varphi_{01}=0$; $\varphi_{10}=0$; $\varphi_{11}=0$;
$q_{00}=a_3e^{-m_2 y}+a_4e^{-m_{10}y}+a_5e^{-m_{16}y}$; $q_{01}=a_6e^{-m_{18}y}$ $q_{10}=0$; $q_{11}=0$

Finally the solutions of the equations yields velocity, temperature and the concentration profiles of the flow field are as follows

$$q=a_3e^{-m_2 y}+a_4e^{-m_{10}y}+a_5e^{-m_{16}y}+a_6e^{-m_{18}y}e^{ipt}$$
$$\theta=e^{-m_2 y}$$
$$\varphi=a_1e^{-m_2 y}+a_2e^{-m_{10}y}$$

4. Results and discussion:

The physical situation of the problem has been shown by the influence of the non-dimensional governing parameters, namely Hall parameter (β_e) the Ion-slip parameter (β_i) Suction parameter (V_0), Grashof number(G_r), Magnetic field parameter(M), Prandtl number (P_r), Rotational parameter (R), Chemical reaction parameter (K_c), Schmidt number (S_c), Soret number (S_0). The effects of various parameters have chosen arbitrary.

The displayed figures (a) of Figs.2-9 have shown that the primary velocity distribution u and (b) of Figs.2-9 have shown that the secondary velocity distribution w for the different values of the various parameter. From the boundary conditions, it observed that the initial value of the velocity is oscillating flux; it can give various values which depend on L_1 , p and t . Therefore in each graph, it has shown that two types of figures, one of its by solid line and another is smooth dashes line for the values of $L_1=0, p=0$ and $L_1=0.5, p=\pi/2$ respectively with time fixed at $t=1$. Starting point of the velocity can easily identified by the values of L_1, p and t , which are displayed in Fig.2(a) and Fig.2(b).

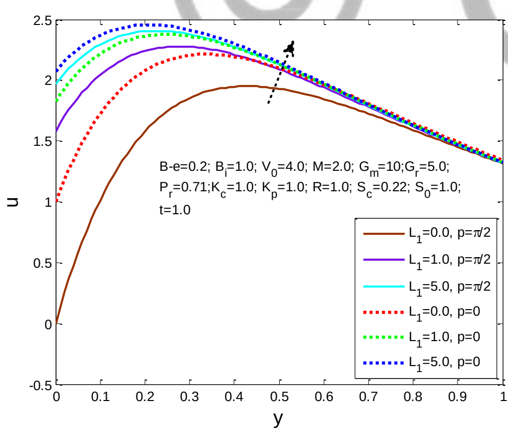

Fig. 2(a) : Primary Velocity profiles u for different values of L_1 and p

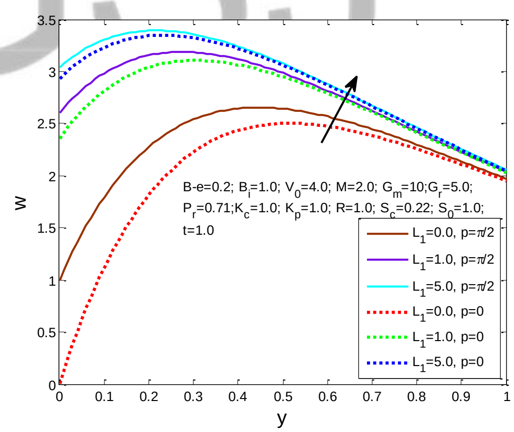

Fig. 2(b) : Seceondary velocity profiles w for different values of L_1 and p

Velocity distributions: It depicts from Figs.3(a)-3(b) that, the primary velocity u and the secondary velocity w are decreased in both cases with the increase of Hall parameter β_e. From Fig.4(a), the primary velocity u decreases with the increase of Ion-slip parameter β_i but Fig.4(b) shows that the secondary velocity w decreases rapidly with the increase of Ion-slip parameter β_i. In Figs.5(a)-5(b), the primary velocity and the secondary velocity are rapidly increased with the increase of Magnetic parameter M. Figs.6(a)-6(b) describe that, the velocity w is more rapidly decreased than u with the increase of Suction parameter. The velocity u and w both are increased with the increasing values of Grashof number G_r which are shown in Figs.7(a)-7(b). It has seen from Figs.8(a)-8(b) and Figs.9(a)-(b), both of the cases u and w have decreased with the increasing values of Prandtl number P_r and rotational parameter R .

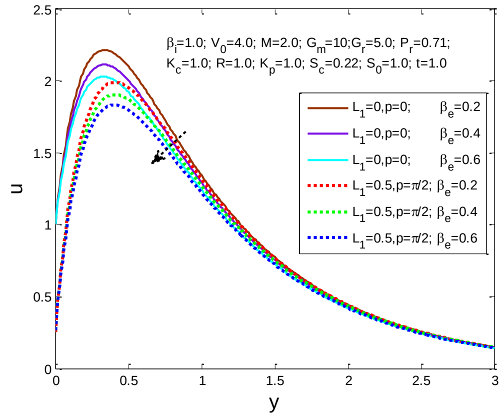

Fig. 3(a) : Primary Velocity profiles u for different values of Hall parameter β_e

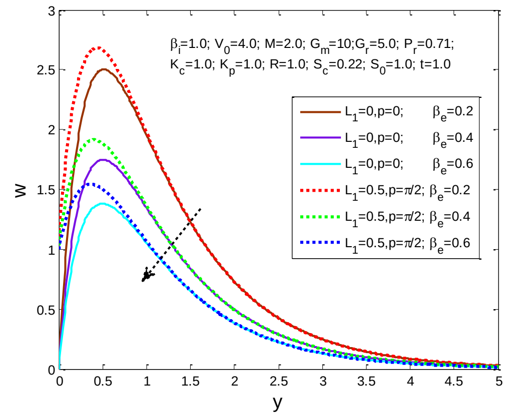

Fig. 3(b) : Seceondary velocity profiles w for different values of Hall parameter β_e

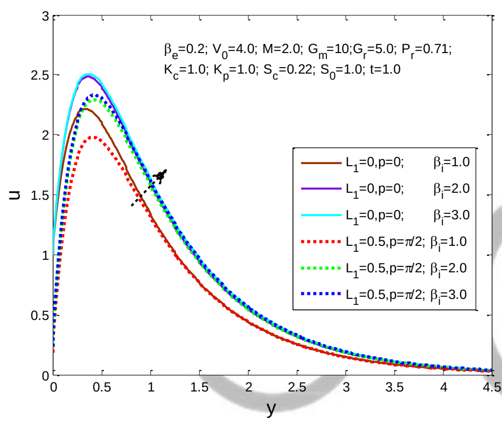

Fig. 4(a) : Primary Velocity profiles u for different values of Ion-slip parameter β_i

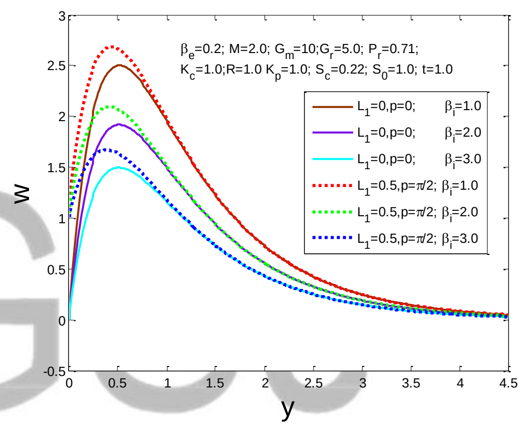

Fig. 4(b) : Seceondary velocity profiles w for different values of Ion-slip parameter β_i

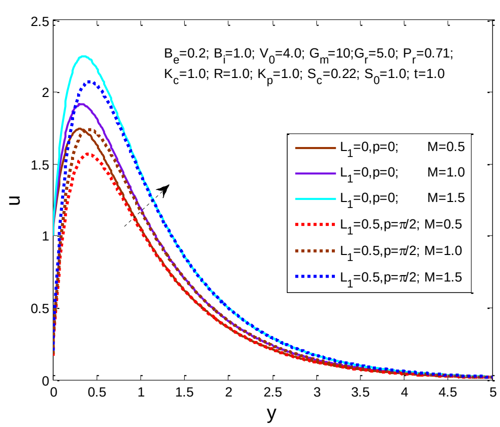

Fig. 5(a) : Primary Velocity profiles u for different values of Magnetic parameter M

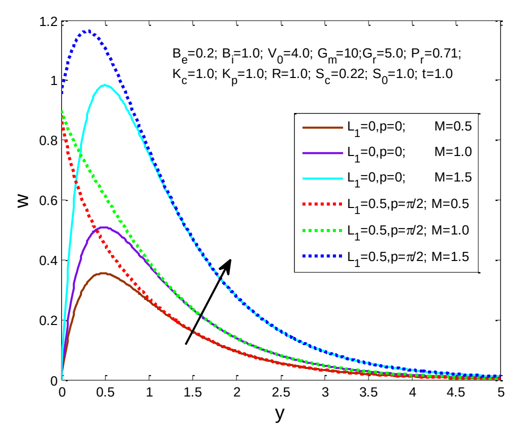

Fig. 5(b) : Seceondary velocity profiles w for different values of Magnetic parameter M

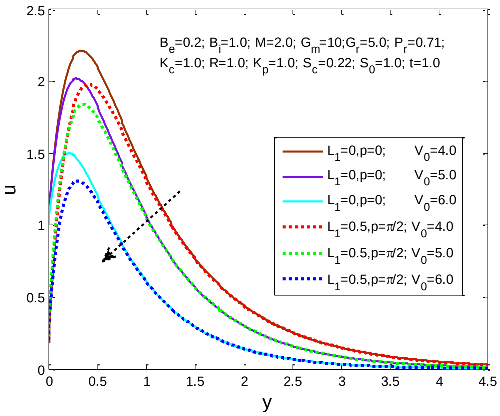

Fig. 6(a) : Primary Velocity profiles u for different values of Suction parameter V_0

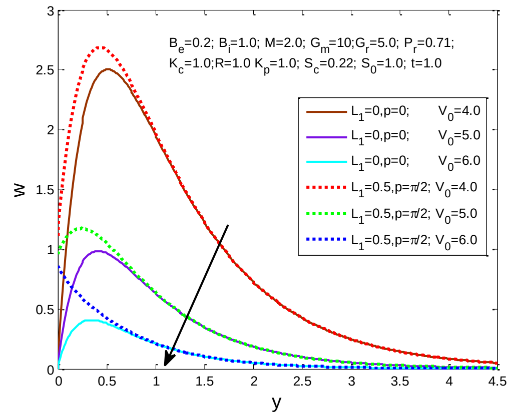

Fig. 6(b) : Seceondary velocity profiles w for different values of Suction parameter V_0

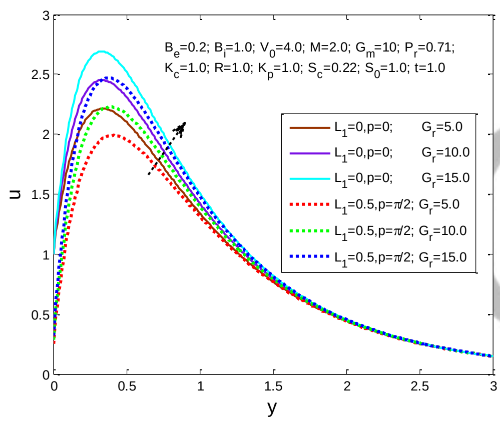

Fig. 7(a) : Primary Velocity profiles u for different values of Grashof number G_r

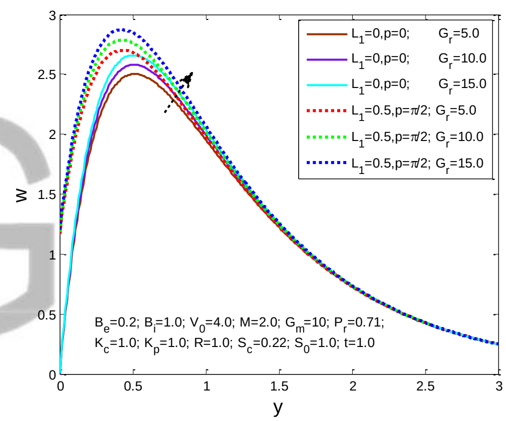

Fig. 7(b) : Seceondary velocity profiles w for different values of Grashof number G_r

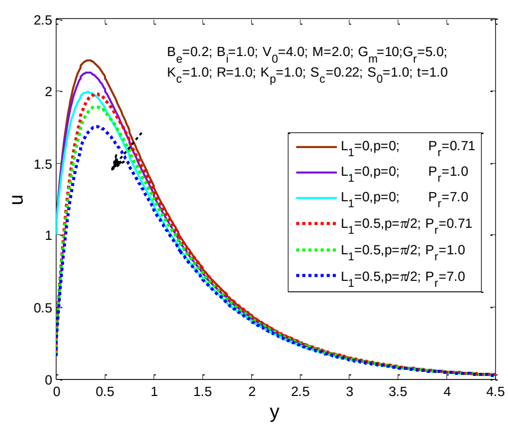

Fig. 8(a) : Primary Velocity profiles u for different values of Prandtl number P_r

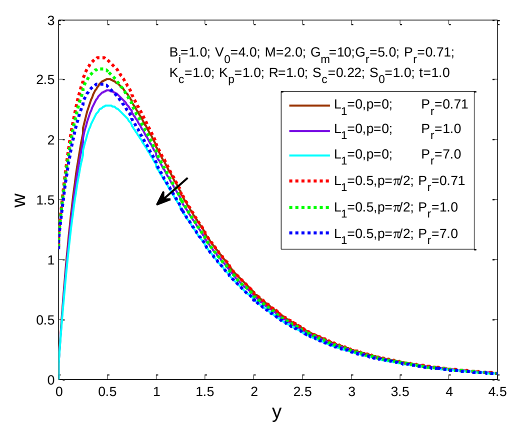

Fig. 8(b) : Seceondary velocity profiles w for different values of Prandtl number P_r

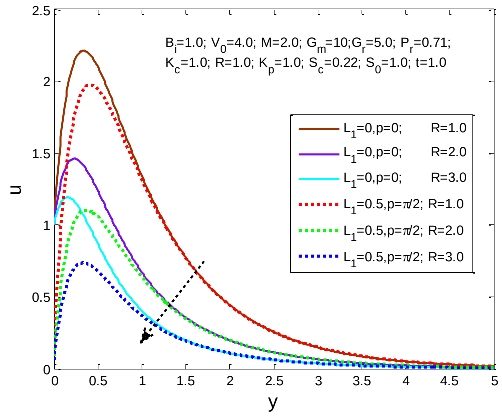

Fig. 9(a) : Primary Velocity profiles u for different values of Rotational parameter R

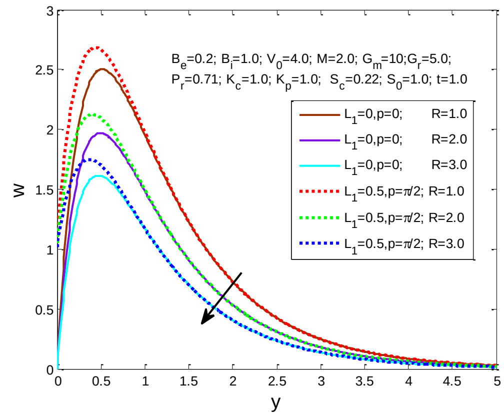

Fig. 9(b) : Seceondary velocity profiles w for different values of Rotational parameter R

Temperature and Concentration distributions: Figs.10-11 exhibit the temperature θ decreases with the increasing values of the Prandtl number P_r and the suction parameter V_0. It is observed from Figs.12-14 that, concentration φ is decreased with the increase of V_0, S_0 and S_c. Fig.15 leads to φ is very minor increasing effect within $0 < y < 1.4$, further it has minor decreasing effect from $y > 1.4$ with the increase of chemical reaction parameter K_c.

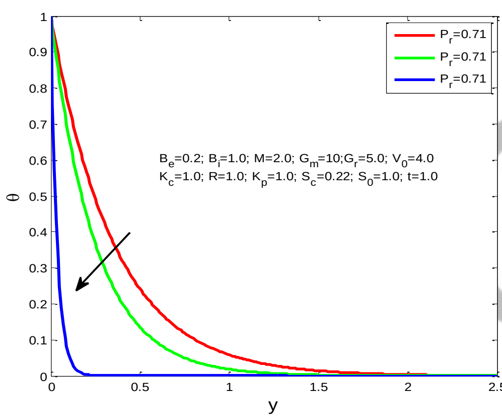

Fig. 10 : Temperature distribution θ for different values Prandtl number P_r

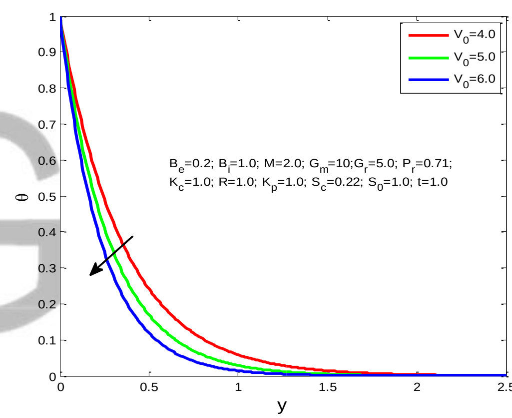

Fig. 11 : Temperature distribution θ for different values Suction parameter V_0

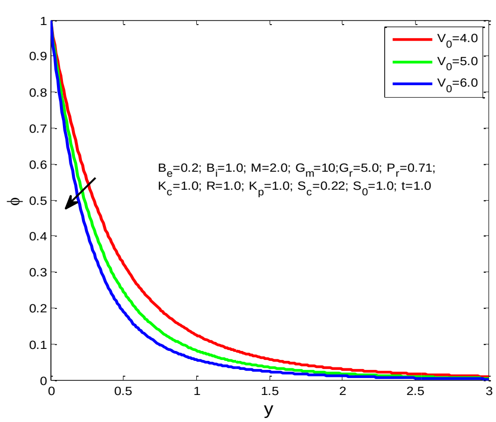

Fig. 12 : Concentration distribution φ for different values Suction parameter V_0

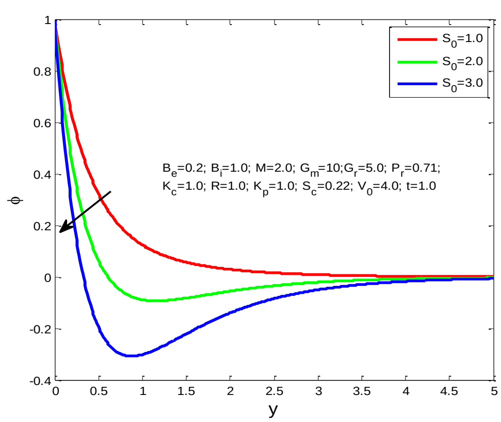

Fig. 13 : Concentration distribution φ for different values Sorret number S_0

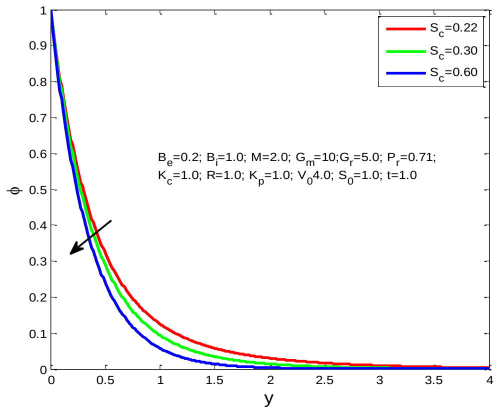

Fig. 14 : Concentration distribution φ for different values Schmidt number S_c

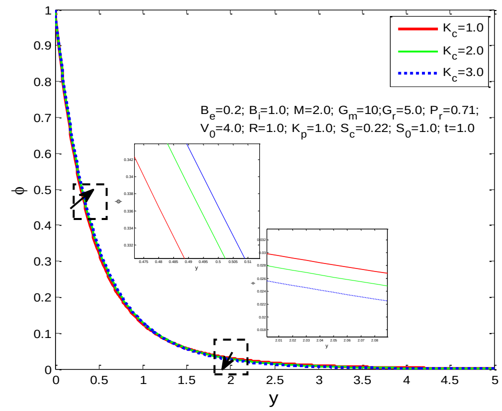

Fig. 15 : Concentration distribution φ for different values Chemical reaction parameter K_c

5. Conclusions

The magnetic field is considered strongly on unsteady MHD fluid flow past a porous vertical plate in a rotating system with Hall current and Ion-slip. The effects of the Hall parameter, Ion-slip parameter, Magnetic parameter, Suction parameter, Prandtl number, Chemical reaction parameter, and the Rotational parameter on the velocity, temperature, and concentration distributions have been investigated. Summaries of the major findings from the graphical representation are

- The primary velocity u increases with the increase of β_i, M, G_r while it decreases with the increase of β_e, V_0, P_r and R.
- The secondary velocity w increases with the increase of M, G_r while it decreases with the increases of β_e, β_i, V_0, P_r and R.
- The temperature θ decreases with the increase V_0 and P_r.
- The concentration φ decreases with the increases of V_0, S_0 and S_c.

The accuracy of this work is qualitatively good in case of all the flow parameters.

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7. Appendix

$$a_1 = -S_0 S_c m_2^2 / \left(m_2^2 - V_0 S_c m_2 - K_c S_c\right); \quad a_2 = 1 - a_1; \quad a_3 = \left(G_r + G_m a_1\right) / \left[m_2^2 - V_0 m_2 + \left(iR + M^2(A+iB) - 1/K'\right)\right]$$

$$a_5 = -\left(1 + L_1 m_{16} e^{-m_{16} y}\right) a_3 + \left(1 + L_1 m_{10} e^{-m_{10} y}\right) a_4 \,/\, \left(1 + L_1 m_{16} e^{-m_{16} y}\right); \quad a_4 = G_m a_2 \left[m_{10}^2 - V_0 m_{10} + \left(iR + M^2(A+iB) - 1/K'\right)\right]$$

$$a_6 = \left(1 + L_1 m_{18} e^{-m_{18} y}\right)^{-1}; \; m_2 = P_r V_0; \quad m_{10} = \left(V_0 S_c + \sqrt{V_0^2 S_c^2 + 4K_c S_c}\right)/2;$$

$$m_{16} = \left[V_0 + \sqrt{V_0^2 + 4\left(iR + M^2(A+iB) - 1/K'\right)}\right]/2 \quad \text{and} \quad m_{18} = \left[V_0 + \sqrt{V_0^2 + 4\left(iR - M^2(A+iB) - 1/K' - ip\right)}\right]/2$$