CHAPTER 3

MHD AND RADIATION EFFECTS ON VERTICAL OSCILLATING PLATE IN THE PRESENCE OF FIRST ORDER CHEMICAL REACTION

3.1 INTRODUCTION

Thermal radiation is an important factor in the thermodynamic analysis of much high temperature system like solar collectors, boilers, gas turbines, nuclear power plants and furnaces. It also plays a vital role in fossil fuel combustion energy process, astrophysical flows, solar power technology and space vehicle re-entry. MHD is of importance in connection with many engineering problems, such as sustained plasma confinement for controlled thermonuclear fusion and electromagnetic casting of metals. MHD plays an important role in agriculture, petroleum industries, geophysics and in astrophysics. Important applications in the study of geological formations, in exploration and thermal recovery of oil and in the assessment of aquifers, geothermal reservoirs and underground nuclear waste storage sites.

Hossain and Takhar (1996) studied the radiation effects on mixed convection along a vertical plate with uniform surface temperature. Das et al. (1998) have studied effect of homogeneous first order chemical reaction on the flow past an impulsively started infinite vertical plate with uniform heat flux and mass transfer. The dimensionless governing equations were solved by the usual Laplace transform technique. Raptis and Perdikis (1999) studied the effects of thermal radiation and free convection flow past a moving vertical plate. The governing equations were solved analytically.

The effects of transversely applied magnetic field, on the flow of an electrically conducting fluid past an impulsively started infinite isothermal vertical plate was studied by Soundalgekar et al. (1979). MHD effects on impulsively started vertical infinite plate
with variable temperature in the presence of transverse magnetic field were studied by Soundalgekar et al. (1981). The dimensionless governing equations were solved using Laplace transform technique.

In chapter 2, the radiation and MHD effects on vertical oscillating plate with variable temperature in the presence of chemical reaction are discussed. In this chapter, section 3.2 studies the chemical reaction and radiation effects on vertical oscillating plate and the section 3.3 studies the effects of MHD and chemical reaction with variable temperature and mass diffusion. The governing equations are tackled using the Laplace transform technique.

3.2 CHEMICAL REACTION AND RADIATION EFFECTS ON VERTICAL OSCILLATING PLATE

3.2.1 GOVERNING EQUATIONS

The unsteady flow of a viscous incompressible fluid which is initially at rest and surrounds an infinite vertical plate with temperature $T_\infty$ and concentration $C'_\infty$. Here, the $x$-axis is taken along the plate in the vertically upward direction and the $y$-axis is taken normal to the plate. Initially, it is assumed that the plate and the fluid are of the same temperature and concentration. At time $t' > 0$, the plate starts oscillating in its own plane with frequency $\omega'$ and the temperature of the plate is raised linearly with respect to time and the concentration level near the plate is also raised linearly with respect to time. The fluid considered here is a gray, absorbing-emitting radiation but a non-scattering medium. It is also assumed that there exists a homogeneous first order chemical reaction between the fluid and species concentration. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations:
\[
\frac{\partial u}{\partial t'} = g\beta (T - T_\infty) + g\beta' (C' - C'_\infty) + \nu \frac{\partial^2 u}{\partial y^2} \tag{3.2.1}
\]

\[
\rho C_p \frac{\partial T}{\partial t'} = k \frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y} \tag{3.2.2}
\]

\[
\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y^2} - K_i C' \tag{3.2.3}
\]

The initial and boundary conditions are as follows:

\[
t' \leq 0: \quad u = 0, \quad T = T_\infty, \quad C' = C'_\infty, \quad \text{for all } y
\]

\[
t' > 0: \quad u = u_0 \cos \omega t', \quad T = T_\infty + (T_w - T_\infty) A t', \quad C' = C'_\infty + (C'_w - C'_\infty), \quad \text{at } y = 0
\]

\[
u = 0, \quad T \to T_\infty, \quad C' \to C'_\infty, \quad \text{as } y \to \infty \tag{3.2.4}
\]

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

\[
\frac{\partial q_r}{\partial y} = -4 a^* \sigma (T_\infty^4 - T^4) \tag{3.2.5}
\]

It is assumed that the temperature differences within the flow are sufficiently small such that \(T^4\) may be expressed as a linear function of the temperature. This is accomplished by expanding \(T^4\) in a Taylor series about \(T_\infty\) and neglecting higher-order terms, thus

\[
T^4 \approx 4 T_\infty^3 T - 3 T_\infty^4 \tag{3.2.6}
\]

By using equations (3.2.5) and (3.2.6), equation (3.2.2) reduces to

\[
\rho C_p \frac{\partial T}{\partial t'} = k \frac{\partial^2 T}{\partial y^2} + 16 a^* \sigma T_\infty^3 (T_w - T) \tag{3.2.7}
\]
The dimensionless quantities are defined as

\[ U = \frac{u}{u_0}, \quad t = \frac{t' u_0^2}{\nu}, \quad Y = \frac{y u_0}{\nu}, \quad \theta = \frac{T - T_\infty}{T_w - T_\infty}, \]

\[ Gr = \frac{g \beta \nu (T_w - T_\infty)}{u_0^3}, \quad C = \frac{C' - C'_\infty}{C_w - C'_\infty}, \quad Gc = \frac{\nu g \beta^* (C_w' - C'_\infty)}{u_0^3}, \quad (3.2.8) \]

\[ Pr = \frac{\mu C_p}{k}, \quad Sc = \frac{\nu}{D}, \quad R = \frac{16 \alpha^* v^2 \sigma T_\infty^3}{k u_0^2}, \quad K = \frac{\nu K_i}{u_0^2}, \quad \omega = \frac{\omega' \nu}{u_0^2} \]

in equations (3.2.1) to (3.2.4), lead to

\[ \frac{\partial U}{\partial t} = Gr \theta + Gc C + \frac{\partial^2 U}{\partial Y^2} \quad (3.2.9) \]

\[ \frac{\partial \theta}{\partial t} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial Y^2} - \frac{R}{Pr} \theta \quad (3.2.10) \]

\[ \frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial Y^2} - K C \quad (3.2.11) \]

The initial and boundary conditions in non-dimensional form are

\[ U = 0, \quad \theta = 0, \quad C = 0, \quad \text{for all } Y, t \leq 0 \]

\[ t > 0: \quad U = \cos \omega t, \quad \theta = t, \quad C = t, \quad \text{at } Y = 0 \quad (3.2.12) \]

\[ U = 0, \quad \theta \to 0, \quad C \to 0, \quad \text{as } Y \to \infty \]

All the physical variables are defined in the nomenclature. The solutions are obtained for hydrodynamic flow field in the presence of thermal radiation and chemical reaction.
3.2.2 SOLUTION

The equations (3.2.9) to (3.2.11), subject to the boundary conditions (3.2.12), are solved by the usual Laplace transform technique and the solutions are derived as follows:

\[
U = \frac{\exp(i\omega t)}{4} \left[ \exp(2\eta \sqrt{i\omega t}) \text{erfc}(\eta + \sqrt{i\omega t}) + \exp(-2\eta \sqrt{i\omega t}) \text{erfc}(\eta - \sqrt{i\omega t}) \right] + \frac{\exp(-i\omega t)}{4} \left[ \exp(2\eta \sqrt{-i\omega t}) \text{erfc}(\eta + \sqrt{-i\omega t}) + \exp(-2\eta \sqrt{-i\omega t}) \text{erfc}(\eta - \sqrt{-i\omega t}) \right] + 2(d + e) \text{erfc}(\eta) + 2t(bd + ce) \left[ (1 + 2\eta^2) \text{erfc}(\eta) - \frac{2\eta}{\sqrt{\pi}} \exp(-\eta^2) \right] - d \exp(bt) \left[ \exp(2\eta \sqrt{bt}) \text{erfc}(\eta + \sqrt{bt}) + \exp(-2\eta \sqrt{bt}) \text{erfc}(\eta - \sqrt{bt}) \right] - e \exp(ct) \left[ \exp(2\eta \sqrt{ct}) \text{erfc}(\eta + \sqrt{ct}) + \exp(-2\eta \sqrt{ct}) \text{erfc}(\eta - \sqrt{ct}) \right] - d(1 + bt) \left[ \exp(2\eta \sqrt{Rt}) \text{erfc}(\eta \sqrt{Pr} + \sqrt{at}) + \exp(-2\eta \sqrt{Rt}) \text{erfc}(\eta \sqrt{Pr} - \sqrt{at}) \right] + \frac{bd\eta \sqrt{Pr}}{\sqrt{R}} \left[ \exp(-2\eta \sqrt{Rt}) \text{erfc}(\eta \sqrt{Pr} - \sqrt{at}) - \exp(2\eta \sqrt{Rt}) \text{erfc}(\eta \sqrt{Pr} + \sqrt{at}) \right] + d \exp(bt) \left[ \exp(-2\eta \sqrt{Pr(a + b)t}) \text{erfc}(\eta \sqrt{Pr} - \sqrt{(a + b)t}) + \exp(2\eta \sqrt{Pr(a + b)t}) \text{erfc}(\eta \sqrt{Pr} + \sqrt{(a + b)t}) \right] - e(1 + ct) \left[ \exp(2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} + \sqrt{Kt}) + \exp(-2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} - \sqrt{Kt}) \right] + \frac{ecn \sqrt{Sc}}{\sqrt{K}} \left[ \exp(-2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} - \sqrt{Kt}) - \exp(2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} + \sqrt{Kt}) \right] + e \exp(ct) \left[ \exp(-2\eta \sqrt{Sc(K + c)t}) \text{erfc}(\eta \sqrt{Sc} - \sqrt{(K + c)t}) + \exp(2\eta \sqrt{Sc(K + c)t}) \text{erfc}(\eta \sqrt{Sc} + \sqrt{(K + c)t}) \right]
\]

(3.2.13)
$$\theta = \frac{t}{2} \left[ \exp(2\eta\sqrt{Rt}) \text{erfc}(\eta\sqrt{Pr} + \sqrt{at}) + \exp(-2\eta\sqrt{Rt}) \text{erfc}(\eta\sqrt{Pr} - \sqrt{at}) \right]$$

$$- \frac{\eta Pr\sqrt{t}}{2\sqrt{R}} \left[ \exp(-2\eta\sqrt{Rt}) \text{erfc}(\eta\sqrt{Pr} - \sqrt{at}) - \exp(2\eta\sqrt{Rt}) \text{erfc}(\eta\sqrt{Pr} + \sqrt{at}) \right]$$

(3.2.14)

$$C = \frac{t}{2} \left[ \exp(2\eta\sqrt{KtSc}) \text{erfc}(\eta\sqrt{Sc} + \sqrt{Kt}) + \exp(-2\eta\sqrt{KtSc}) \text{erfc}(\eta\sqrt{Sc} - \sqrt{Kt}) \right]$$

$$- \frac{\eta\sqrt{Sc}}{2\sqrt{K}} \left[ \exp(-2\eta\sqrt{KtSc}) \text{erfc}(\eta\sqrt{Sc} - \sqrt{Kt}) - \exp(2\eta\sqrt{KtSc}) \text{erfc}(\eta\sqrt{Sc} + \sqrt{Kt}) \right]$$

(3.2.15)

Where, $$a = \frac{R}{Pr}$$, $$b = \frac{R}{1-Pr}$$, $$c = \frac{KSc}{1-Sc}$$, $$d = \frac{Gr}{2b^2(1-Pr)}$$, $$e = \frac{Gc}{2c^2(1-Sc)}$$ and $$\eta = \frac{Y}{2\sqrt{t}}$$.

### 3.2.3 RESULTS AND DISCUSSION

For physical understanding of the problem, the numerical computation of the velocity, temperature and concentration are carried out for different physical parameters like phase angle, radiation parameter, Schmidt number and time upon the nature of the flow and transport, in the presence of air ($Pr = 0.71$) and water vapor ($Sc = 0.6$). The Laplace transform solutions are in terms of exponential and complementary error function.

Figure 3.2.1 demonstrates the effect of the concentration profiles for different values of the chemical reaction parameter ($K = 0.2, 2, 5, 10$, $Sc = 0.6$) and time $t = 0.2$. This shows that there is a fall in wall concentration due to influence of chemical reaction. Figure 3.2.2 represents the effect of concentration profiles at time $t = 1$ for different Schmidt numbers ($Sc = 0.16, 0.3, 0.6, 2.01$) and $K = 0.2$. It is observed that the wall concentration increases with decreasing values of the Schmidt number.
The temperature profiles are calculated for different values of thermal radiation parameters \(( R = 0.2, 2, 5, 10 )\) from equation (3.2.14) and these are shown in figure 3.2.3. for air at time \( t = 1 \). The effect of thermal radiation parameter is important in temperature profiles. It is observed that the temperature increases with decreasing radiation parameter. The temperature profiles are calculated for different values of time \(( t = 0.2, 0.4, 0.6, 1)\) are shown in figure 3.2.4 at \( R = 0.2 \). It is observed that the temperature increases with increasing time.

The velocity profiles for different phase angles \(( \omega t = 0, \pi 6, \pi 4, \pi 2)\), \( R = 5, K = 2, Gr = Gc = 2 \) and \( t = 0.2 \) are shown in figure 3.2.5. It is observed that the velocity increases with decreasing phase angle. The effect of velocity for different values of the radiation parameter \(( R = 0.2, 5, 20)\), \( \omega t = \pi 6, K = 0.2, Gr = 10, Gc = 2 \) and \( t = 0.4 \) are shown in figure 3.2.6. It is observed that the velocity decreases in the presence of high thermal radiation.

Figure 3.2.7 illustrates the effect of the velocity for different values of the reaction parameter \(( K = 0.2, 5, 15)\), \( \omega t = \pi 6, R = 5, Gr = Gc = 2 \) and \( t = 0.6 \). The trend shows that the velocity increases with decreasing chemical reaction parameter. The effect of velocity profiles for different time \(( t = 0.2, 0.3, 0.4)\), \( R = 5, K = 0.2, \omega t = \pi 4, Gr = Gc = 5, Pr = 0.71, Sc = 0 \) are shown in figure 3.2.8. In this case, the velocity increases gradually with respect to time \( t \). The velocity profiles for different thermal Grashof number \(( Gr = 5, 10)\), mass Grashof number \(( Gc = 5, 10)\), \( \omega t = \pi 4, K = 0.2, R = 5 \) and time \( t = 0.4 \) are shown in figure 3.2.9. It is clear that the velocity increases with increasing thermal Grashof number or mass Grashof number.
Fig. 3.2.1: Concentration profiles for different values of $K$

Fig. 3.2.2: Concentration profiles for different values of $Sc$
Fig. 3.2.3: Temperature profiles for different values of $R$

Fig. 3.2.4: Temperature profiles for different values of $t$
Fig. 3.2.5: Velocity profiles for different values of $\omega t$

Fig. 3.2.6: Velocity profiles for different values of $R$
Fig. 3.2.7: Velocity profiles for different values of $K$

Fig. 3.2.8: Velocity profiles for different values of $t$
Fig. 3.2.9: Velocity profiles for different values of $Gr$, $Gc$
3.3 MHD AND CHEMICAL REACTION EFFECTS WITH VARIABLE TEMPERATURE AND MASS DIFFUSION

3.3.1 MATHEMATICAL ANALYSIS

Hydromagnetic effects on infinite vertical oscillating plate with variable temperature and mass diffusion in the presence of chemical reaction of first order is studied. Initially, it is assumed that the plate and the fluid are of the same temperature and concentration. At time $t' > 0$, the plate starts oscillating in its own plane with frequency $\omega'$. The temperature of the plate as well as the wall concentration is raised linearly with respect to time. The plate is also subjected to a uniform magnetic field of strength $B_0$. It is assumed that the effect of viscous dissipation is negligible in the energy equation and there is a first order chemical reaction between the diffusing species and the fluid. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations:

\[
\frac{\partial u}{\partial t'} = g\beta (T - T_\infty) + g\beta' (C' - C'_\infty) + \nu \frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho} u \tag{3.3.1}
\]

\[
\rho C_p \frac{\partial T}{\partial t'} = k \frac{\partial^2 T}{\partial y^2} \tag{3.3.2}
\]

\[
\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y^2} - K \frac{C'}{C'_\infty} \tag{3.3.3}
\]

With the following initial and boundary conditions:

\[
t' \leq 0: \quad u = 0, \quad T = T_\infty, \quad C' = C'_\infty \quad \text{for all } y
\]

\[
t' > 0: \quad u = u_0 \cos \omega' t', \quad T = T_\infty + (T_w - T_\infty) A t', \quad C' = C'_\infty + (C'_w - C'_\infty) A t' \text{ at } y = 0
\]

\[
\begin{align*}
u = 0, & \quad T \rightarrow T_\infty, \quad C' \rightarrow C'_\infty \quad \text{as } y \rightarrow \infty
\end{align*}
\]
Where, \( A = \frac{u_0^2}{v} \).

On introducing the following non dimensional quantities:

\[
U = \frac{u}{u_0}, \quad t = t'u_0^2/v, \quad Y = \frac{y u_0}{v}, \quad \theta = \frac{T - T_{\infty}}{T_{w} - T_{\infty}}, \quad Gr = \frac{g \beta v (T_{w} - T_{\infty})}{u_0^3}, \quad C = \frac{C' - C_{\infty}}{C'_{w} - C_{\infty}}, \quad Gc = \frac{v g \beta^* (C'_{w} - C_{\infty})}{u_0^3}, \quad \omega = \frac{\omega' v}{u_0^2},
\]

(3.3.5)

\[
Pr = \frac{\mu C_p}{k}, \quad Sc = \frac{v}{D}, \quad M = \frac{\sigma B_0^2 v}{\rho u_0^2}, \quad K = \frac{v K_{l}}{u_0^2}
\]

in equations (3.3.1) to (3.3.4), lead to

\[
\frac{\partial U}{\partial t} = Gr \theta + Gc C + \frac{\partial^2 U}{\partial Y^2} - M U
\]

(3.3.6)

\[
\frac{\partial \theta}{\partial t} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial Y^2}
\]

(3.3.7)

\[
\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial Y^2} - K C
\]

(3.3.8)

The initial and boundary conditions in non-dimensional form are

\[
U = 0, \quad \theta = 0, \quad C = 0, \quad \text{for all} \ Y, t \leq 0
\]

(3.3.9)

\[
t > 0: \quad U = \cos \omega t, \quad \theta = t, \quad C = t, \quad \text{at} \ Y = 0
\]

\[
U = 0, \quad \theta \to 0, \quad C \to 0, \quad \text{as} \ Y \to \infty
\]

The solutions are obtained for hydromagnetic flow field in the presence of first order chemical reaction.
3.3.2 SOLUTION PROCEDURE

The equations (3.3.6) to (3.3.8), subject to the boundary conditions (3.3.9), are solved by the usual Laplace transform technique and the solutions are derived as follows:

\[
\theta = t \left[ (1 + 2 \eta^2 \text{Pr}) \text{erfc}(\eta \sqrt{\text{Pr}}) - \frac{2}{\sqrt{\pi}} \eta \sqrt{\text{Pr}} \exp(-\eta^2 \text{Pr}) \right] \tag{3.3.10}
\]

\[
C = \frac{t}{2} \left[ \exp(2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} + \sqrt{Kt}) + \exp(-2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} - \sqrt{Kt}) \right]
- \frac{\eta \sqrt{Sc}}{2\sqrt{K}} \left[ \exp(-2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} - \sqrt{Kt}) - \exp(2\eta \sqrt{KtSc}) \text{erfc}(\eta \sqrt{Sc} + \sqrt{Kt}) \right] \tag{3.3.11}
\]

\[
U = \frac{\exp(i\omega t)}{4} \left[ \exp(2\eta \sqrt{(M + i\omega)t}) \text{erfc}(\eta + \sqrt{(M + i\omega)t}) + \exp(-2\eta \sqrt{(M + i\omega)t}) \text{erfc}(\eta - \sqrt{(M + i\omega)t}) \right]
+ \frac{\exp(-i\omega t)}{4} \left[ \exp(2\eta \sqrt{(M - i\omega)t}) \text{erfc}(\eta + \sqrt{(M - i\omega)t}) + \exp(-2\eta \sqrt{(M - i\omega)t}) \text{erfc}(\eta - \sqrt{(M - i\omega)t}) \right]
+ \left[ (c + d) + (ac + bd)t \right] \left[ \exp(2\eta \sqrt{Mt}) \text{erfc}(\eta + \sqrt{Mt}) + \exp(-2\eta \sqrt{Mt}) \text{erfc}(\eta - \sqrt{Mt}) \right]
- \frac{\eta \sqrt{t}}{\sqrt{M}} (ac + bd) \left[ \exp(-2\eta \sqrt{Mt}) \text{erfc}(\eta - \sqrt{Mt}) - \exp(2\eta \sqrt{Mt}) \text{erfc}(\eta + \sqrt{Mt}) \right]
-c \exp(at) \left[ \exp(2\eta \sqrt{(M + a)t}) \text{erfc}(\eta + \sqrt{(M + a)t}) + \exp(-2\eta \sqrt{(M + a)t}) \text{erfc}(\eta - \sqrt{(M + a)t}) \right]
-d \exp(bt) \left[ \exp(2\eta \sqrt{(M + b)t}) \text{erfc}(\eta + \sqrt{(M + b)t}) + \exp(-2\eta \sqrt{(M + b)t}) \text{erfc}(\eta - \sqrt{(M + b)t}) \right]
\]
\[-2c \, \text{erfc}(\eta \sqrt{\text{Pr}}) - 2 \alpha t \left(1 + 2\eta^2 \, \text{Pr} \right) \, \text{erfc}(\eta \sqrt{\text{Pr}}) - \frac{2\eta \sqrt{\text{Pr}}}{\sqrt{\pi}} \, \exp(-\eta^2 \, \text{Pr}) \]

\[+ \, c \, \exp(at) \left[ \exp(2\eta \sqrt{a \, \text{Pr} \, t}) \, \text{erfc}(\eta \sqrt{\text{Pr}} + \sqrt{at}) + \exp(-2\eta \sqrt{a \, \text{Pr} \, t}) \, \text{erfc}(\eta \sqrt{\text{Pr}} - \sqrt{at}) \right] \]

\[-(1 + bt) \frac{d}{\sqrt{K}} \left[ \exp(2\eta \sqrt{Kt \, \text{Sc}}) \, \text{erfc}(\eta \sqrt{\text{Sc} + Kt}) + \exp(-2\eta \sqrt{Kt \, \text{Sc}}) \, \text{erfc}(\eta \sqrt{\text{Sc} - Kt}) \right] \]

\[+ \frac{bd \eta \sqrt{\text{Sc}}}{\sqrt{K}} \left[ \exp(-2\eta \sqrt{Kt \, \text{Sc}}) \, \text{erfc}(\eta \sqrt{\text{Sc} - Kt}) - \exp(2\eta \sqrt{Kt \, \text{Sc}}) \, \text{erfc}(\eta \sqrt{\text{Sc} + Kt}) \right] \]

\[+ d \exp(bt) \left[ \exp(2\eta \sqrt{\text{Sc}(K + bt)}) \, \text{erfc}(\eta \sqrt{\text{Sc} + (K + bt)}) \right. \]

\[\left. + \exp(-2\eta \sqrt{\text{Sc}(K + bt)}) \, \text{erfc}(\eta \sqrt{\text{Sc} - (K + bt)}) \right] \]

(3.3.12)

Where, \(a = \frac{M}{\text{Pr} - 1}\), \(b = \frac{M - K \, \text{Sc}}{\text{Sc} - 1}\), \(c = \frac{Gr}{2a^2(1 - \text{Pr})}\), \(d = \frac{Gc}{2b^2(1 - \text{Sc})}\) and \(\eta = \frac{Y}{2\sqrt{t}}\).

### 3.3.3 DISCUSSION OF RESULTS

The numerical values of the velocity and concentration are computed for different parameters like magnetic field parameter, chemical reaction parameter, Schmidt number, thermal Grashof number, mass Grashof number and time. The purpose of the calculations given here is to assess the effects of the parameters \(\omega, M, K, Gr, Gc\) and \(\text{Sc}\) upon the nature of the flow and transport. The solutions are in terms of exponential and complementary error function.

Figure 3.3.1 demonstrates the effect of the concentration profiles for different values of the chemical reaction parameter \((K = 0.2, 2, 5, 10), \text{Sc} = 0.6\) and time \(t = 0.2\). It is observed that the concentration increases with decreasing chemical reaction parameter.

The velocity profiles for different phase angles \((\omega = 0, \pi/6, \pi/3, \pi/2)\), \(M = 2, K = 2, Gr = Gc = 5, \text{Sc} = 0.6, \text{Pr} = 7.0\), and \(t = 0.2\) are shown in figure 3.3.2. It is
observed that the velocity increases with decreasing phase angle. Figure 3.3.3 demonstrates the effects of the magnetic field parameter on the velocity when ($M = 0.2, 2, 5$), $\omega t = \pi/4$, $Gr = Gc = 5$, $Sc = 0.6$, $K = 8$, $Pr = 7.0$, and $t = 0.6$. It is observed that the velocity increases with decreasing magnetic field parameter. Figure 3.3.4 illustrates the effect of the velocity for different values of the reaction parameter ($K = 0.5, 5, 15$), $\omega t = \pi/4$, $M = 0.2$, $Gr = Gc = 5$, $Sc = 0.6$, $Pr = 7.0$ and $t = 0.6$. The trend shows that the velocity increases with decreasing chemical reaction parameter.

The velocity profiles for different thermal Grashof number ($Gr = 5,10$), mass Grashof number ($Gc = 5,10$), $\omega t = \pi/4$, $K = 8$, $M = 2$, $Sc = 0.6$, $Pr = 7.0$, and time $t = 0.2$ are shown in figure 3.3.5. It is clear that the velocity increases with increasing thermal Grashof number or mass Grashof number. The effect of velocity profiles for different time ($t = 0.2, 0.4, 0.6, 0.8$), $M = 2$, $K = 2$, $\omega t = \pi/4$, $Gr = Gc = 5$, $Pr = 7.0$, $Sc = 0.6$ are shown in figure 3.3.6. In this case, the velocity increases gradually with respect to time $t$. 

62
Fig. 3.3.1: Concentration profiles for different values of $K$

Fig. 3.3.2: Velocity profiles for different values of $\omega t$
Fig. 3.3.3: Velocity profiles for different values of $M$

Fig. 3.3.4: Velocity profiles for different values of $K$
Fig. 3.3.5: Velocity profiles for different values of $Gr, Gc$

Fig. 3.3.6: Velocity profiles for different values of $t$
3.4 CONCLUDING REMARKS

Thermal radiation and hydromagnetic effects on unsteady flow past an infinite vertical oscillating plate in the presence of variable temperature and mass diffusion with first order chemical reaction have been studied. The dimensionless equations are solved using Laplace transform technique. The effects of velocity, temperature and concentration for different parameters like \( \omega, t, R, K, M, Gr, Gc, Sc \) and \( t \) are discussed graphically.

The study concludes that the velocity increases with decreasing phase angle, radiation parameter, magnetic field parameter and chemical reaction parameter. The trend is just reversed with respect to time. It is observed that the velocity increases with increasing thermal Grashof number or mass Grashof number. It is also observed that the concentration increases with decreasing Schmidt number and chemical reaction parameter. It is also observed that the leading edge effect is not affected by the oscillation of the plate.