

# Unsteady MHD Flow Past an Impulsively Started Inclined oscillating Plate with Variable Temperature and Mass Diffusion in the presence of Hall current

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**ABSTRACT-** Unsteady MHD flow past an impulsively started inclined oscillating plate with variable temperature and mass diffusion in the presence of Hall current is studied here. The fluid considered is gray, absorbing-emitting radiation but a non-scattering medium. The Governing equations involved in the present analysis are solved by the Laplace-transform technique. The velocity profile is discussed with the help of graphs drawn for different parameters like Grashof number, mass Grashof Number, Prandtl number, Hall current parameter, phase angle, the magnetic field parameter and Schmidt number, and the numerical values of skin-friction have been tabulated.

**Keywords:** MHD, oscillating inclined plate, variable temperature, mass diffusion and Hall current.

## 1. Introduction

The study of MHD flow with heat and mass transfer play important role in different areas of science and technology, like chemical engineering, mechanical engineering, biological science, petroleum engineering, biomechanics, irrigation engineering and aerospace technology. The influence of magnetic field on viscous, incompressible and electrically conducting fluid is of great importance in many applications such as magnetic material processing, glass manufacturing control processes and purification of crude oil. The response of laminar skin friction and heat transfer to fluctuations in the stream velocity was studied by Lighthill [16]. The study of MHD flow past an impulsively started vertical plate with variable temperature and mass diffusion was studied by Rajput and Kumar [3]. MHD flow between two parallel plates with heat transfer was investigated by Attia et al. [8]. Raptis and Kafousias [10] have further studied flow of a viscous fluid through a porous medium bounded by a vertical surface. Datta and Jana [11] have studied oscillatory magnetohydrodynamic flow past a flat plate with Hall effects. Soundalgekar [12] has investigated free convection effects on the oscillatory flow an infinite, vertical porous plate with constant suction. The researchers have studied the effect of Hall current in various flow models. Attia [7] has considered the effect of variable properties on the unsteady Hartmann flow with heat transfer considering the Hall effect. Attia and Ahmed [6] have studied the Hall effect on unsteady MHD couette flow and heat transfer of a Bingham fluid with suction and injection. Deka [4] has considered Hall effects on MHD flow past an accelerated plate. Muthucumaraswamy and Janakiraman [5] have analyzed mass transfer effect on isothermal vertical oscillating plate in the presence of chemical reaction. Pop [13] has investigated the effect of Hall current on hydromagnetic flow near an accelerated plate. Pop and Watanabe [9] have further studied Hall effect on magnetohydrodynamic boundary layer flow over a continuous moving flat plate. The effect of Hall current on the magneto hydrodynamic boundary layer flow past a semi-

infinite fast plate was studied by Katagiri [14]. Combined effects of radiation and Hall current on MHD flow past an exponentially accelerated vertical plate in the presence of rotation were studied by Thamizhsudar and Pandurangan [2]. Maripala and Naikoti [1] have analyzed Hall effects on unsteady MHD free convection flow over a stretching sheet with variable viscosity and viscous dissipation. Longitudinal vortices in natural convection flow on inclined plates were studied by Sparrow and Husar [15]. We are considering the unsteady MHD flow past an impulsively started inclined oscillating plate with variable temperature and mass diffusion in the presence of Hall current. The results are shown with the help of graphs and table.

## 2. Mathematical Analysis

The geometrical model of the problem is shown in Figure-1

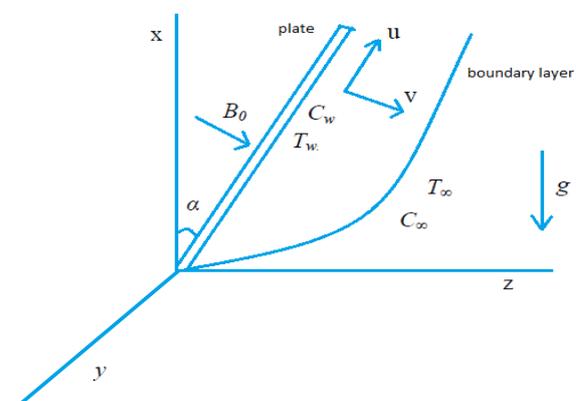


Figure 1: Physical model

MHD flow past an electrically non conducting plate inclined at an angle  $\alpha$  from vertical is considered.  $x$  axis is taken along the plate and  $z$  normal to it. A transverse magnetic field  $B_0$  of uniform strength is applied on the flow. The viscous dissipation and induced magnetic field has been neglected due to its small effect. Initially it has been considered that the plate as well as the fluid is at the same temperature  $T_\infty$  and the concentration level  $C_\infty$  everywhere in the fluid is same in stationary

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condition. At time  $t > 0$ , the plate starts oscillating in its own plane with frequency  $\omega$  and temperature of the plate is raised to  $T_w$  and the concentration level near the plate is raised linearly with respect to time. Due to the Hall effect there will be two components of the momentum equation, the flow modal is as under:

$$\frac{\partial u}{\partial t} = \nu \frac{\partial^2 u}{\partial z^2} + g\beta \cos \alpha (T - T_\infty) + g\beta^* \cos \alpha (C - C_\infty) - \frac{\sigma B_0^2 (u + mv)}{\rho(1 + m^2)}, \quad (1)$$

$$\frac{\partial v}{\partial t} = \nu \frac{\partial^2 v}{\partial z^2} + \frac{\sigma B_0^2 (mu - v)}{\rho(1 + m^2)}, \quad (2)$$

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial z^2}, \quad (3)$$

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial z^2}. \quad (4)$$

The boundary conditions for the flow are as under:

$$\left. \begin{aligned} t \leq 0 : u = 0, v = 0, T = T_\infty, C = C_\infty, \text{ for every } z. \\ t > 0 : u = u_0 \cos \omega t, v = 0, \\ T = T_\infty + (T_w - T_\infty) A, \quad \text{at } z=0. \\ C = C_\infty + (C_w - C_\infty) A, \\ u \rightarrow 0, v \rightarrow 0, T \rightarrow T_\infty, C \rightarrow C_\infty \text{ as } z \rightarrow \infty. \end{aligned} \right\} (5)$$

Here  $u$  is the primary velocity,  $v$ - the secondary velocity,  $g$ - the acceleration due to gravity,  $\beta$  -volumetric coefficient of thermal expansion,  $t$ - time,  $m = \omega_e \tau_e$ - the Hall current parameter with  $\omega_e$ - cyclotron frequency of electrons and  $\tau_e$ - electron collision time,  $\nu$ - the kinematic viscosity,  $\rho$ - the density,  $C_p$ - the specific heat at constant pressure,  $k$ - thermal conductivity of the fluid,  $D$ -the mass diffusion coefficient,  $T$ - temperature of the fluid,  $\beta^*$ - volumetric coefficient of concentration expansion,  $C$ - species concentration in the fluid,  $T_w$ - temperature of the plate at  $z = 0$ ,  $C_w$ - species concentration at the plate  $z = 0$ ,  $B_0$ - the uniform magnetic field,  $\sigma$ - electrical conductivity.

The following non-dimensional quantities are introduced to transform equations (1), (2), (3) and (4) into dimensionless form:

$$\left. \begin{aligned} \bar{z} = \frac{z u_0}{\nu}, \bar{u} = \frac{u}{u_0}, \bar{v} = \frac{v}{u_0}, \bar{\theta} = \frac{(T - T_\infty)}{(T_w - T_\infty)}, \\ S_c = \frac{\nu}{D}, P_r = \frac{\mu C_p}{k}, G_r = \frac{g\beta \nu (T_w - T_\infty)}{u_0^3}, \\ M = \frac{\sigma B_0^2 \nu}{\rho u_0^2}, G_m = \frac{g\beta^* \nu (C_w - C_\infty)}{u_0^3}, \bar{\omega} = \frac{\omega \nu}{u_0^2} \\ \mu = \rho \nu, \bar{C} = \frac{(C - C_\infty)}{(C_w - C_\infty)}, \bar{t} = \frac{t u_0^2}{\nu}. \end{aligned} \right\} (6)$$

Where  $\bar{u}$  is the dimensionless primary velocity,  $\bar{v}$  - the secondary velocity,  $\bar{t}$  - dimensionless time,  $\bar{\theta}$ - the dimensionless temperature,  $\bar{C}$  - the dimensionless concentration,  $G_r$ - thermal Grashof number,  $G_m$ - mass Grashof number,  $\mu$ - the coefficient of viscosity,  $P_r$ - the Prandtl number,  $S_c$ - the Schmidt number,  $M$ - the magnetic parameter.

Thus the model becomes:

$$\frac{\partial \bar{u}}{\partial \bar{t}} = \frac{\partial^2 \bar{u}}{\partial \bar{z}^2} + G_r \cos \alpha \bar{\theta} + G_m \cos \alpha \bar{C} - \frac{M(\bar{u} + m\bar{v})}{(1 + m^2)}, \quad (7)$$

$$\frac{\partial \bar{v}}{\partial \bar{t}} = \frac{\partial^2 \bar{u}}{\partial \bar{z}^2} + \frac{M(m\bar{u} - \bar{v})}{(1 + m^2)}, \quad (8)$$

$$\frac{\partial \bar{C}}{\partial \bar{t}} = \frac{1}{S_c} \frac{\partial^2 \bar{C}}{\partial \bar{z}^2}, \quad (9)$$

$$\frac{\partial \bar{\theta}}{\partial \bar{t}} = \frac{1}{P_r} \frac{\partial^2 \bar{\theta}}{\partial \bar{z}^2}. \quad (10)$$

The boundary conditions (5) become:

$$\left. \begin{aligned} \bar{t} \leq 0 : \bar{u} = 0, \bar{v} = 0, \bar{\theta} = 0, \bar{C} = 0, \text{ for every } \bar{z}. \\ \bar{t} > 0 : \bar{u} = \cos \bar{\omega} \bar{t}, \bar{v} = 0, \bar{\theta} = \bar{t}, \bar{C} = \bar{t}, \text{ at } \bar{z} = 0. \\ \bar{u} \rightarrow 0, \bar{v} \rightarrow 0, \bar{\theta} \rightarrow 0, \bar{C} \rightarrow 0, \text{ as } \bar{z} \rightarrow \infty \end{aligned} \right\} (11)$$

Dropping bars in the above equations, we get

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial z^2} + G_r \cos \alpha \theta + G_m \cos \alpha C - \frac{M(u + mv)}{(1 + m^2)}, \quad (12)$$

$$\frac{\partial v}{\partial t} = \frac{\partial^2 v}{\partial z^2} + \frac{M(mu - v)}{(1 + m^2)}, \quad (13)$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c} \frac{\partial^2 C}{\partial z^2}, \quad (14)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r} \frac{\partial^2 \theta}{\partial z^2}. \quad (15)$$

The corresponding boundary conditions become:

$$\left. \begin{aligned} t \leq 0 : u = 0, v = 0, \theta = 0, C = 0, \text{ for every } z. \\ t > 0 : u = \cos \omega t, v = 0, \theta = t, C = t, \text{ at } z=0. \\ u \rightarrow 0, v \rightarrow 0, \theta \rightarrow 0, C \rightarrow 0, \text{ as } z \rightarrow \infty. \end{aligned} \right\} (16)$$

Writing the equations (12) and (13) in Combined form:

$$\frac{\partial q}{\partial t} = \frac{\partial^2 q}{\partial z^2} + G_r \cos \alpha \theta + G_m \cos \alpha C - qa, \quad (17)$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c} \frac{\partial^2 C}{\partial z^2}, \quad (18)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r} \frac{\partial^2 \theta}{\partial z^2}. \quad (19)$$

The boundary conditions (16) are reduced to:

$$\left. \begin{aligned} t \leq 0 : q = 0, \theta = 0, C = 0, \text{ for every } z. \\ t > 0 : q = \cos \omega t, \theta = t, C = t, \text{ at } z=0. \\ q \rightarrow 0, \theta \rightarrow 0, C \rightarrow 0, \text{ as } z \rightarrow \infty. \end{aligned} \right\} (20)$$

Here  $q = u + iv$ ,  $a = \frac{M(1 - im)}{1 + m^2}$ .

The dimensionless governing equations (17) to (19), subject to the boundary conditions (20), are solved by the usual Laplace - transform technique.

The solution obtained is as under:

$$C = t \left\{ \left( 1 + \frac{z^2 S_c}{2t} \right) \operatorname{erfc} \left[ \frac{\sqrt{S_c}}{2\sqrt{t}} \right] - \frac{z\sqrt{S_c}}{\sqrt{\pi}\sqrt{t}} e^{-\frac{z^2}{4t}} S_c \right\},$$

$$\theta = t \left\{ \left( 1 + \frac{z^2 P_r}{2t} \right) \operatorname{erfc} \left[ \frac{\sqrt{P_r}}{2\sqrt{t}} \right] - \frac{z\sqrt{P_r}}{\sqrt{\pi}\sqrt{t}} e^{-\frac{z^2}{4t}} P_r \right\},$$

$$q = \frac{1}{4} e^{-it\omega} A_{15} + \frac{\cos\alpha}{4a^2\sqrt{\pi}} [\sqrt{\pi}G_r \{-A_9z + \sqrt{ae^{-\sqrt{a}z}} A_2z\}$$

$$+ \frac{1}{2A_{13}A_3} + 2e^{-\sqrt{a}z} A_1P_r + 2A_{13}A_3P_r] - G_rP_r \{-aA_{10}z$$

$$+ \frac{1}{\sqrt{P_r}} A_{13}\sqrt{\pi}A_4 + \frac{2\sqrt{\pi}A_{11}}{\sqrt{P_r}} - \frac{2a\sqrt{\pi}tA_{11}}{\sqrt{P_r}} + \frac{1}{A_{13}\sqrt{\pi}A_8\sqrt{P_r}}$$

$$- 2\sqrt{\pi}P_r A_{11}\} - \sqrt{\pi}G_m \{A_9z - \sqrt{ae^{-\sqrt{a}z}} A_2z - 2e^{-\sqrt{a}z} A_1S_c$$

$$+ 2A_{14}A_5S_c\} + \sqrt{S_c}G_m \{-aA_{16}z + \frac{1}{\sqrt{\pi}S_c A_{14}A_7} + \frac{2\sqrt{\pi}A_{12}}{\sqrt{S_c}}$$

$$+ \frac{1}{A_{14}\sqrt{\pi}S_c A_6} - 2A_{12}\sqrt{\pi}S_c \}].$$

The expressions for the symbols involved in the above solutions are given in the appendix.

### 3. Skin Friction

The dimensionless skin friction at the plate  $z=0$ :

$$\left( \frac{dq}{dz} \right)_{z=0} = \tau_x + i\tau_y,$$

Separating real and imaginary part in  $\left( \frac{dq}{dz} \right)_{z=0}$ , the

dimensionless skin - friction component  $\tau_x = \left( \frac{du}{dz} \right)_{z=0}$

and  $\tau_y = \left( \frac{dv}{dz} \right)_{z=0}$  can be computed.

### 4. Result and Discussions

The velocity profile for different parameters like, thermal Grashof number  $Gr$ , magnetic field parameter  $M$ , Hall parameter  $m$ , Prandtl number  $Pr$  and time  $t$  is shown in figures 1.1 to 2.9. It is observed from figures 1.1 and 2.1 that the primary and secondary velocities of fluid decrease when the angle of inclination ( $\alpha$ ) is increased. It is observed from figure 1.2 and 2.2, when the mass Grashof number is increased then the velocities are increased. From figures 1.3 and 2.3 it is

deduced that when thermal Grashof number  $Gr$  is increased then the velocities are increased. If Hall current parameter  $m$  is increased then the primary velocity increased and secondary velocity decreased (figures 1.4 and 2.4). It is observed from figures 1.5 and 2.5 that the effect of increasing values of the parameter  $M$  results in decreasing  $u$  and increasing  $v$ . It is deduced that when phase angle  $\omega t$  is increased then the velocities are decreased (figures 1.6 and 2.6). Further, it is observed that velocities decrease when Prandtl number is increased (figures 1.7 and 2.7). When the Schmidt number is increased then the velocities get decreased (figures 1.8 and 2.8). Further, from figures 1.9 and 2.9 it is observed that velocities increase with time.

Skin friction is given in table 1. The value of  $\tau_x$  increases with the increase in thermal Grashof number, mass Grashof Number, Hall current parameter, phase angle and time, and it decreases with the angle of inclination of plate, the magnetic field, Prandtl number and Schmidt number. The value of  $\tau_y$  increases with the increase in thermal Grashof number, the magnetic field, mass Grashof Number and time, and it decreases with the angle of inclination of plate, Hall current parameter, phase angle, Prandtl number and Schmidt number.

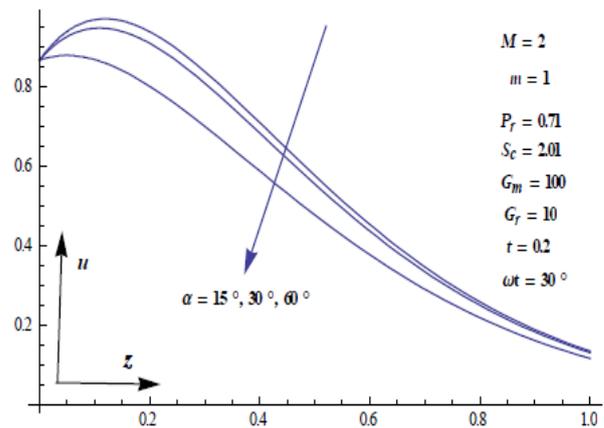


Figure 1.1:  $u$  v/s  $z$ .

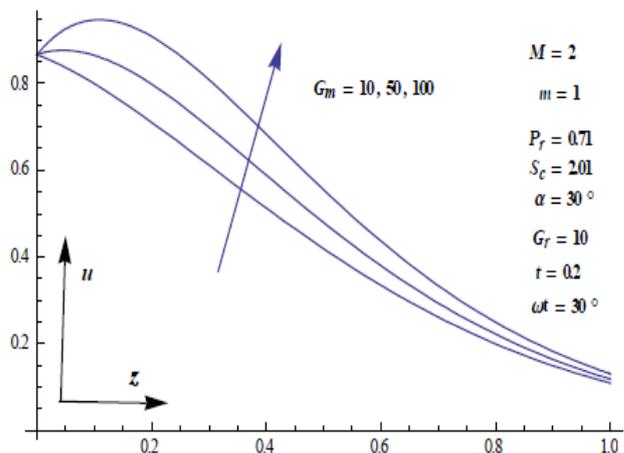


Figure 1.2:  $u$  v/s  $z$ .

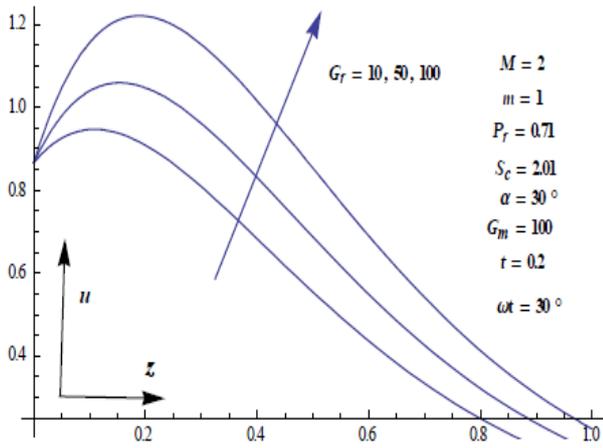


Figure 1.3:  $u$  v/s  $z$

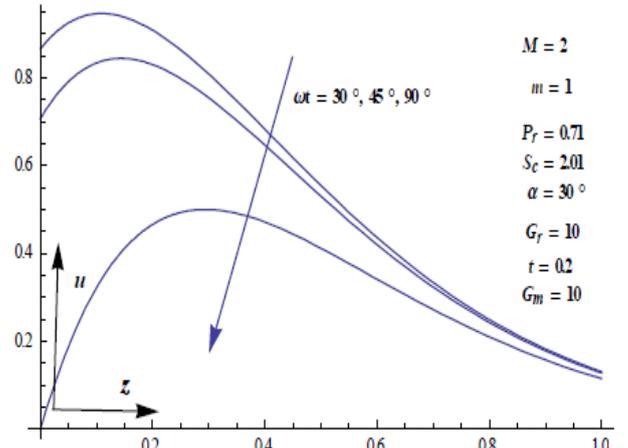


Figure 1.6:  $u$  v/s  $z$

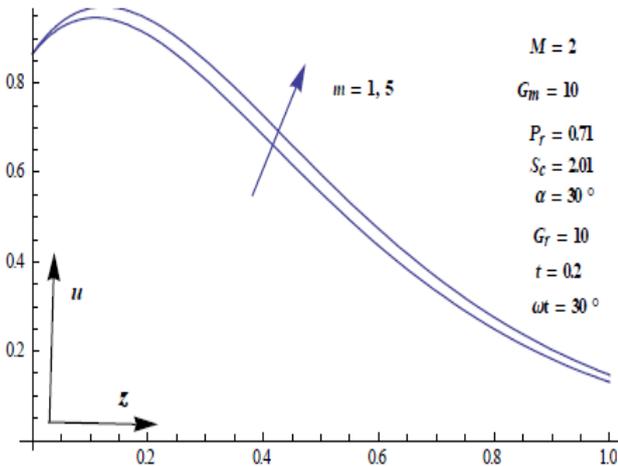


Figure 1.4:  $u$  v/s  $z$

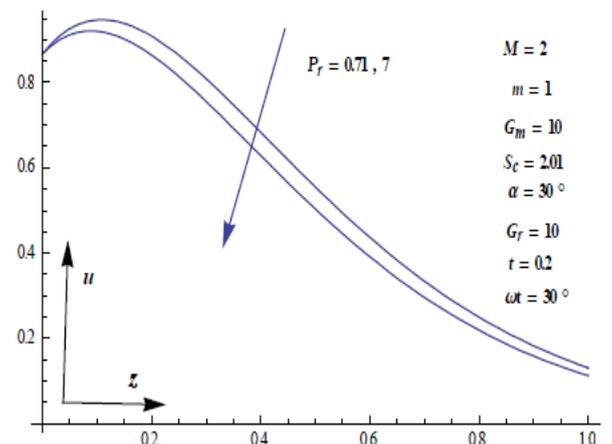


Figure 1.7:  $u$  v/s  $z$

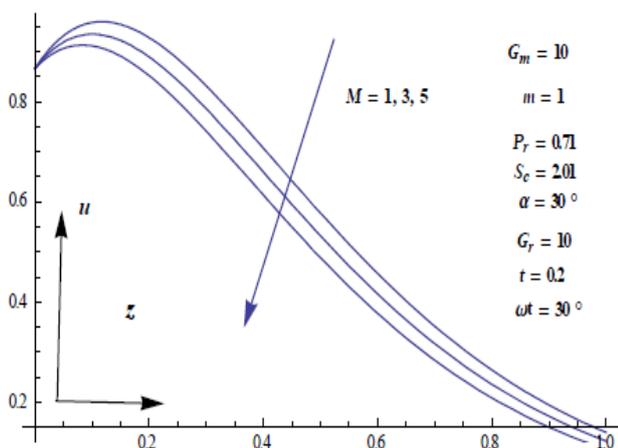


Figure 1.5:  $u$  v/s  $z$

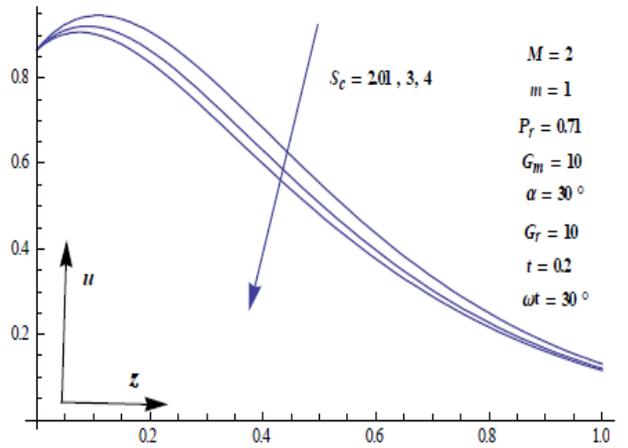


Figure 1.8:  $u$  v/s  $z$

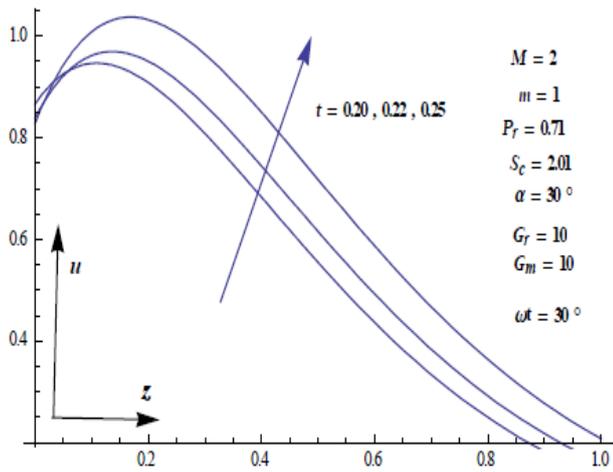


Figure 1.9:  $u$  v/s  $z$

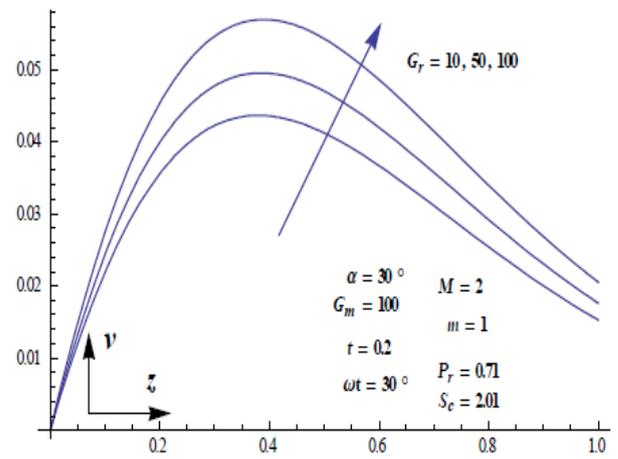


Figure 2.3:  $v$  v/s  $z$

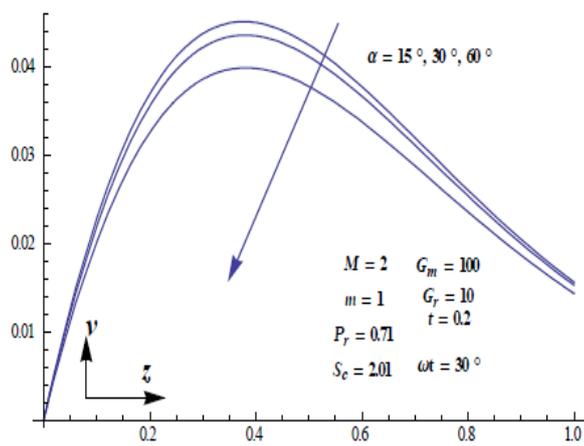


Figure 2.1:  $v$  v/s  $z$

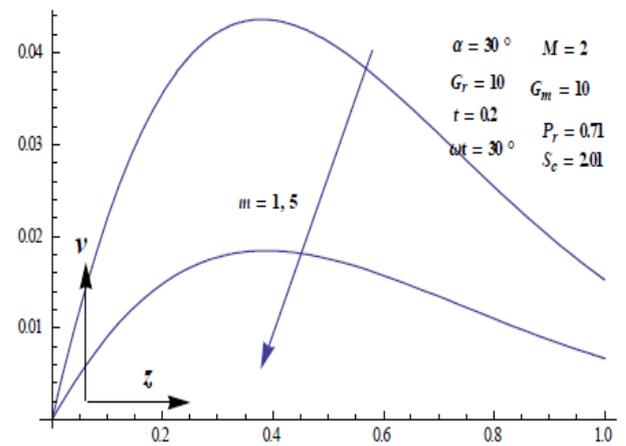


Figure 2.4:  $v$  v/s  $z$

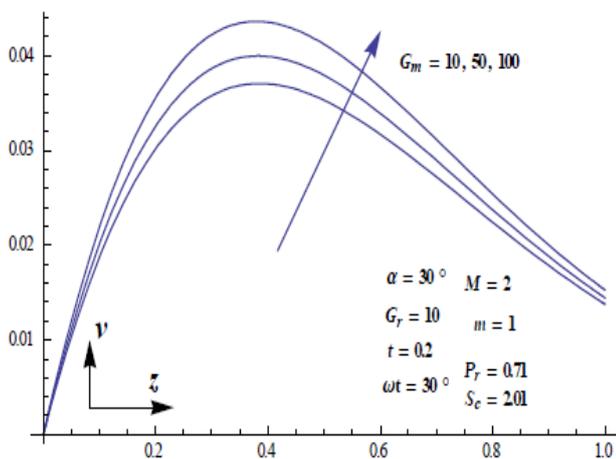


Figure 2.2:  $v$  v/s  $z$

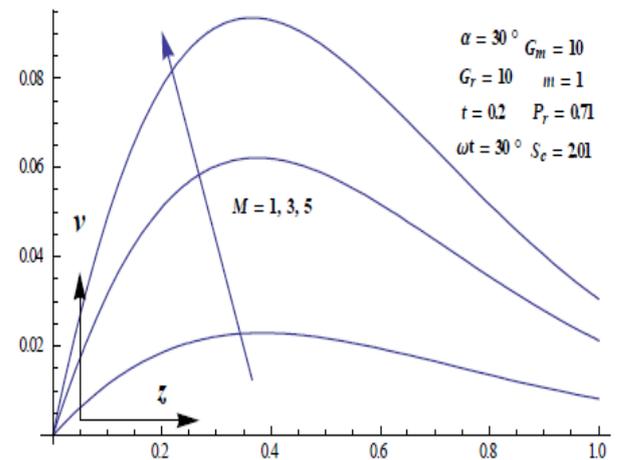


Figure 2.5:  $v$  v/s  $z$

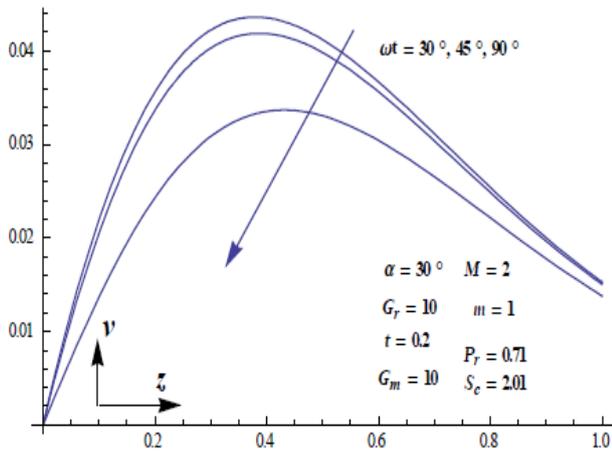


Figure 2.6:  $v$  v/s  $z$

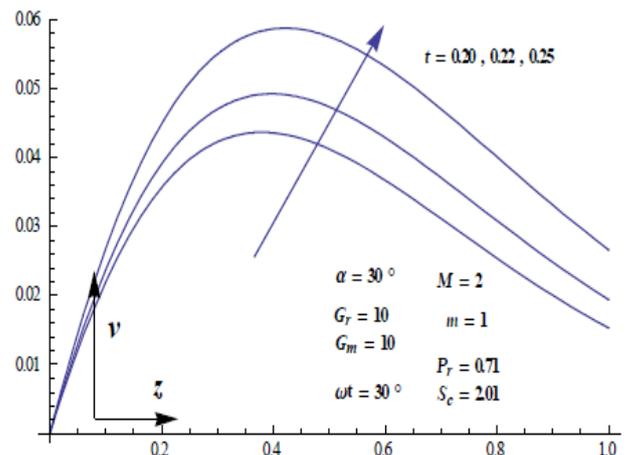


Figure 2.9:  $v$  v/s  $z$

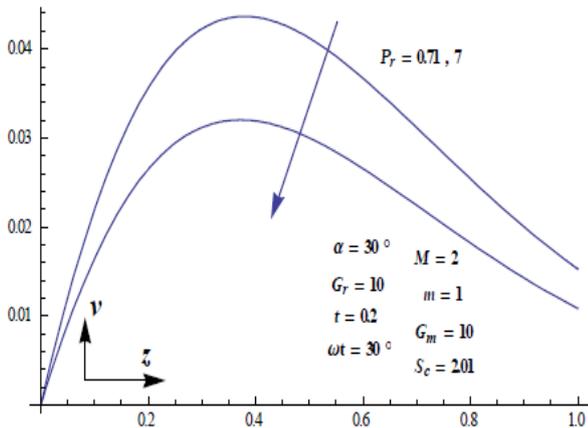


Figure 2.7:  $v$  v/s  $z$

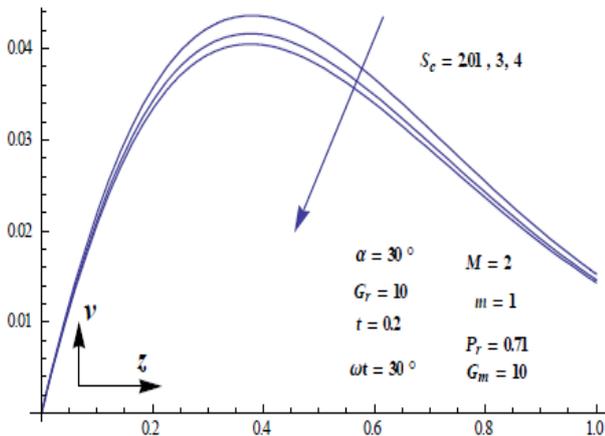


Figure 2.8:  $v$  v/s  $z$

## 5. Conclusion

The conclusions of the study are as follows:

- Primary velocity increases with the increase in thermal Grashof number, mass Grashof Number, Hall current parameter and time.
- Primary velocity decreases with the angle of inclination of plate, the magnetic field, phase angle, Prandtl number and Schmidt number.
- Secondary velocity increases with the increase in thermal Grashof number, mass Grashof Number, the magnetic field and time.
- Secondary velocity decreases with the angle of inclination of plate, Hall current parameter, Prandtl number and Schmidt number.
- $\tau_x$  increases with the increase in  $Gr$ ,  $Gm$ ,  $\omega t$ ,  $m$  and  $t$ , and it decreases with angle of inclination of plate,  $M$ ,  $Pr$  and  $Sc$ .
- $\tau_y$  increases with the increase in  $Gr$ ,  $Gm$ ,  $M$  and  $t$ , and it decreases with the angle of inclination of plate,  $\omega t$ ,  $m$ ,  $Pr$  and  $Sc$ .

## Appendix

$$A = \frac{u_0^2 t}{\nu}, A_1 = -1 - e^{2\sqrt{a}z} - A_{16} + e^{2\sqrt{a}z} A_{17},$$

$$A_2 = -1 - e^{2\sqrt{a}z} + A_{16} + e^{2\sqrt{a}z} A_{17},$$

$$A_3 = -1 - A_{18} + \operatorname{erf}\left[\frac{z - 2t\sqrt{\frac{aP_r}{-1 + P_r}}}{2t}\right]$$

$$+ A_{18}\operatorname{erf}\left[\frac{z + 2t\sqrt{\frac{aP_r}{-1 + P_r}}}{2t}\right],$$

$$A_4 = 1 + A_{18} + \operatorname{erf}\left[\frac{2t\sqrt{\frac{a}{-1 + P_r}} - z\sqrt{P_r}}{2t}\right],$$

$$- A_{18}\operatorname{erf}\left[\frac{2t\sqrt{\frac{a}{-1 + P_r}} + z\sqrt{P_r}}{2t}\right]$$

$$A_8 = -A_4,$$

$$A_5 = -1 - A_{19} + \operatorname{erf}\left[\frac{z - 2t\sqrt{\frac{aS_c}{-1+S_c}}}{2t}\right]$$

$$+ A_{19}\operatorname{erf}\left[\frac{z + 2t\sqrt{\frac{aS_c}{-1+S_c}}}{2t}\right],$$

$$A_6 = -1 - A_{19} - \operatorname{erf}\left[\frac{2t\sqrt{\frac{a}{-1+S_c}} - 2\sqrt{S_c}}{2t}\right]$$

$$- A_{19}\operatorname{erf}\left[\frac{2t\sqrt{\frac{a}{-1+S_c}} + 2\sqrt{S_c}}{2t}\right],$$

$$A_7 = -A_6, A_9 = \frac{2e^{-\sqrt{a}z}A_1}{z}(1-at),$$

$$A_{10} = (2e^{-\frac{z^2P_r}{4t}}\sqrt{t} + \sqrt{\pi zA_{11}})\sqrt{P_r},$$

$$A_{11} = -1 + \operatorname{erf}\left[\frac{z\sqrt{P_r}}{2\sqrt{t}}\right], A_{12} = -1 + \operatorname{erf}\left[\frac{z\sqrt{S_c}}{2\sqrt{t}}\right],$$

$$A_{13} = e^{\frac{at}{-1+P_r} - z\sqrt{\frac{aP_r}{-1+P_r}}}, A_{14} = e^{\frac{at}{-1+S_c} - z\sqrt{\frac{aS_c}{-1+S_c}}},$$

$$A_{15} = A_{20} + A_{21} - A_{22} - A_{23}, A_{16} = \operatorname{erf}\left[\frac{2\sqrt{at} - z}{2\sqrt{t}}\right],$$

$$A_{17} = \operatorname{erf}\left[\frac{2\sqrt{at} + z}{2\sqrt{t}}\right], A_{18} = e^{-2z\sqrt{\frac{aP_r}{-1+P_r}}},$$

$$A_{19} = e^{-2z\sqrt{\frac{aS_c}{-1+S_c}}}, A_{20} = e^{-z\sqrt{a-iw}} + e^{z\sqrt{a-iw}},$$

$$A_{21} = e^{-z\sqrt{a+iw}+2itw} + e^{z\sqrt{a+iw}+2itw},$$

$$A_{22} = e^{-z\sqrt{a-iw}}\operatorname{erf}\left[\frac{z - 2t\sqrt{a-iw}}{2\sqrt{t}}\right]$$

$$+ e^{z\sqrt{a-iw}}\operatorname{erf}\left[\frac{z + 2t\sqrt{a-iw}}{2\sqrt{t}}\right],$$

$$A_{23} = e^{-z\sqrt{a+iw}+2itw}\operatorname{erf}\left[\frac{z - 2t\sqrt{a+iw}}{2\sqrt{t}}\right]$$

$$+ e^{z\sqrt{a+iw}+2itw}\operatorname{erf}\left[\frac{z + 2t\sqrt{a+iw}}{2\sqrt{t}}\right].$$

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**Table 1: Skin friction for different parameter**  
*( $\alpha$  and  $\omega t$  are in degrees)*

$\alpha$	$M$	$m$	$Pr$	$Sc$	$Gm$	$Gr$	$\omega t$	$t$	$\tau_x$	$\tau_y$
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
30	2	1	0.71	2.01	100	10	30	0.2	1.63135	0.26284
45	2	1	0.71	2.01	100	10	30	0.2	1.13963	0.25471
60	2	1	0.71	2.01	100	10	30	0.2	0.49880	0.24412
15	1	1	0.71	2.01	100	10	30	0.2	2.08301	0.13847
15	3	1	0.71	2.01	100	10	30	0.2	1.79885	0.38900
15	5	1	0.71	2.01	100	10	30	0.2	1.51994	0.60795
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
15	2	2	0.71	2.01	100	10	30	0.2	2.10722	0.22293
15	2	3	0.71	2.01	100	10	30	0.2	2.16583	0.16497
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
15	2	1	7.00	2.01	100	10	30	0.2	1.77170	0.26259
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
15	2	1	0.71	3.00	100	10	30	0.2	1.64084	0.25882
15	2	1	0.71	4.00	100	10	30	0.2	1.43431	0.25311
15	2	1	0.71	2.01	10	10	30	0.2	-0.43884	0.22998
15	2	1	0.71	2.01	50	10	30	0.2	0.61862	0.24685
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
15	2	1	0.71	2.01	100	50	30	0.2	3.32072	0.29681
15	2	1	0.71	2.01	100	100	30	0.2	5.04060	0.33893
15	2	1	0.71	2.01	100	10	30	0.2	1.94046	0.26795
15	2	1	0.71	2.01	100	10	45	0.2	2.48161	0.24679
15	2	1	0.71	2.01	100	10	90	0.2	4.70809	0.14803
15	2	1	0.71	2.01	100	10	30	0.2	1.94268	0.26795
15	2	1	0.71	2.01	100	10	30	0.3	4.49268	0.39125
15	2	1	0.71	2.01	100	10	30	0.4	7.40324	0.55391