

Chemical Reaction Effect on MHD Flow in Porous Media Past an Impulsively Started Oscillating Vertical Plate with Variable Mass Diffusion and Constant Wall Temperature in the Presence of Hall Current.

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ABSTRACT

In the present paper, chemical reaction effect on MHD flow in porous media past an impulsively started oscillating vertical plate with variable mass diffusion and constant wall temperature in the presence of Hall current is studied here. The fluid considered is an electrically conducting. The Laplace transform technique has been used to find the solutions for the velocity, Sherwood number and skin friction. The velocity profile, heat transfer and mass diffusion have been studied for different parameters like Schmidt number, Hall parameter, magnetic parameter, chemical reaction parameter, mass Grashof number, thermal Grashof number, Prandtl number, and time. The effect of various parameters are shown graphically and the value of the skin-friction and Sherwood number for different parameters has been tabulated.

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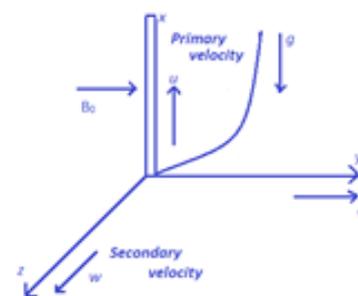
Introduction

The fluid flows through porous medium are very important especially in the fields of irrigation and Agronomy engineering, in petroleum technology to study Petroleum transport and in chemical engineering for clarify and purification. Hossain et al [8] have studied Hall effect on hydro magnetic free-convection flows along a porous flat plate with mass transfer. Attia et al. [3] have studied heat transfer between two parallel porous plates for Couette flow under pressure gradient and Hall current. Seth et al [5] have studied Hall effect on unsteady MHD natural convection flow of a heat absorbing fluid past an accelerated moving vertical plate with ramped wall temperature and by using Laplace transform technique. Ibrahim [1] have studied heat source and chemical effects on MHD convection flow embedded in a porous medium with Soret, viscous and Joules dissipation. Mythreye [4] have studied chemical reaction on unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption. Maleque and Abdus [6] have studied convective flow due to a rotating disk with Hall effect. Kim [7] has studied heat and mass transfer in MHD micro polar flow over a vertical moving porous plate in a porous medium. Earlier, we [2] have studied MHD flow past a vertical plate with variable temperature and mass diffusion in the presence of Hall current. In this paper, we are considering chemical reaction effect on MHD flow in porous media past an impulsively started oscillating vertical plate with variable mass diffusion and constant wall temperature in the presence of Hall current. The effect of Hall current on the velocity have been analyzed with the help of graphs, and skin friction and Sherwood number have been tabulated.

Mathematical Analysis

The unsteady flow of an electrically conducting, incompressible, viscous fluid past a vertical plate has been

considered. The x axis is taken in the direction of the motion and z normal to it. A transverse magnetic field B_0 of uniform strength is applied on the flow. Initially it has been considered that the plate as well as the fluid is at the same temperature T_∞ . The species concentration in the fluid is taken as C_∞ . At time $t > 0$, the plate starts oscillating in its own plane with frequency ω , the temperature of the plate and the concentration of the fluid, respectively are raised to T_w and C_w . Using the relation $\nabla \cdot \vec{B} = 0$ for the magnetic field $\vec{B} = (B_x, B_y, B_z)$, we obtain B_y (say B_0) = constant, i.e. $B = (0, B_0, 0)$, where B_0 is externally applied transverse magnetic field. Figure 1 is physical description of the model.



The fluid model is as under

$$\frac{\partial u}{\partial t} = \nu \frac{\partial^2 u}{\partial y^2} + g\beta(T - T_\infty) - \frac{\sigma B_0^2}{\rho(1+m^2)}(u + mw) - \frac{\nu}{K}u, \quad (1)$$

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

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial y^2} - K_c(C - C_\infty), \quad (3)$$

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial y^2} \tag{4}$$

The initial and boundary conditions are

$$\left. \begin{aligned} t \leq 0 : u = 0, w = 0, C = C_\infty, T = T_\infty, \text{ for all } y \\ t > 0 : u = u_0 \cos \omega t, w = 0, T = T_w, C = C_\infty + (C_w - C_\infty) \frac{u_0^2 t}{\nu} \text{ at } y = 0 \\ u \rightarrow 0, w \rightarrow 0, C \rightarrow C_\infty, T \rightarrow T_\infty \text{ as } y \rightarrow \infty. \end{aligned} \right\} \tag{5}$$

Here u and w are the primary and the secondary velocities along x and z respectively, ν - the kinematic viscosity, ρ - the density, C_p - the specific heat at constant pressure, k - thermal conductivity of the fluid, K -the permeability parameter, D - the mass diffusion coefficient, g - gravitational acceleration, β - volumetric coefficient of thermal expansion, t - time, m - the Hall current parameter, T - temperature of the fluid, β^* - volumetric coefficient of concentration expansion, C - species concentration in the fluid, T_w - temperature of the plate, C_w - species concentration, B_0 - the uniform magnetic field, σ - electrical conductivity.

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

$$\left. \begin{aligned} \bar{u} = \frac{u}{u_0}, \bar{w} = \frac{w}{u_0}, \bar{y} = \frac{yu_0}{\nu}, Sc = \frac{\nu}{D}, Pr = \frac{\mu C_p}{k}, \bar{\omega} = \frac{\omega \nu}{u_0^2}, \\ M = \frac{\sigma B_0^2 \nu}{\rho u_0^2}, \bar{t} = \frac{tu_0^2}{\nu}, Gm = \frac{g \beta^* \nu (C_w - C_\infty)}{u_0^3}, Gr = \frac{g \beta \nu (T_w - T_\infty)}{u_0^3}, \\ \bar{C} = \frac{C - C_\infty}{C_w - C_\infty}, \theta = \frac{(T - T_\infty)}{(T_w - T_\infty)}, \bar{K} = \frac{K u_0}{\nu^2}, K_0 = \frac{\nu K_c}{u_0^2}. \end{aligned} \right\} \tag{6}$$

Symbols used are:

θ - the temperature, \bar{C} - the concentration, Gr - thermal Grashof number, \bar{u} - the primary velocity, \bar{w} - the secondary velocity, μ - the coefficient of viscosity, Pr - the Prandtl number, Sc - the Schmidt number, \bar{K} -the permeability parameter, K_0 - chemical reaction, \bar{t} - time, Gm - mass Grashof number, Q - heat generation parameter, M - the magnetic parameter.

The dimension less flow model becomes

$$\frac{\partial \bar{u}}{\partial \bar{t}} = \frac{\partial^2 \bar{u}}{\partial \bar{y}^2} + Gr \theta - \frac{M(\bar{u} + m\bar{w})}{(1+m^2)} - \frac{1}{K} u, \tag{7}$$

$$\frac{\partial \bar{w}}{\partial \bar{t}} = \frac{\partial^2 \bar{w}}{\partial \bar{y}^2} - \frac{M(\bar{w} - m\bar{u})}{(1+m^2)} - \frac{1}{K} w, \tag{8}$$

$$\frac{\partial \bar{C}}{\partial \bar{t}} = \frac{1}{Sc} \frac{\partial^2 \bar{C}}{\partial \bar{y}^2} - K_0 \bar{C}, \tag{9}$$

$$\frac{\partial \theta}{\partial \bar{t}} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial \bar{y}^2}, \tag{10}$$

The corresponding boundary conditions become

$$\left. \begin{aligned} \bar{t} \leq 0, \bar{u} = 0, \bar{C} = 0, \theta = 0, \bar{w} = 0, \text{ for all values of } \bar{y}, \\ \bar{t} > 0, \bar{u} = \cos \bar{\omega} \bar{t}, \bar{w} = 0, \theta = 1, \bar{C} = \bar{t} \text{ at } \bar{y} = 0, \\ \bar{u} \rightarrow 0, \bar{C} \rightarrow 0, \theta \rightarrow 0, \bar{w} \rightarrow 0 \text{ as } \bar{y} \rightarrow \infty. \end{aligned} \right\} \tag{11}$$

Dropping the bars and combining equations (7) and (8), we get

$$\frac{\partial q}{\partial t} = \frac{\partial^2 q}{\partial y^2} + Gr \theta - \left(\frac{M}{1+m^2} (1-mi) + \frac{1}{K} \right) q, \tag{12}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial y^2} - K_0 C, \tag{13}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial y^2}, \tag{14}$$

where $q = u + iw$,

The boundary conditions become:

$$\left. \begin{aligned} t \leq 0 : q = 0, \theta = 0, C = 0, \text{ for all values of } y, \\ t < 0 : q = \cos \omega t, w = 0, \theta = 1, C = t, \text{ at } y = 0, \\ q \rightarrow 0, C \rightarrow 0, \theta \rightarrow 0, \text{ as } y \rightarrow \infty. \end{aligned} \right\} \tag{15}$$

The solution of above equations obtained by Laplace - transform method, which is an under

$$\theta = \text{Erfc} \left[\frac{\sqrt{Pr} y}{2\sqrt{t}} \right],$$

$$C = \frac{1}{4\sqrt{ScK_0}} e^{-y\sqrt{ScK_0}} [B_{11}](-Scy + 2t\sqrt{ScK_0}) + e^{2y\sqrt{ScK_0}} [B_{12}](Scy + 2t\sqrt{ScK_0}),$$

$$q = \frac{1}{2} e^{-\sqrt{i\omega}} (P_1 + P_2 - P_3 - P_4 - P_5 - P_6) + \frac{1}{2a} (-e^{-\sqrt{ay}} (A_0) + e^{\frac{at}{-1+Pr}} y^{\frac{at}{-1+Pr}} (A_{13} + e^{2y\sqrt{\frac{at}{-1+Pr}}} A_{14})) Gr + \frac{1}{4(a-K_0Sc)^2} y Gm \left(\frac{2e^{-\sqrt{ay}} A_{01}}{y} (1-a_0) + \sqrt{a} e^{-\sqrt{ay}} (A_0 - e^{2\sqrt{ay}} A_{12}) \right. \\ \left. + \frac{1}{y} 2e^{\frac{at}{-1+Sc}} \frac{tK_0Sc}{-1+Sc} y^{A_{17}} (-1 - e^{2yA_{17}} + A_{15} + e^{2yA_{17}} A_{16}) [1 - Sc] + \frac{1}{y} 2e^{-\sqrt{ay}} (-1 - e^{\sqrt{ay}} - A_{11} + e^{2\sqrt{ay}} A_{12}) Sc [1 - tK_0] - \frac{1}{\sqrt{a}} e^{-\sqrt{ay}} (A_0 - e^{2\sqrt{ay}}) K_0 Sc \right) \\ - \frac{1}{2a} (e^{\frac{at}{-1+Pr}} y^{\frac{at}{-1+Pr}} (1 + A_{18} + e^{2y\sqrt{\frac{at}{-1+Pr}}} A_{19}) - 2 \text{Erfc} \left[\frac{y\sqrt{Pr}}{2\sqrt{t}} \right]) Gr \\ + \frac{1}{4(a-K_0Sc)^2} y Gm \sqrt{Sc} \left(-\frac{1}{\sqrt{K_0}} a e^{-y\sqrt{K_0Sc}} (-1 - e^{2y\sqrt{K_0Sc}} + A_{20} + e^{2y\sqrt{K_0Sc}} A_{21}) \right. \\ \left. + \frac{1}{y\sqrt{Sc}} 2e^{-y\sqrt{K_0Sc}} (-1 - e^{2y\sqrt{K_0Sc}} + A_{20} + e^{2y\sqrt{K_0Sc}} A_{21}) [1 - t - Sc] \right) \\ \left. - \frac{1}{y\sqrt{Sc}} 2e^{\frac{at}{-1+Sc}} \frac{tK_0Sc}{-1+Sc} y^{A_{17}} (-1 - e^{2yA_{17}} - A_{22} + e^{2y\sqrt{\frac{a-K_0}{-1+Sc}} \sqrt{Sc}} A_{23}) [1 - Sc] + e^{-y\sqrt{K_0Sc}} \right).$$

More details of the notations are described in the appendix.

Skin friction

The dimensionless skin friction at the plate $y = 0$ is computed by

$$\left(\frac{dq}{dy} \right)_{y=0} = \tau_x + i \tau_z$$

Sherwood number

The dimensionless Sherwood number at the plate $y = 0$ is computed by

$$Sh = \left(\frac{\partial C}{\partial y} \right)_{y=0}$$

$$Sh = -\frac{1}{4} e^{-y\sqrt{ScK_0}} (B_{11}(-Scy + 2t\sqrt{ScK_0}) + e^{2y\sqrt{ScK_0}} (B_{12}(Scy + 2t\sqrt{ScK_0}))) + \frac{1}{4\sqrt{ScK_0}}$$

$$e^{-y\sqrt{ScK_0}} (-ScB_{11}e^{2y\sqrt{ScK_0}} ScB_{12}) - \sqrt{\frac{Sc}{\pi}} (e^{B_{11}^2} (-Sc + 2t\sqrt{ScK_0}) + e^{-B_{12}^2 + 2y\sqrt{ScK_0}} (Sc + 2t\sqrt{ScK_0})) + 2e^{2y\sqrt{ScK_0}} B_{12} (Sc + 2t\sqrt{ScK_0}).$$

Interpretation of results

The numerical values of velocity and skin friction are computed for different parameters. The values of the main parameters considered are:

$Gr = 10, 20, 30; M = 1, 3, 5; m = 1, 2, 3, K = 0.1, 0.2, 0.3; Pr = 2, 3, 4; Sc = 2, 3, 7; \omega t = 30^\circ, 45^\circ, 90^\circ; K_0 = 1, 10, 20; Gm = 10, 20, 30; t = 0.1, 0.2, 0.3.$

Figures 2, 3, 4, 9 and 10 show that primary velocity increases when Gm, Gr, m, K and t are increased. In this case primary velocity increases with m , it means Hall current has increasing effect on the flow of the fluid along the plate. Figures 5, 6, 7, 8, and 11 show that primary velocity decreases when M, Pr, Sc, K_0 and ωt are increased. And figures 12, 13, 15, 19 and 20 show that the secondary velocity increases when Gm, Gr, M, K , and t are increased. Figures 14, 16, 17,

18 and 21 show that secondary velocity decreases when m , Pr , Sc , K_0 and ωt are increased.

Here secondary velocity decreases when m is increased; this implies that the Hall parameter slows down the transverse velocity. Figures 22 and 23 show that concentration decreases with increase in Sc and K_0 , and figure 24 shows that it increases with increase in t . From table – 2 it is observed that τ_x decreases with increase in Pr , M , Sc , K_0 , and it increases with increase in m , Gm , K , Gr , ωt and t . τ_z increases with increase in Gr , t , Gm , K , and M , and it decreases when Sc , Pr , K_0 , ωt and m are increased. From table – 1 it is observed that Sherwood number decreases with increase in Sc , K_0 , and t . The results of the model can suitably be applied in the industries and organizations dealing with eclectically conducting fluid in the presence of magnetic field.

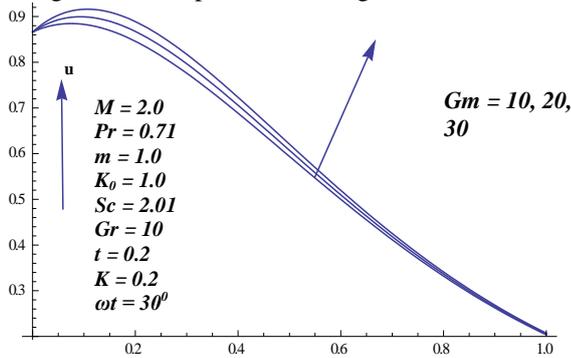


Figure 2. velocity u for different values of Gm .

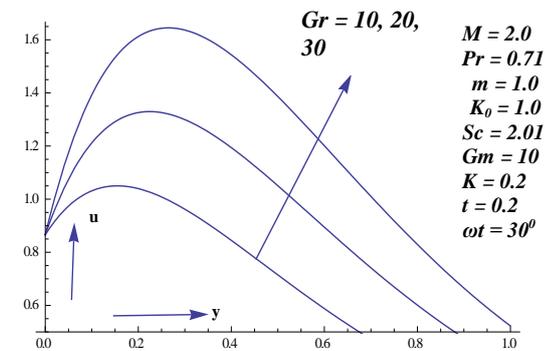


Figure 3. velocity u for different values of Gr .

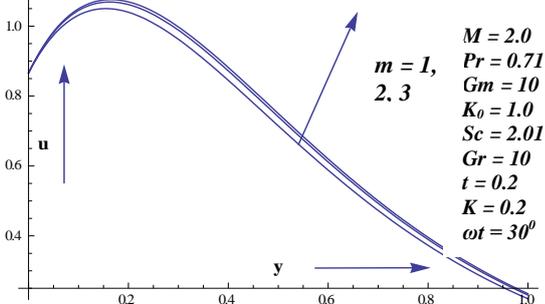


Figure 4. velocity u for different values of m .

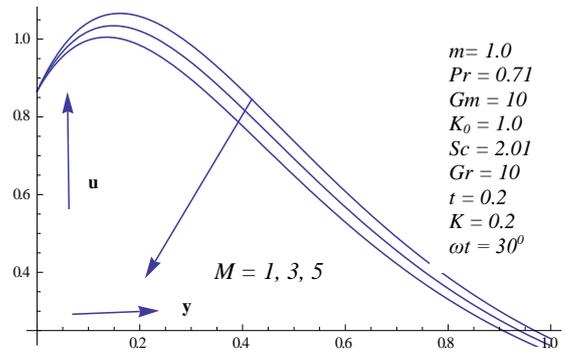


Figure 5. velocity u for different values of M .

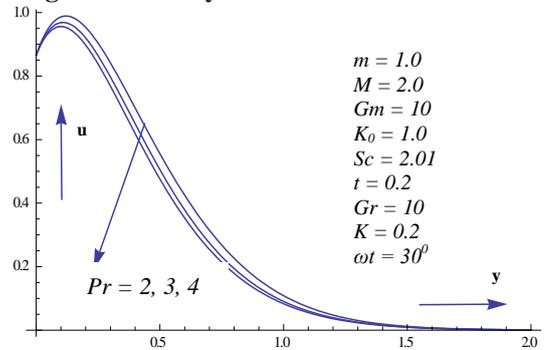


Figure 6. velocity u for different values of Pr .

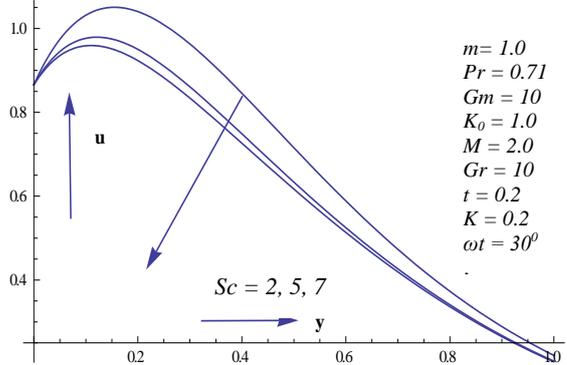


Figure 7. velocity u for different values of Sc .

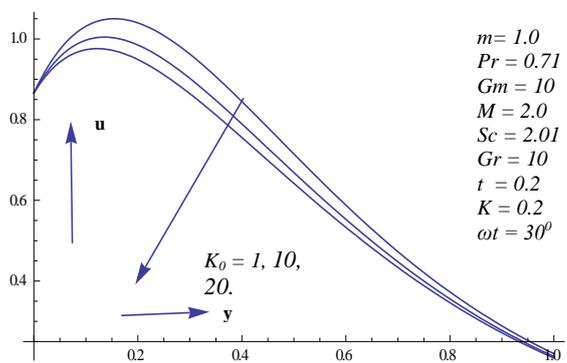


Figure 8. velocity u for different values of K_0 .

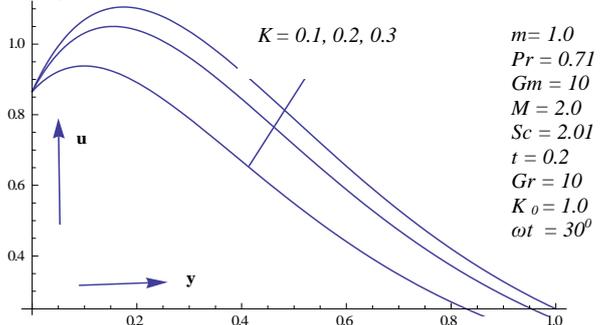


Figure 9. Velocity u for different values of K .

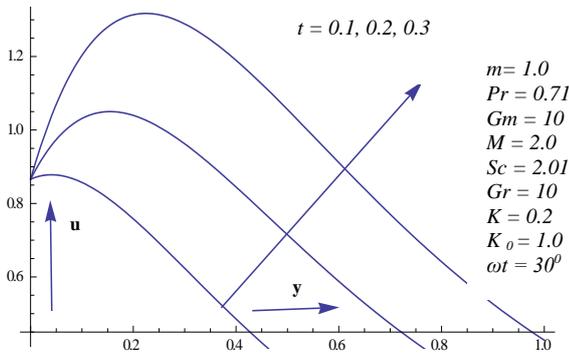


Figure 10. velocity u for different values of t.

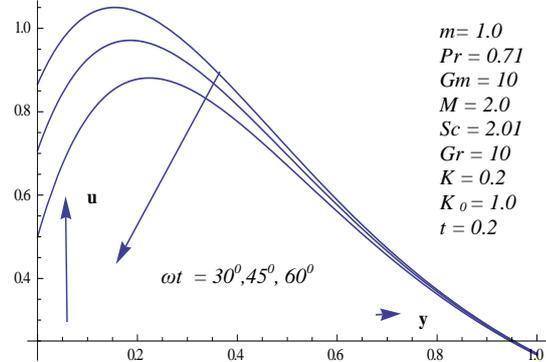


Figure 11 . velocity u for different values of ωt .

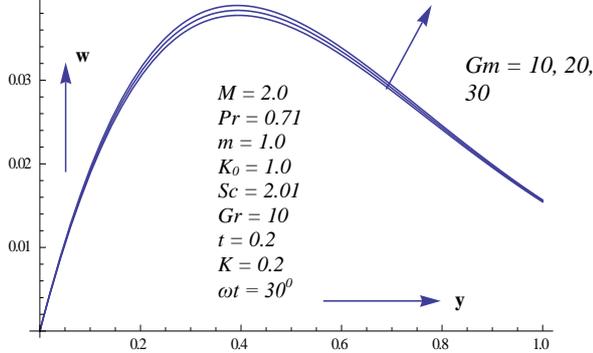


Figure 12. velocity w for different values of Gm.

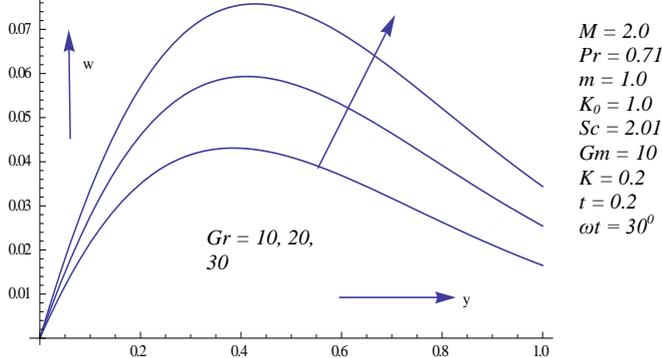


Figure 13. velocity w for different values of Gr.

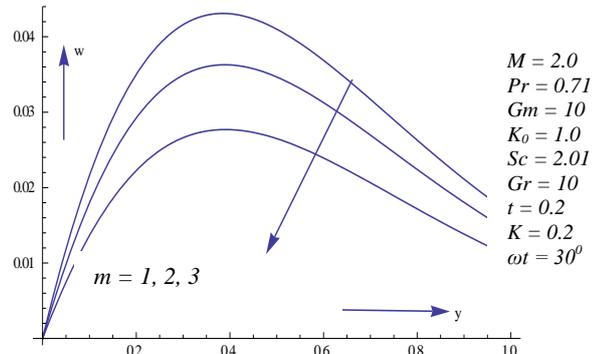


Figure 14. velocity w for different values of m.

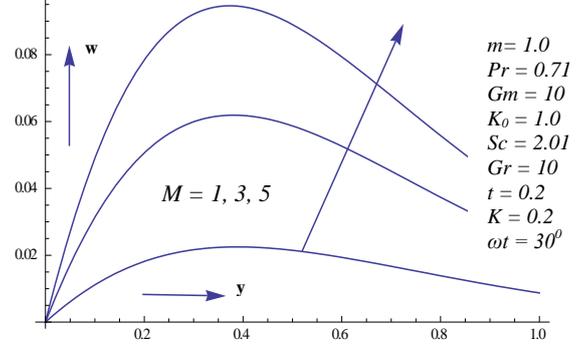


Figure 15. velocity w for different values of M.

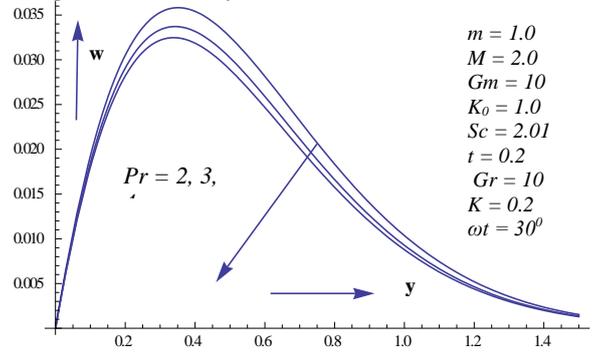


Figure 16. velocity w for different values of Pr.

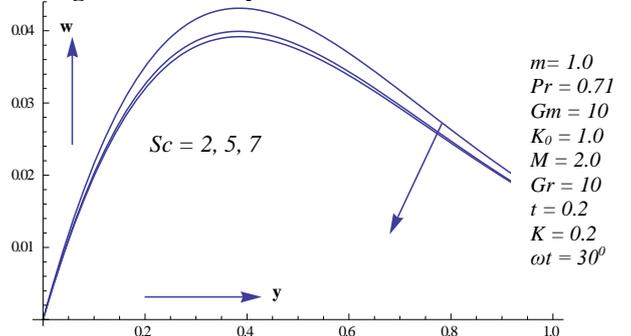


Figure 17. velocity w for different values of Sc

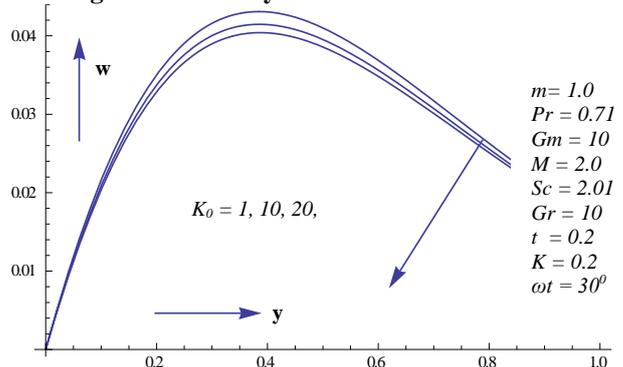


Figure 18. velocity w for different values of K_0

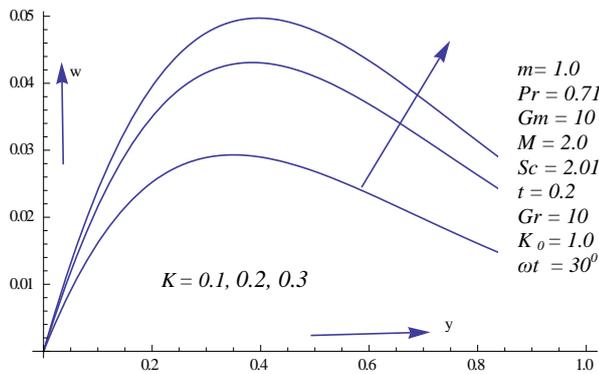


Figure 19. velocity w for different values of K.

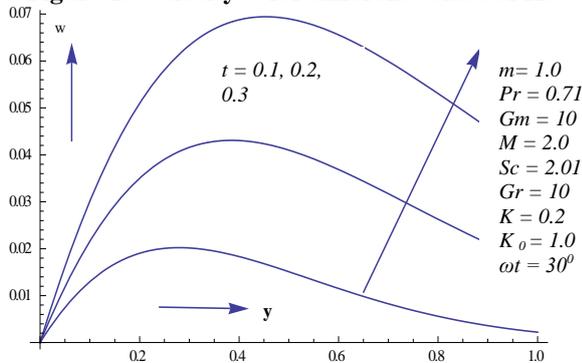


Figure 20. velocity w for different values of t.

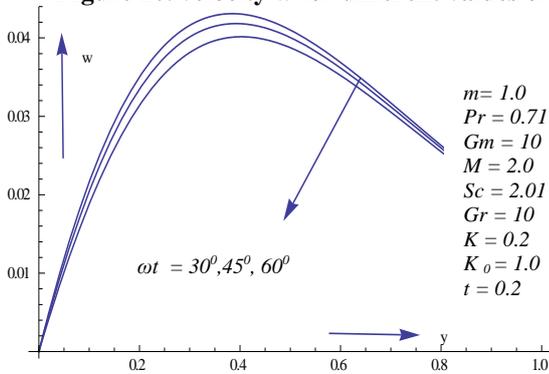


Figure 21. velocity w for different values of ωt

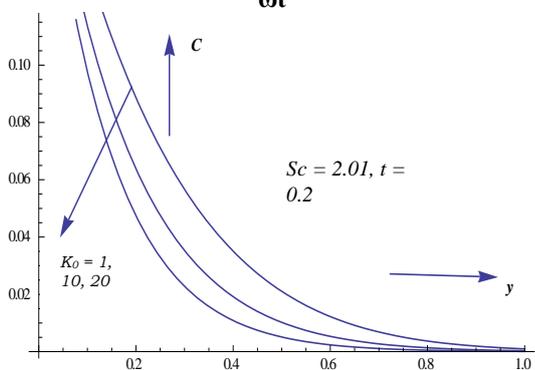


Figure 22. concentration profile for different values of K₀.

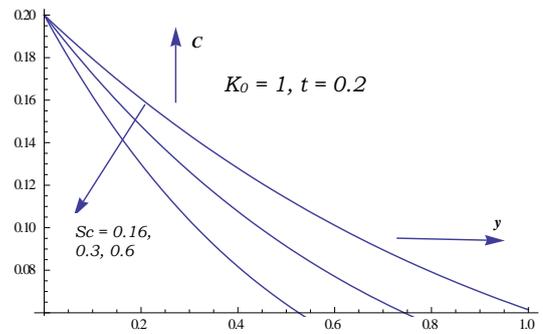


Figure 23. concentration profile for different values of Sc.

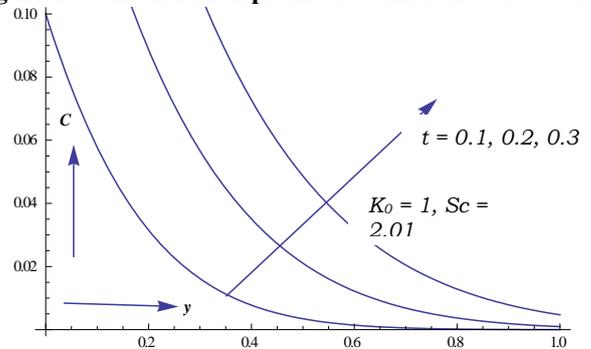


Figure 24. Concentration profile for different values of t.

Conclusions

The conclusions of the study are as under:

- Primary velocity increases with the increase in Gr , m , K , Gm and t .
- Primary velocity decreases with the increase in Pr , M , Sc , K_0 and ωt .
- Secondary velocity increases with increase in Gr , Gm , K , t and M .
- Secondary velocity decreases with the increase in m , Pr , Sc , K_0 and ωt .
- Skin fraction τ_x decreases with increase in Sc , Pr , M , K_0 .

It increases with Gr , Gm , m , K , t , and ωt . τ_z increases with increase Gr , Gm , K , t , and M . And it decreases with Pr , m , Sc , K , and ωt .

- Concentration decreases with increase in Sc and K and it increases with increase in t .
- Sherwood number decreases with increase in Sc , K and t .

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Appendix

$$P_1 = e^{-y\sqrt{a-i\omega}} + e^{y\sqrt{a-i\omega}}, P_2 = e^{-y\sqrt{a+i\omega}-2it\omega} + e^{y\sqrt{a+i\omega}+2it\omega},$$

$$P_3 = e^{-y\sqrt{a-i\omega}} \operatorname{Erf}\left\{\frac{y-2t\sqrt{a-i\omega}}{2\sqrt{t}}\right\}, P_4 = e^{-y\sqrt{a-i\omega}} \operatorname{Erf}\left\{\frac{y+2t\sqrt{a-i\omega}}{2\sqrt{t}}\right\},$$

$$P_5 = e^{-y\sqrt{a-i\omega}+2it\omega} \operatorname{Erf}\left\{\frac{y-2t\sqrt{a+i\omega}}{2\sqrt{t}}\right\},$$

$$P_6 = e^{y\sqrt{a-i\omega}+2it\omega} \operatorname{Erf}\left\{\frac{y+2t\sqrt{a+i\omega}}{2\sqrt{t}}\right\}, A_0 = 1 + A_{11} + e^{2\sqrt{a}y} A_{12},$$

$$A_{01} = 1 + e^{2\sqrt{a}y} + A_{11} - e^{2\sqrt{a}y} A_{12}, A_{11} = \operatorname{Erf}\left\{\frac{2a\sqrt{t}-y}{2\sqrt{t}}\right\},$$

$$A_{12} = \operatorname{Erf}\left\{\frac{2a\sqrt{t}-y}{2\sqrt{t}}\right\}, A_{13} = \operatorname{Erf}\left\{\frac{y-2t\sqrt{a(1+\frac{1}{-1+Pr})}}{2\sqrt{t}}\right\},$$

$$A_{14} = \operatorname{Erf}\left\{\frac{y+2t\sqrt{a(1+\frac{1}{-1+Pr})}}{2\sqrt{t}}\right\},$$

$$A_{15} = \operatorname{Erf}\left\{\frac{y-2t\sqrt{y-\frac{(a-K_0)Sc}{-1+Sc}}}{2\sqrt{t}}\right\}, A_{16} = \operatorname{Erf}\left\{\frac{y+2t\sqrt{y-\frac{(a-K_0)Sc}{-1+Sc}}}{2\sqrt{t}}\right\},$$

$$A_{17} = \sqrt{\frac{(a-K_0)Sc}{-1+Sc}}, A_{18} = \operatorname{Erf}\left\{\frac{2t\sqrt{\frac{a}{-1+Pr}} - y\sqrt{Pr}}{2\sqrt{t}}\right\},$$

$$A_{19} = \operatorname{Erf}\left\{\frac{2t\sqrt{\frac{a}{-1+Pr}} + y\sqrt{Pr}}{2\sqrt{t}}\right\}, A_{20} = \operatorname{Erf}\left\{\frac{2t\sqrt{K_0} - y\sqrt{Sc}}{2\sqrt{t}}\right\},$$

$$A_{21} = \operatorname{Erf}\left\{\frac{2t\sqrt{K_0} + y\sqrt{Sc}}{2\sqrt{t}}\right\}, A_{22} = \operatorname{Erf}\left\{\frac{2t\sqrt{\frac{a-K_0}{-1+Sc}} - y\sqrt{Sc}}{2\sqrt{t}}\right\},$$

$$A_{23} = \operatorname{Erf}\left\{\frac{2t\sqrt{\frac{a-K_0}{-1+Sc}} + y\sqrt{Sc}}{2\sqrt{t}}\right\}, B_{11} = \operatorname{Erfc}\left\{\frac{\sqrt{Sc}y - 2t\sqrt{K_0}}{2\sqrt{t}}\right\},$$

$$B_{12} = \operatorname{Erfc}\left\{\frac{\sqrt{Sc}y + 2t\sqrt{K_0}}{2\sqrt{t}}\right\}, a = \frac{M}{1+m^2}(1-im) + \frac{1}{K}.$$

Table 2. Skin friction for different Parameters.

m	Gr	Gm	M	Sc	K	Pr	ωt	t	K_0	τ_x	τ_z
1.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	0.5230	0.5265
2.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	0.6652	0.1899
3.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	0.7148	0.1441
1.0	20	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	2.7863	0.29173
1.0	30	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	5.0496	0.35409
1.0	10	20	2.0	2.01	0.2	0.71	30°	0.2	1.0	0.7718	0.2327
1.0	10	30	2.0	2.01	0.2	0.71	30°	0.2	1.0	1.0205	0.2360
1.0	10	10	1.0	2.01	0.2	0.71	30°	0.2	1.0	0.6441	0.1180
1.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	0.4025	0.3343
1.0	10	10	5.0	2.01	0.2	0.71	30°	0.2	1.0	0.1645	0.5265
1.0	10	10	2.0	2.00	0.2	0.71	30°	0.2	1.0	0.5233	0.2229
1.0	10	10	2.0	5.00	0.2	0.71	30°	0.2	1.0	0.4633	0.2279
1.0	10	10	2.0	7.00	0.2	0.71	30°	0.2	1.0	0.4433	0.2275
1.0	10	10	2.0	2.01	0.2	2.00	30°	0.2	1.0	0.0653	0.2055
1.0	10	10	2.0	2.01	0.2	3.00	30°	0.2	1.0	-0.1177	0.1929
1.0	10	10	2.0	2.01	0.2	4.00	30°	0.2	1.0	-0.2457	0.1929
1.0	10	10	2.0	2.01	0.2	0.71	45°	0.2	1.0	1.1632	0.2107
1.0	10	10	2.0	2.01	0.2	0.71	60°	0.2	1.0	1.9804	0.1861
1.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	0.2	0.5230	0.2293
1.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	0.3	0.9233	0.2526
1.0	10	10	2.0	2.01	0.2	0.71	30°	0.2	1.0	0.5230	0.2293
1.0	10	10	2.0	2.01	0.2	0.71	30°	0.3	1.0	0.9978	0.2755
1.0	10	10	10	2.01	0.2	0.71	30°	0.2	1.0	0.4850	0.2286
1.0	10	100	20	2.01	0.2	0.71	30°	0.3	1.0	0.4582	0.2280

Table 1. Sherwood number.

Sc	K_0	t	Sh
0.16	1.0	0.2	-0.2150
0.3	1.0	0.2	-0.2944
0.6	1.0	0.2	-0.4164
2.01	1.0	0.2	-0.7621
2.01	10	0.2	-1.1182
2.01	20	0.2	-1.4264
2.01	1.0	0.1	-0.5225
2.01	1.0	0.2	-0.7621
2.01	1.0	0.3	-0.9613