

EFFECTS OF RADIATION AND CHEMICAL REACTION ON MHD FLOW PAST AN EXPONENTIALLY ACCELERATED INCLINED PLATE WITH VARIABLE TEMPERATURE AND MASS DIFFUSION IN THE PRESENCE OF HALL CURRENT

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Abstract. *The present study is carried out to examine the effects of radiation and chemical reaction on unsteady flow of a viscous, incompressible and electrically conducting fluid past an exponentially accelerated inclined plate with variable wall temperature and mass diffusion in the presence of transversely applied uniform magnetic field and Hall current. The plate temperature and the concentration level near the plate increase linearly with time. The flow model under consideration has been solved by Laplace transform technique. The model contains equations of motion, diffusion equation and equation of energy. To analyze the solution of the model, desirable sets of the values of the parameters have been considered. The numerical data obtained is discussed with the help of graphs and tables. The numerical values obtained for skin-friction, Sherwood number and Nusselt number have been tabulated. We found that the values obtained for velocity, concentration and temperature are in concurrence with the actual flow of the fluid.*

Keywords: *Radiation, chemical reaction, mass diffusion, Hall current.*

1. INTRODUCTION

The MHD flow problems play important role in different areas of science and technology. These have many applications in industry, for instance, magnetic material processing, glass manufacturing control processes and purification of crude oil. Influence of chemical reaction and radiation on unsteady MHD free convection flow and mass transfer through viscous incompressible fluid past a heated vertical plate immersed in porous medium in the presence of heat source was analyzed by Sharma et al. [9]. Narayana and Sravanthi [5] have studied influence of variable permeability on unsteady MHD convection flow past a semi-infinite inclined plate with thermal radiation and chemical reaction. MHD boundary layer flow due to exponential stretching surface with radiation and chemical reaction was considered by Seini and Makinde [8]. Mondal et al. [4] have developed effects of radiation and chemical reaction on MHD free convection flow past a vertical plate in the porous medium. Analytical study of MHD free convective, dissipative boundary layer flow past a porous vertical surface in the presence of thermal radiation, chemical reaction and constant suction was presented by Reddy et al. [7]. Anitha [1] has explained chemical reaction and radiation effects on unsteady MHD natural convection flow of a rotating fluid past a vertical porous plate in the presence of viscous dissipation. Radiation effect on unsteady MHD convective heat and mass transfer past a vertical plate with chemical reaction and viscous dissipation was discussed by Balla and Naikoti [2]. Jonnadula et al. [3] have worked on influence of thermal radiation and chemical reaction on MHD flow, heat and mass transfer

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over a stretching surface. Chemical reaction effect on unsteady MHD flow past an impulsively started oscillating inclined plate with variable temperature and mass diffusion in the presence of Hall current was studied by us [6]. The objective of the present paper is to study the effects of radiation and chemical reaction on flow past exponentially accelerated inclined plate with variable wall temperature and mass diffusion in the presence of transversely applied uniform magnetic field and Hall current. The model has been solved using the Laplace transforms technique. The effects of various parameters on the velocity, temperature and concentration as well as on the skin-friction, Nusselt number and Sherwood number are presented graphically and discussed quantitatively.

2. MATHEMATICAL ANALYSIS

The geometric model of the problem is shown in Fig. 1.

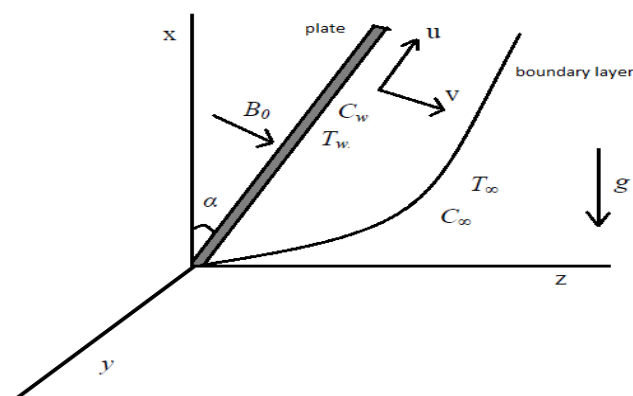


Figure1. Physical model

The x axis is taken along the vertical plane and z axis is normal to it. Thus the z axis lies in the horizontal plane. The plate is inclined at angle α from vertical. The magnetic field B_0 of uniform strength is applied perpendicular to 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 exponentially accelerating in its own plane with velocity $u = u_0 e^{bt}$ and temperature of the plate is raised to T_w . The concentration C_w near the plate is raised linearly with respect to time.

The flow model is as under:

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

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

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

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

The initial and boundary conditions are

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

The local radiant for the case of an optically thin gray gas is expressed by

$$\frac{\partial q_r}{\partial z} = -4a^* \sigma (T_\infty^4 - T^4) \quad (6)$$

Let the temperature difference within the flow be sufficiently small, then T^4 can be expressed as the linear function of temperature. This is accomplished by expanding T^4 in a Taylor series about T_∞ and neglecting higher-order terms

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \quad (7)$$

Using equations (6) and (7), equation (4) becomes

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial z^2} - 16a^* \sigma T_\infty^3 (T - T_\infty) \quad (8)$$

The following non-dimensional quantities are introduced to transform equations (1), (2), (3) and (8) into dimensionless form:

$$\left. \begin{aligned} \bar{z} &= \frac{zu_0}{v}, \bar{u} = \frac{u}{u_0}, \bar{v} = \frac{v}{u_0}, S_c = \frac{v}{D}, K_0 = \frac{vK_c}{u_0^2}, P_r = \frac{\mu u_0}{k}, \bar{b} = \frac{bv}{u_0^2}, \\ R &= \frac{16a^* v^2 \sigma T_\infty^3}{ku_0}, \theta = \frac{(T - T_\infty)}{(T_w - T_\infty)}, G_r = \frac{g\beta v (T_w - T_\infty)}{u_0^3}, M = \frac{\sigma B_0^2 v}{\rho u_0^2}, \\ G_m &= \frac{g\beta^* v (C_w - C_\infty)}{u_0^3}, \mu = \rho v, \bar{C} = \frac{(C - C_\infty)}{(C_w - C_\infty)}, \bar{t} = \frac{tu_0^2}{v}. \end{aligned} \right\} \quad (9)$$

The flow model in dimensionless form is

$$\frac{\partial \bar{u}}{\partial \bar{t}} = \frac{\partial^2 \bar{u}}{\partial \bar{z}^2} + G_r \text{Cosa} \theta + G_m \text{Cosa} \bar{C} - \frac{M(\bar{u} + m\bar{v})}{(1+m^2)} \quad (10)$$

$$\frac{\partial \bar{v}}{\partial \bar{t}} = \frac{\partial^2 \bar{u}}{\partial \bar{z}^2} + \frac{M(m\bar{u} - \bar{v})}{(1+m^2)} \quad (11)$$

$$\frac{\partial \bar{C}}{\partial \bar{t}} = \frac{1}{S_c} \frac{\partial^2 \bar{C}}{\partial \bar{z}^2} - K_0 \bar{C} \quad (12)$$

$$\frac{\partial \theta}{\partial \bar{t}} = \frac{1}{P_r} \frac{\partial^2 \theta}{\partial \bar{z}^2} - \frac{R\theta}{P_r} \quad (13)$$

The corresponding boundary conditions (5) become:

$$\left. \begin{aligned} \bar{t} \leq 0 : \bar{u} = 0, \bar{v} = 0, \theta = 0, \bar{C} = 0, \text{ for every } \bar{z}. \\ \bar{t} > 0 : \bar{u} = e^{\bar{b}\bar{t}}, \bar{v} = 0, \theta = \bar{t}, \bar{C} = \bar{t}, \text{ at } \bar{z} = 0. \\ \bar{u} \rightarrow 0, \bar{v} \rightarrow 0, \theta \rightarrow 0, \bar{C} \rightarrow 0, \text{ as } \bar{z} \rightarrow \infty. \end{aligned} \right\} \quad (14)$$

Dropping bars in the above equations, we get

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial z^2} + G_r \text{Cosa} \theta + G_m \text{Cosa} C - \frac{M(u + mv)}{(1+m^2)} \quad (15)$$

$$\frac{\partial v}{\partial t} = \frac{\partial^2 v}{\partial z^2} + \frac{M(mu - v)}{(1+m^2)} \quad (16)$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c} \frac{\partial^2 C}{\partial z^2} - K_0 C \quad (17)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r} \frac{\partial^2 \theta}{\partial z^2} - \frac{R\theta}{P_r} \quad (18)$$

The boundary conditions become

$$\left. \begin{aligned} t \leq 0 : u = 0, v = 0, \theta = 0, C = 0, \text{ for every } z. \\ t > 0 : u = e^{bt}, v = 0, \theta = t, C = t, \text{ at } z=0. \\ u \rightarrow 0, v \rightarrow 0, \theta \rightarrow 0, C \rightarrow 0, \text{ as } z \rightarrow \infty. \end{aligned} \right\} \quad (19)$$

Writing the equations (15) and (16) in combined form (using $q = u + iv$)

$$\frac{\partial q}{\partial t} = \frac{\partial^2 q}{\partial z^2} + G_r \text{Cosa} \theta + G_m \text{Cosa} C - qa \quad (20)$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c} \frac{\partial^2 C}{\partial z^2} - K_0 C \quad (21)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r} \frac{\partial^2 \theta}{\partial z^2} - \frac{R\theta}{P_r} \quad (22)$$

Finally, the boundary conditions become:

$$\left. \begin{aligned} t \leq 0 : q = 0, \theta = 0, C = 0, \text{ for every } z. \\ t > 0 : q = e^{bt}, \theta = t, C = t, \text{ at } z=0. \\ q \rightarrow 0, \theta \rightarrow 0, C \rightarrow 0, \text{ as } z \rightarrow \infty. \end{aligned} \right\} \quad (23)$$

The dimensionless governing equations (20) to (22), subject to the boundary conditions (23), are solved by the usual Laplace transform technique. The solution obtained is as under:

$$\begin{aligned} q &= \frac{1}{2} e^{bt - \sqrt{a+bz}} A_{33} + \frac{G_r \text{Cosa}}{4(a-R)^2} ((\exp(-\sqrt{a}z)(2RtA_1 - 2atA_1 + z\sqrt{a}A_2 + 2A_1(P_r + 1)) - \frac{A_2 z}{\sqrt{a}}) \\ &- \frac{2A_5 P_r z}{\sqrt{A_{32} A_{11}}} (at - Rt + P_r - 1) + \frac{2A_{28} A_6 P_r z}{A_{11}} (P_r - 1) - 2A_{26} A_3 (P_r - 1) - \frac{P_r z \sqrt{A_{32} P_r}}{A_{10} \pi \sqrt{R}} (\frac{1}{a} - \frac{1}{R})) \\ &+ \frac{G_m \text{Cosa}}{4(a - K_0 S_c)^2} ((\exp(-\sqrt{a}z)(z\sqrt{a}A_2 - 2atA_1 - 2A_1(S_c - 1) + 2tA_1 K_0 S_c) - \frac{z \exp(-\sqrt{a}z) A_2 K_0 S_c}{\sqrt{a}} \\ &- 2A_{27} A_4 (S_c - 1) + \exp(-z\sqrt{S_c K_0}) (-\frac{aA_8 z \sqrt{S_c}}{\sqrt{K_0}} - 2atA_7 - 2A_7 - 2A_7(S_c - 1) + 2tA_7 K_0 S_c \\ &+ zA_8 S_c \sqrt{S_c K_0}) + 2A_{27} A_9 (S_c - 1)) \\ \theta &= \frac{e^{-\sqrt{R}z}}{4\sqrt{R}} \{ \text{erfc}[\frac{-2\sqrt{R}t + zP_r}{\sqrt{P_r t}}] (2\sqrt{R}t - zR) + e^{2\sqrt{R}z} \text{erfc}[\frac{2\sqrt{R}t + zP_r}{\sqrt{P_r t}}] (2\sqrt{R}t + zR) \}, \\ C &= \frac{e^{-z\sqrt{S_c K_0}}}{4\sqrt{K_0}} \left\{ \text{erfc}[\frac{z\sqrt{S_c} - 2t\sqrt{K_0}}{2\sqrt{t}}] (-z\sqrt{S_c} + 2t\sqrt{K_0}) + e^{2z\sqrt{S_c K_0}} \text{erfc}[\frac{z\sqrt{S_c} + 2t\sqrt{K_0}}{2\sqrt{t}}] (z\sqrt{S_c} + 2t\sqrt{K_0}) \right\} \end{aligned}$$

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

2.1 SKIN FRICTION

The dimensionless skin friction at the plate is

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

2.2 NUSSELT NUMBER

The dimensionless Nusselt number at the plate is given by

$$Nu = \left(\frac{\partial\theta}{\partial z}\right)_{z=0} = \operatorname{erfc}\left[\frac{\sqrt{Rt}}{\sqrt{tP_r}}\right]\left(\sqrt{Rt} - \frac{\sqrt{R}}{2}t + \frac{P_r}{4\sqrt{R}}\right) - \operatorname{erfc}\left[-\frac{\sqrt{Rt}}{\sqrt{tP_r}}\right]\left(\frac{\sqrt{R}}{2}t + \frac{P_r}{4\sqrt{R}}\right) - \frac{e^{-\frac{Rt}{P_r}}\sqrt{tP_r}}{\sqrt{\pi}} .$$

2.3 SHERWOOD NUMBER

The dimensionless Sherwood number at the plate is given by

$$S_h = \left(\frac{\partial C}{\partial z}\right)_{z=0} = \operatorname{erfc}\left[-\sqrt{tK_0}\right]\left(-\frac{1}{4\sqrt{K_0}}\sqrt{S_c} - \frac{t\sqrt{S_c K_0}}{2}\right) + \sqrt{S_c}\operatorname{erfc}\left[\sqrt{tK_0}\right]\left(\frac{1}{4\sqrt{K_0}} + t\sqrt{K_0}\right) - \frac{e^{-tK_0}\sqrt{tS_c K_0}}{\sqrt{\pi K_0}} ,$$

3. RESULTS AND DISCUSSION

The present study is carried out to examine the effects of radiation and chemical reaction on the flow. The behavior of other parameters like magnetic field, Hall current and thermal buoyancy is almost similar to the earlier model studied by us (2016). The analytical results are shown graphically in figures 2 to 9. The numerical values of skin-friction, Sherwood number and Nusselt number are presented in Tables 1-3. Chemical reaction effect on fluid flow behavior is shown by Figs.2 and 3. It is seen here that when chemical reaction parameter (K_0) increases, primary and secondary velocities decrease throughout the boundary layer region. Figs.4 and 5, indicate that effect of radiation (R) in the boundary layer region near the plate tends to accelerate primary and secondary velocities. It is deduced that velocities get increased when acceleration parameter b is increased (Figs.6 and 7). Further, it is observed that the temperature and concentration of the fluid near the plate decrease when radiation and chemical reaction parameters are increased (Figs. 8 and 9).

Skin friction is given in Table 1. The values of τ_x and τ_y increase with the increase in radiation parameter and acceleration parameter. These get decreased with chemical reaction parameter. Sherwood number is given in Table 2. The value of S_h decreases with the increase in the chemical reaction parameter, Schmidt number and time. Nusselt number is given in Table 3. The value of Nu decreases with increase in Prandtl number, radiation parameter and time.

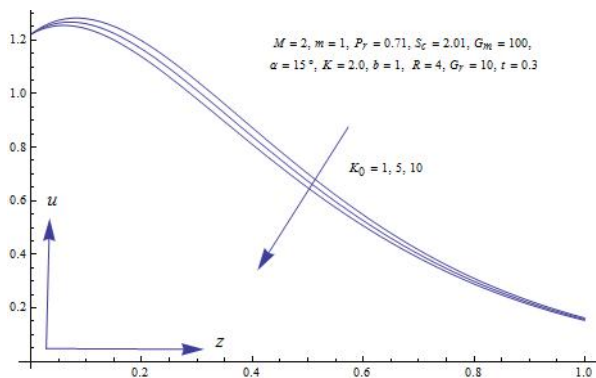


Figure 2. Velocity u for different values of K_0

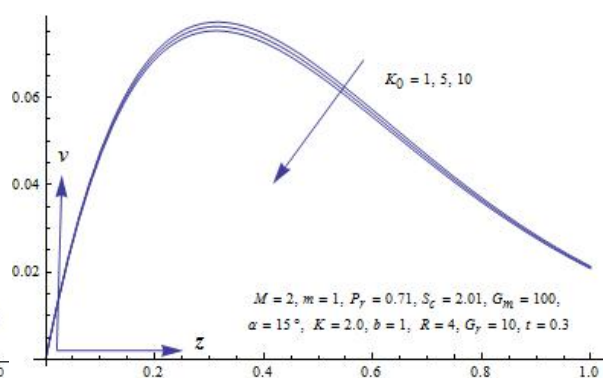


Figure 3. velocity v for different values of K_0

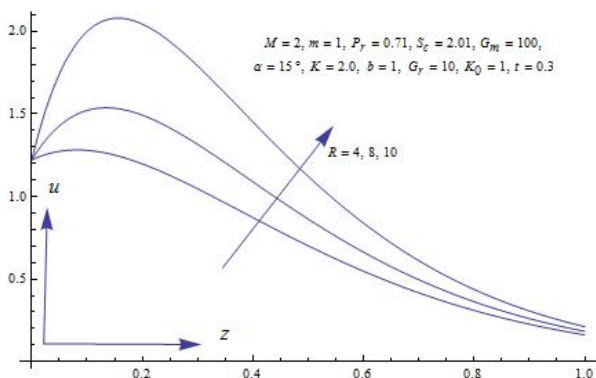


Figure 4. Velocity u for different values of R

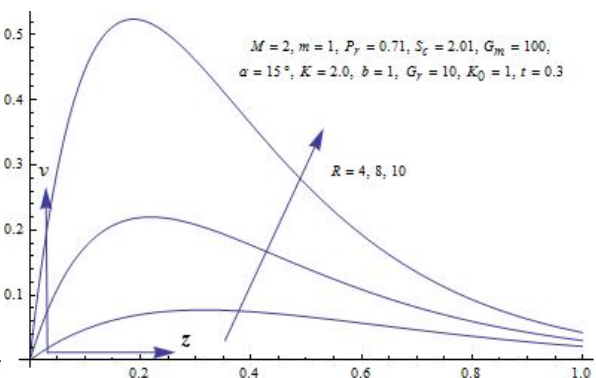


Figure 5. Velocity v for different values of R

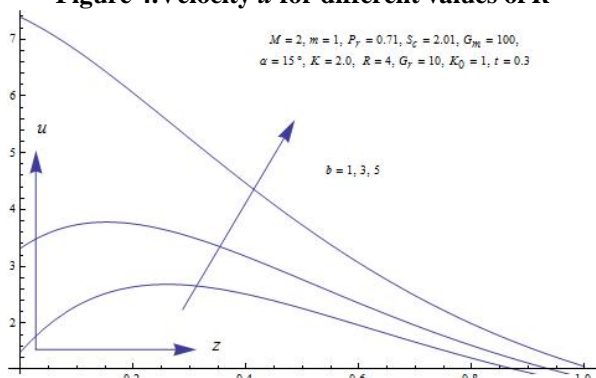


Figure 6. Velocity u for different values of b

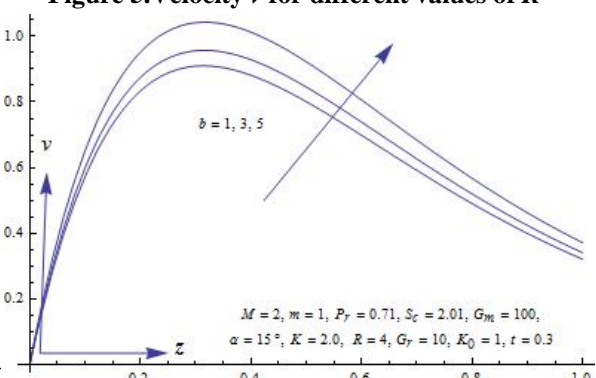


Figure 7. Velocity v for different values of b

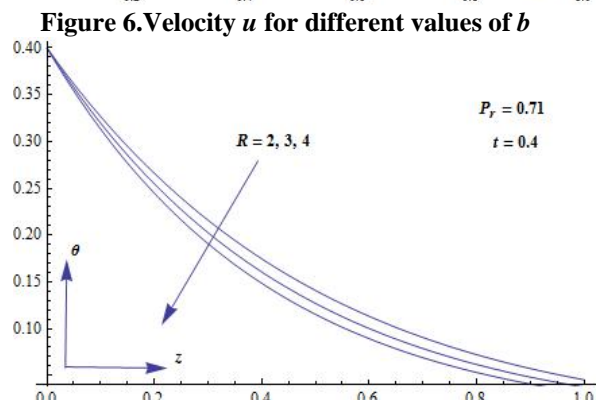


Figure 8. θ for different values of R

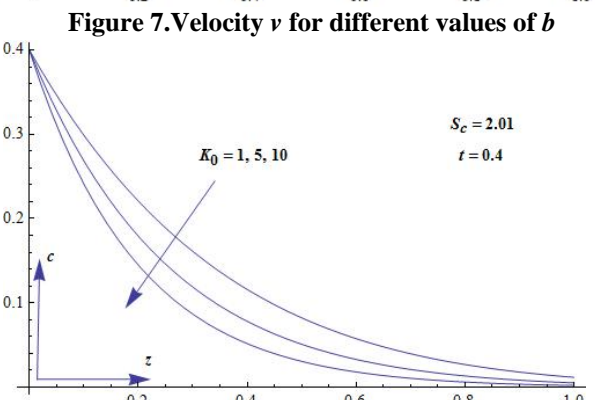


Figure 9. c for different values of K_0

Table 1. Skin friction for different parameters

α (in degree)	M	m	Pr	Sc	Gm	Gr	R	K_0	b	t	τ_x	τ_y
15	2	1	0.71	2.01	100	10	04	01	1	0.3	0475.9255	0285.1900
15	2	1	0.71	2.01	100	10	08	01	1	0.3	5713.8393	5377.6583
15	2	1	0.71	2.01	100	10	04	05	1	0.3	0475.4082	0285.1724
15	2	1	0.71	2.01	100	10	04	10	1	0.3	0474.9490	0285.1569
15	2	1	0.71	2.01	100	10	04	01	3	0.3	0477.0062	0285.1919
15	2	1	0.71	2.01	100	10	04	01	5	0.3	0478.9688	0285.1950

Table 2. Sherwood number for different Parameters.

K_0	Sc	t	S_h
01	2.01	0.2	-0.762200
05	2.01	0.2	-0.933049
10	2.01	0.2	-1.118240
01	3.00	0.2	-0.931175
01	4.00	0.2	-1.075230
01	2.01	0.3	-0.961323
01	2.01	0.4	-1.141570

Table 3: Nusselt number for different parameter

P_r	R	T	Nu
0.71	2	0.4	-0.805273
7.00	2	0.4	-1.959260
0.71	3	0.4	-0.894014
0.71	4	0.4	-0.976083
0.71	2	0.5	-0.950956
0.71	2	0.6	-1.094940

4. CONCLUSION

In this paper a theoretical analysis has been done to study the unsteady MHD flow past a moving inclined plate with variable wall temperature and mass diffusion in the presence of Hall current, radiation and chemical reaction. The results obtained are in agreement with the usual flow. It has been found that the velocity in the boundary layer increases with the values of acceleration parameter and radiation parameter. But trend is reversed with chemical reaction parameter. That is the velocity decreases when chemical reaction parameter is increased. It is also observed that the permeability parameter, acceleration parameter and radiation parameter increases the drag at the plate surface, and decreases with chemical reaction parameter. Sherwood number and Nusselt number decreases with increase in radiation parameter and chemical reaction parameter.

APPENDIX

$$\begin{aligned}
 A &= \frac{u_0^2 t}{v}, \quad a = \frac{M(1-im)}{1+m^2} + \frac{1}{K}, \quad A_1 = (1 + A_{12} + e^{2\sqrt{az}}(1 - A_{13})), \quad A_2 = (1 + A_{12} - e^{2\sqrt{az}}(1 - A_{13})), \\
 A_3 &= (A_{14} - 1 + A_{29}(A_{15} - 1)), \quad A_4 = (A_{16} - 1 + A_{30}(A_{17} - 1)), \quad A_5 = (A_{18} - 1 + A_{33}(A_{19} - 1)), \\
 A_6 &= (A_{20} - 1 + A_{31}(A_{21} - 1)), \quad A_7 = (e^{2z\sqrt{K_0 S_c}}(A_{23} - 1) - A_{22} - 1), \quad A_8 = (e^{2z\sqrt{K_0 S_c}}(A_{23} - 1) + A_{22} + 1), \\
 A_9 &= (A_{30}(A_{25} - 1) - A_{24} - 1), \quad A_{10} = (1 - A_{18} + A_{32}(A_{19} - 1)), \quad A_{11} = \text{Abs}[z]\text{Abs}[P_r], \\
 A_{12} &= \text{erf}\left[\frac{1}{2\sqrt{t}}(2\sqrt{at} - z)\right], \quad A_{13} = \text{erf}\left[\frac{1}{2\sqrt{t}}(2\sqrt{at} + z)\right], \quad A_{14} = \text{erf}\left[\frac{1}{2\sqrt{t}}\left(z - 2t\sqrt{\frac{aP_r - R}{P_r - 1}}\right)\right], \\
 A_{15} &= \text{erf}\left[\frac{1}{2\sqrt{t}}\left(z + 2t\sqrt{\frac{aP_r - R}{P_r - 1}}\right)\right], \quad A_{16} = \text{erf}\left[\frac{1}{2\sqrt{t}}\left(z - 2t\sqrt{\frac{(a - K_0)S_c}{S_c - 1}}\right)\right], \quad A_{17} = \text{erf}\left[\frac{1}{2\sqrt{t}}\left(z + 2t\sqrt{\frac{(a - K_0)S_c}{S_c - 1}}\right)\right], \\
 A_{18} &= \text{erf}\left[\frac{A_{11}}{2\sqrt{t}} - \sqrt{\frac{tR}{P_r}}\right], \quad A_{19} = \text{erf}\left[\frac{A_{11}}{2\sqrt{t}} + \sqrt{\frac{tR}{P_r}}\right], \quad A_{20} = \text{erf}\left[\frac{A_{11}}{2\sqrt{t}} - \sqrt{\frac{(R - aP_r)t}{P_r - P_r^2}}\right], \\
 A_{21} &= \text{erf}\left[\frac{A_{11}}{2\sqrt{t}} + \sqrt{\frac{(R - aP_r)t}{P_r - P_r^2}}\right], \quad A_{22} = \text{erf}\left[\frac{1}{2\sqrt{t}}(2t\sqrt{K_0} - z\sqrt{S_c})\right], \quad A_{23} = \text{erf}\left[\frac{1}{2\sqrt{t}}(2t\sqrt{K_0} + z\sqrt{S_c})\right], \\
 A_{24} &= \text{erf}\left[\frac{1}{2\sqrt{t}}\left(2t\sqrt{\frac{(a - K_0)S_c}{S_c - 1}} - z\sqrt{S_c}\right)\right], \quad A_{25} = \text{erf}\left[\frac{1}{2\sqrt{t}}\left(2t\sqrt{\frac{(a - K_0)S_c}{S_c - 1}} + z\sqrt{S_c}\right)\right], \\
 A_{26} &= \exp\left(\frac{at}{P_r - 1} - \frac{Rt}{P_r - 1} - z\sqrt{\frac{aP_r - R}{P_r - 1}}\right), \quad A_{27} = \exp\left(\frac{at}{S_c - 1} - \frac{tS_c K_0}{S_c - 1} - z\sqrt{\frac{(a - K_0)S_c}{S_c - 1}}\right), \\
 A_{28} &= \frac{1}{A_{31}} \exp\left(\frac{at}{P_r - 1} - \frac{Rt}{P_r - 1}\right), \quad A_{29} = \exp\left(2z\sqrt{\frac{-R + aP_r}{P_r - 1}}\right), \quad A_{30} = \exp\left(2z\sqrt{\frac{(a - K_0)S_c}{S_c - 1}}\right), \\
 A_{31} &= \exp\left(2\text{Abs}[z]\sqrt{\frac{P_r(aP_r - R)}{P_r - 1}}\right), \quad A_{32} = \exp\left(2\text{Abs}[z]\sqrt{P_r R}\right),
 \end{aligned}$$

$$A_{33} = 1 + A_{34} + e^{2\sqrt{a+bz}} A_{35}, \quad A_{34} = \operatorname{erf}\left[\frac{2\sqrt{a+bt}-z}{2\sqrt{t}}\right], \quad A_{35} = \operatorname{erfc}\left[\frac{2\sqrt{a+bt}+z}{2\sqrt{t}}\right],$$

NOMENCLATURE			
a^*	absorption constant	ω_e	Cyclotron frequency of electrons
b	acceleration parameter	τ_e	Electron collision time
\bar{b}	dimensionless acceleration parameter	β	Volumetric coeff. of thermal expansion
C	Species concentration in the fluid	β^*	Volumetric coeff. of concentration
\bar{C}	The dimensionless concentration	ν	The kinematic viscosity
C_p	Specific heat at constant pressure	ρ	The fluid density
C_w	Species concentration at the plate	σ	Electrical conductivity
C_∞	The concentration in the fluid	μ	The magnetic permeability
D	Mass diffusion	θ	The dimensionless temperature
u, v	Velocity of the fluid in x and z- direction	μ	The coefficient of viscosity
$\bar{u} \bar{v}$	dimensionless velocity in x and z- direction	G_m	Mass Grashof number
T	Temperature of the fluid	G_r	Thermal Grashof number
K_0	The chemical reaction parameter	k	The thermal conductivity
M	The magnetic parameter,	T_∞	The temperature of the fluid
m	The Hall parameter($m=\omega_e\tau_e$)	g	Gravity acceleration
Pr	Prandtl number	T_w	Temperature of the plate
R	Radiation parameter	K	Permeability of the medium
Sc	Schmidt number	t	Time

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