

## RADIATION AND CHEMICAL REACTION EFFECTS ON MHD ROTATING FLUID PAST A MOVING VERTICAL PLATE

V SRI HARI BABU<sup>1</sup>, NAGARAJU VELLANKI<sup>2</sup>, G RAMI REDDY<sup>3</sup>, V. OMESWAR REDDY<sup>4</sup>

**Abstract.** The present paper analyses radiation effect on MHD unsteady free convection heat and mass transfer over a moving isothermal vertical plate in a rotating fluid in the presence of chemical reaction presented. The governing partial differential equations are solved by using perturbation technique. The effects of velocity, temperature and concentration profiles for different parameters discussed graphically.

KEYWORDS: Radiation, Chemical reaction, MHD, Rotating Fluid

### 1. Introduction

Many research works have been done based on the action of a uniform transverse magnetic field either fixed to the fluid or to the plate. Heat and mass transfer on MHD flows have applications in Meteorology, solar physics, cosmic fluid dynamics, astrophysics and geophysics. Magneto convection plays an important role in various industrial applications such as magnetic control of molten iron flow in the steel industry, liquid metal cooling in nuclear reactors, electromagnetic pumps, controlled fusion research, crystal growing, MHD couples and bearings, plasma jets, chemical synthesis and underground nuclear waste storage sites. Radiative heat and mass transfer play an important role in manufacturing industries for the design of reliable equipment, Nuclear power plants, gas turbines and various propulsion devices for aircraft, missiles, satellites and space vehicles. The effect of coriolis force has wide applications in science and technology. The study of hydromagnetic flow is called hydromagnetic or magnetohydrodynamics (MHD), which studies the dynamics of electrically conducting fluids. The set of equations which describe MHD are a combination of the Navier-Stokes equation of fluid dynamics and Maxwell's equations of electromagnetism. Viskanta and Grosh [1] studied the transfer of energy in boundary layer flow of an incompressible and radiating medium over wedge. The Rosseland approximation for the radiant heat flux vector was used to simplify the energy equation. Arpaci [2] studied the interaction between thermal radiation and laminar convection of heated vertical plate in a stagnant radiating gas. Greenspan, H.P [3] discussed the theory of rotating fluids owing to its numerous applications in cosmical and geophysical fluid dynamics, meteorology and engineering. England and Emery [4] have presented a correlation between the analytical solution and the experimental results of the convection-radiation interaction upon a vertical flat plate for absorbing and non absorbing gases. The flow past a horizontal plate has been studied by Debnath [5, 6], Puri and Kulshrestha [7]. Soundalgekar et al [8] presented an exact solution of flow past an impulsively started isothermal vertical plate under the action of transversely applied magnetic field.

Flows with chemical reaction in porous media are fundamental phenomena encountered in many natural, industrial and scientific areas. For such flows, most existing studied use continuum assumptions and focus on volume averaged properties on macroscopic scales. Considering the complex porous structures and fluid solid interactions in realistic situations. Flows of miscible fluids in porous media are frequently encountered in natural and industrial processes, like underground water movement, geologic carbon sequestration, enhanced oil recovery and blood transport. Dynamics of such flows are complex due to the unsteady flow, heat and mass transfer, and porous structure involved. This situation becomes more complicated when chemical reactions are introduced. In a porous medium, two fluids containing chemical reaction solutes re put into

contact along an interface. Chemical solutes are transported through the interface to react and thereby modify fluids properties, like density and viscosity. Again Soundalgekar et al [9] studied Stokes' problem for an infinite vertical plate whose temperature varies with time in the presence of transverse magnetic field for an incompressible fluid. Singh [10] studied the effects of coriolis as well as magnetic force on the flow field of an electrically conducting fluid past an impulsively started infinite vertical plate. Bestman and Adjepong [11] studied the magnetohydrodynamic free convection flow, with radiative heat transfer, past an infinite moving plate in rotating incompressible, viscous and optically transparent medium. Das et al. [12] have analyzed radiation effects on flow past an impulsively started infinite isothermal vertical plate. An analysis of the unsteady magneto hydrodynamic flow of a viscous and electrically conducting fluid past a vertical flat plate by the presence of radiation was done by Raptis and Massalas [13]. Basant Kumar Jha [14] presented the effects of uniform transverse magnetic field on the transient free convective flow of an electrically conducting fluid in a vertical channel, Chenna Kesavaiah et. al. [17] considered natural convection heat transfer oscillatory flow of an elastico-viscous fluid from vertical plate, Narahari [18] explained effects of thermal radiation and free convection currents on the unsteady Couette flow between two vertical parallel plates with constant heat flux at one boundary, Srinathuni Lavanya et. al. [19] has been considered radiation effect on unsteady free convective MHD flow of a viscoelastic fluid past a tilted porous plate with heat source, Chenna Kesavaiah and Devika [20] studied free convection and heat transfer of a Couette flow an infinite porous plate in the presence radiation effect.

Due to plethora of applications in astronomical technology and processes entangling high temperatures, the payoffs of thermal radiation on the free convection flows have been drawing the consideration of enormous research interest. Furthermore, free convection flow in the presence of magnetic field is crucial because of its significant impact on the boundary layer control and the execution of many engineering devices consuming electrically conducting fluids such as in MHD power generation, plasma studies, nuclear reactor using metal coolant and geothermal energy extraction. That's why it's a burning topic for many current researchers in the world. With the consideration of radiation impacts, the energy equation has to lead to an exceptionally non-linear partial differential equations. In view of the above some of the researchers has been studied, Soundalgekar et.al. [21] Scrutinized the radiation effects on free convection flow of gas past a semi-infinite flat plate, Kumar et. al. [22] Influence of heat source/sink on MHD flow between vertical alternate conducting walls with Hall effect, Mallikarjuna Reddy et. al. [23] contemplates Radiation and diffusion thermo effects of viscoelastic fluid past a porous surface in the presence of magnetic field and chemical reaction with heat source, Chenna Kesavaiah et. al. [24] examined radiative MHD Walter's Liquid-B flow past a semi-infinite vertical plate in the presence of viscous dissipation with a heat source, Rami Reddy et. al. [25] appraise hall effect on MHD flow of a visco-elastic fluid through porous medium over an infinite vertical porous plate with heat source, Chenna Kesavaiah and Venkateswarlu [26] reviewed chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, Nagaraju et. al. [27] surveyed MHD Viscoelastic Fluid flow Past an Infinite Vertical Plate in the Presence of Radiation and Chemical Reaction, Panigrahi et. al. [28] Impact of chemical reaction, hall current and radiation on MHD flow between vertical walls, Ch Kesavaiah et. al. [29] Studied Effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction, Raju et. al. [30] viewed on heat generation and chemical reaction impact on MHD rotating flow past a vertical porous plate, Chenna Kesavaiah and Venkateswarlu [31] inspects chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, Nagaraju et. al. [32] Influence of Radiation effects on MHD convective heat and mass transfer flow past a semi-infinite vertical moving porous plate in the presence of chemical reaction.

The main objective of this paper is radiation effect on MHD effects on unsteady free convection heat and mass transfer over a moving isothermal vertical plate in a rotating fluid in the presence of chemical reaction presented. The governing partial differential equations are solved by using perturbation technique. The effects of velocity, temperature and concentration for different parameters discussed graphically.

**2. Mathematical Formulation**

Three dimensional flow of a viscous, incompressible, electrically conducting fluid past an impulsively started infinite vertical isothermal plate with uniform mass diffusion in a rotating fluid [15, 16] is considered. On this plate, the  $x'$ -axis is taken along the plate in the vertically upward direction and the  $y'$ -axis is taken normal to  $x'$ -axis in the plane of the plate and  $z'$ -axis is normal to it. Both the fluid and the plate are in a state of rigid rotation with uniform angular velocity  $\Omega'$  about the  $z'$ -axis. The fluid considered here is a gray, absorbing-emitting radiation but a non-scattering medium. A transverse magnetic field  $B_0$  of uniform strength is applied normal to the plate in the  $z'$  direction. The induced magnetic field and viscous dissipation is assumed to be negligible. Initially, the plate and fluid are at rest with the temperature  $T'_\infty$  and concentration  $C'_\infty$  everywhere. At time  $t' > 0$ , the plate is given an impulsive motion in the vertical direction against gravitational field with constant velocity  $u_0$  in a fluid, in the presence of thermal radiation. At the same time the plate temperature is raised to  $T'_w$  and the concentration to  $T'_w$ , which are there after maintained constant. Since the plate occupying the plane  $z' = 0$  is of infinite extent, all the physical quantities depend only on  $z'$  and  $t'$ . Then by Boussinesq's approximation, the unsteady flow is governed by the following equations:

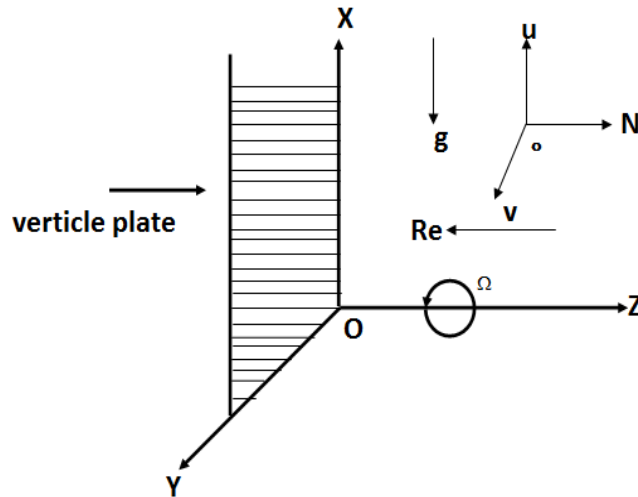


Figure (1): Physical model of the problem

$$\frac{\partial u'}{\partial t'} - 2\Omega'v' = g\beta(T' - T'_\infty) + g\beta^*(C' - C'_\infty) + \nu \frac{\partial^2 u'}{\partial z'^2} - \sigma \frac{B_0^2}{\rho} u' \tag{2.1}$$

$$\frac{\partial v'}{\partial t'} + 2\Omega'u' = \nu \frac{\partial^2 v'}{\partial z'^2} - \frac{\sigma B_0^2}{\rho} v' \tag{2.2}$$

$$\rho C_p \frac{\partial T'}{\partial t'} = k \frac{\partial^2 T'}{\partial z'^2} - \frac{\partial q_r}{\partial z'} \tag{2.3}$$

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial z'^2} - Kr'(C' - C'_\infty) \tag{2.4}$$

The term  $\frac{\partial q_r}{\partial z'}$  represents the change in the radiative flux with distance normal to the plate with the following initial and boundary conditions

$$\begin{aligned} t' \leq 0: \quad u' = 0, \quad T' = T'_\infty, \quad C' = C'_\infty \quad \text{for all } z' \\ t' > 0: \quad u' = u_0, \quad T' = T'_w, \quad C' = C'_w \quad \text{at } z' = 0 \quad (2.5) \\ u = 0, \quad T \rightarrow T_\infty, \quad C' \rightarrow C'_\infty \quad \text{as } z' \rightarrow \infty. \end{aligned}$$

On introducing the following dimensionless quantities:

$$\begin{aligned} (u, v) = \frac{(u', v')}{u_0}, \quad t = \frac{t' u_0^2}{\nu}, \quad z = \frac{z' u_0}{\nu}, \quad \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \quad C = \frac{C' - C'_\infty}{C'_w - C'_\infty} \\ Gr = \frac{g\beta v(T'_w - T'_\infty)}{u_0^3}, \quad Sc = \frac{\nu}{D}, \quad Kr = \frac{\nu Kr'}{u_0^2}, \quad Gc = \frac{vg\beta^*(C'_w - c'_\infty)}{u_0^3} \\ M = \frac{\sigma B_0^2 u_0}{\rho}, \quad Pr = \frac{\mu C_p}{k}, \quad \Omega = \frac{\Omega' \nu}{u_0^2}, \quad R = \frac{16a^* \nu^2 \sigma T_\infty^3}{ku_0^2} \end{aligned} \quad (2.6)$$

and the complex velocity  $q = u + iv$ ,  $i = \sqrt{-1}$  in equations (2.1) to (2.4), the equations relevant to the problem reduces to

$$\frac{\partial q}{\partial t} + 2i\Omega i = Gr \theta + Gc C + \frac{\partial^2 q}{\partial z^2} - Mq, \quad (2.7)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial z^2} - \frac{R}{Pr} \theta \quad (2.8)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial z^2} - Kr C \quad (2.9)$$

The initial and boundary conditions in non-dimensional form are

$$\begin{aligned} q = 0, \quad \theta = 0, \quad C = 0, \quad \text{for all } z \leq 0 \text{ \& } t \leq 0 \\ t > 0: \quad q = 1, \quad \theta = 1, \quad C = 1, \quad \text{at } z = 0 \quad (2.10) \\ q = 0, \quad \theta \rightarrow 0, \quad C \rightarrow 0, \quad \text{as } z \rightarrow \infty. \end{aligned}$$

All the physical variables are defined in the nomenclature.

### 3. Solution Of The Problem

Equation (2.7) - (2.9) are coupled, non - linear partial differential equations and these cannot be solved in closed - form using the initial and boundary conditions (2.10). However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. This can be done by representing the velocity, temperature and concentration of the fluid in the neighbourhood of the fluid in the neighbourhood of the plate as

$$\begin{aligned} q(z, t) = q_0(z) + \varepsilon e^{nt} q_1(z) + O(\varepsilon^2) \\ \theta(z, t) = \theta_0(z) + \varepsilon e^{nt} \theta_1(z) + O(\varepsilon^2) \end{aligned} \quad (3.1)$$

$$C(z, t) = C_0(z) + \varepsilon e^{nt} C_1(z) + O(\varepsilon^2)$$

Substituting (2.11) in Equation (2.7) - (2.9) and equating the harmonic and non - harmonic terms, and neglecting the higher order terms of  $O(\varepsilon^2)$ , we obtain

$$q_0'' - Mq_0 = -Gr \theta_0 - Gc C_0 - 2\Omega \quad (3.2)$$

$$q_1'' - (M + n)q_1 = -Gr \theta_1 - Gc C_1 \quad (3.3)$$

$$\theta_0'' - R\theta_0 = 0 \quad (3.4)$$

$$\theta_1'' - (R + n)\theta_1 = 0 \quad (3.5)$$

$$C_0'' - Kr Sc C_0 = 0 \tag{3.6}$$

$$C_1'' - (Kr + n) Sc C_1 = 0 \tag{3.7}$$

The corresponding boundary conditions can be written as

$$\begin{aligned} q = 0, \quad \theta = 0, \quad C = 0, \quad \text{for all } z = 0 \text{ and } t \leq 0 \\ t > 0: \quad q_0 = 1, \quad \theta_0 = 1, \quad C_0 = 1, \quad q_1 = 0, \quad \theta_1 = 0, \quad C_1 = 0 \quad \text{at } z = 0 \\ q_0 \rightarrow 0, \theta_0 \rightarrow 0, C_0 \rightarrow 0, q_1 \rightarrow 0, \theta_1 \rightarrow 0, C_1 \rightarrow 0 \quad \text{as } z \rightarrow \infty. \end{aligned} \tag{3.8}$$

Solving Equations (3.2) - (3.7) under the boundary conditions (3.8) we obtain the velocity, temperature and concentration distributions in the boundary layer as

$$q_0 = A_1 e^{m_6 z} + A_2 e^{m_2 z} + A_3 + A_4 e^{m_8 z}; q_1 = 0$$

$$\theta_0 = e^{m_6 z}; \theta_1 = 0$$

$$C_0 = e^{m_2 z}; C_1 = 0$$

In view of the above

$$q(z, t) = A_1 e^{m_6 z} + A_2 e^{m_2 z} + A_3 + A_4 e^{m_8 z}$$

$$\theta(z, t) = e^{m_6 z}$$

$$C(z, t) = e^{m_2 z}$$

#### 4. Results and discussion

The analysis of radiation effect on MHD effects on unsteady free convection heat and mass transfer over a moving isothermal vertical plate in a rotating fluid in the presence of chemical reaction presented. The governing partial differential equations are solved by using perturbation technique. The velocity profiles, temperature profiles, concentration profiles, skin friction, Nusselt number and Sherwood number for different values of the various parameter viz., magnetic field ( $M$ ), rotation parameter ( $\Omega$ ), radiation parameter ( $R$ ), Schmidt number ( $Sc$ ), chemical reaction ( $Kr$ ), thermal Grashof number ( $Gr$ ) and mass Grashof number ( $Gc$ ). The primary velocity profiles of air for different values of the rotation parameter ( $\Omega = 0.2, 0.4, 0.6, 0.8$ ) are shown in **figure (2)**. It is observed that the primary velocity decreases with increasing the rotation parameter  $\Omega$  in cooling of the plate. This shows that primary velocity decreases in the presence of high thermal rotation parameter. Effects of magnetic field and rotation parameter on primary velocity the primary velocity profiles of air for different values of the magnetic parameter ( $M = 1, 2, 3, 4$ ) are depicted in **figure (3)**. It is observed that the primary velocity decreases with increasing magnetic parameter. This shows that primary velocity decreases in the presence of high magnetic field and rotation parameter. In fact rotation parameter has more influence than magnetic field on primary velocity. Effects of Grashof number ( $Gr = 1, 2, 3, 4$ ), mass Grashof number ( $Gc = 1, 2, 3, 4$ ) on primary velocity the primary for different thermal are shown in **figure 4(a) and 4 (b)**. It is clear that the primary velocity increases with increasing thermal Grashof number or mass Grashof number. The effects of chemical reaction parameter ( $Kr = 1, 2, 3, 4$ ) on primary velocity appears in **figure (5)**, from this figure it is clear that an increasing chemical reaction parameter the results are decreases, and the same effect observed for Schmidt number ( $Sc = 1, 2, 3, 4$ ) observed on primary velocity in **figure (6)**. The effect of thermal radiation parameter is

important in temperature profiles, the temperature profiles are calculated for different values of thermal radiation parameter ( $R = 1, 2, 3, 4$ ) are displayed in figure (7). It is observed that the temperature increases with decreasing radiation parameter. Variations in the concentration profiles for different values of the chemical reaction parameter ( $Kr = 1, 2, 3, 4$ ) and Schmidt number ( $Sc = 0.2, 0.4, 0.6, 0.8$ ) are depicted in figure 8(a) and 8(b). It is observed that there is a fall in concentration due to increasing the values of the chemical reaction parameter and Schmidt number.

**Skin friction**

Using equation (3.6) we get the following expression for skin-friction components

$$\tau_x \text{ and } \tau_y \text{ then } \tau_x + i\tau_y = \left( \frac{\partial q}{\partial z} \right)_{z=0}$$

In equation (3.6), (3.7) the argument of the complementary error function and error function is complex. Hence in order to obtain the u and v components of the velocity and skin-friction, we have used the following formula due to Abramowitz and stegun [20]: The skin-friction components for different parameter are calculated using Equation (3.6). The skin-friction components at the wall for different values of  $\Omega$  are shown in table (1).

Table (1): Skin-friction $\tau$ for different values of $\Omega$ versus $Gr$ with $Gc = 5.0 R = 1.0 M = 1.0 Sc = 0.6 Kr = 1.0 n = 0.1$	
$\Omega$	$\tau_x$
0.2	4.5845
0.4	4.3000
0.6	3.7985
0.8	3.5472

The effect of rotation on skin-friction decreases the component  $\tau_x$  as  $\Omega$  increases. As time advances the component  $\tau_x$  increases. Greater cooling of the plate, due to free-convection currents, lower rises  $\tau_x$ .

**Nusselt number**

Using equation (3.5) we get the following expression for Nusselt number

$$N_u = \left( \frac{\partial \theta}{\partial z} \right)_{z=0} = m_6$$

**Sherwood Number:**

Using equation (14) we get the following expression for Sherwood number

$$S_h = \left( \frac{\partial C}{\partial z} \right)_{z=0} = m_2$$

Table (2): Sherwood number for different values of $Sc$ versus $Kr$	
$Sc$	$Sh$

0.16	0.0035300
0.22	0.0003355
0.31	$5.612 e^{-005}$
0.60	$1.245 e^{-005}$

Sherwood numbers for different Schmidt number and time are calculated using equation (3.8), table (2) shows that as Schmidt number increases Sherwood number increases, but the trend is reversed with time.

**APPENDIX**

$$m_2 = -\sqrt{Kr Sc}, m_6 = -\sqrt{R}, m_8 = -\sqrt{M}, A_1 = -\frac{Gr}{m_6^2 + M}$$

$$A_2 = -\frac{Gc}{m_2^2 + M}, A_3 = -\frac{2\Omega}{M}, A_4 = (1 - A_1 - A_2 - A_3)$$

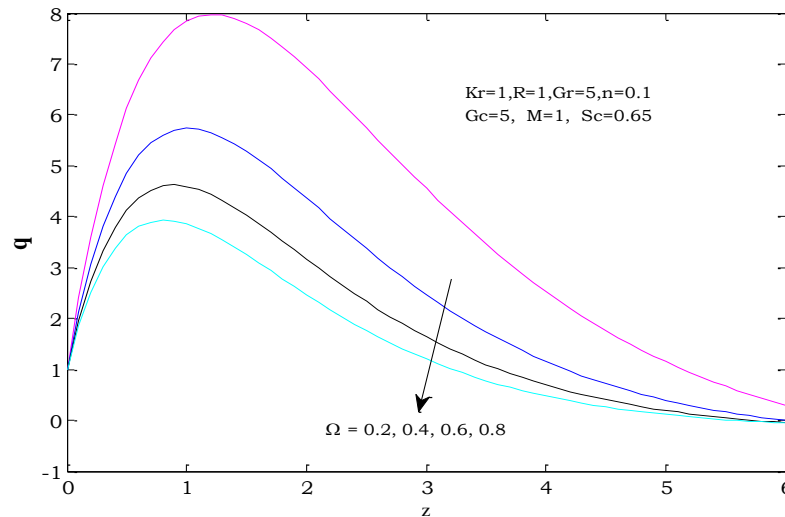


Figure (2): Primary velocity profiles for different values of  $\Omega$

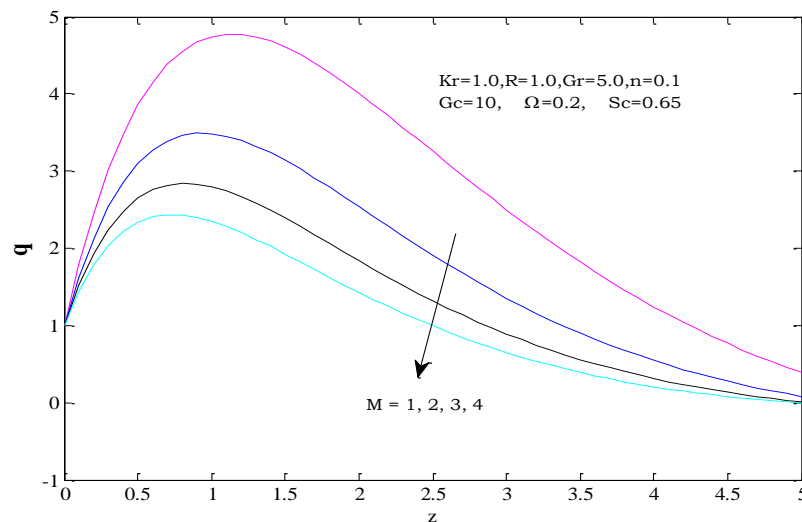


Figure (3): Primary Velocity profiles for different values of  $M$

RADIATION AND CHEMICAL REACTION EFFECTS ON MHD ROTATING FLUID  
PAST A MOVING VERTICAL PLATE

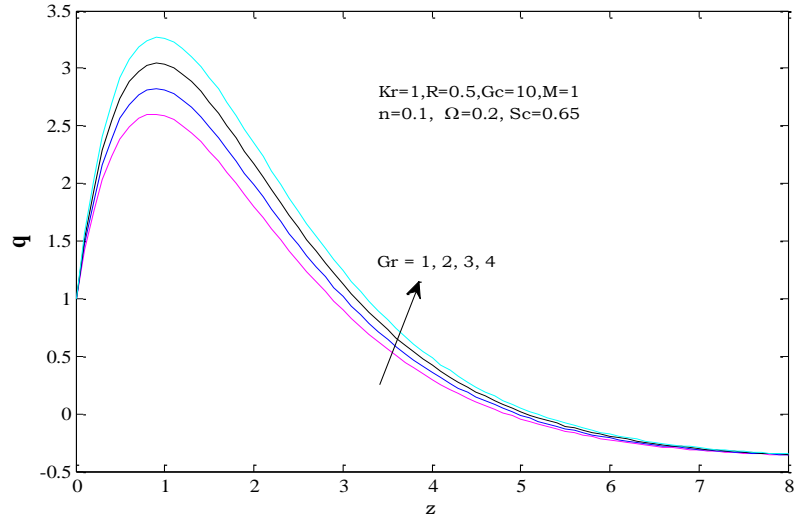


Figure 4 (a): Primary Velocity Profiles for different values of  $Gr$

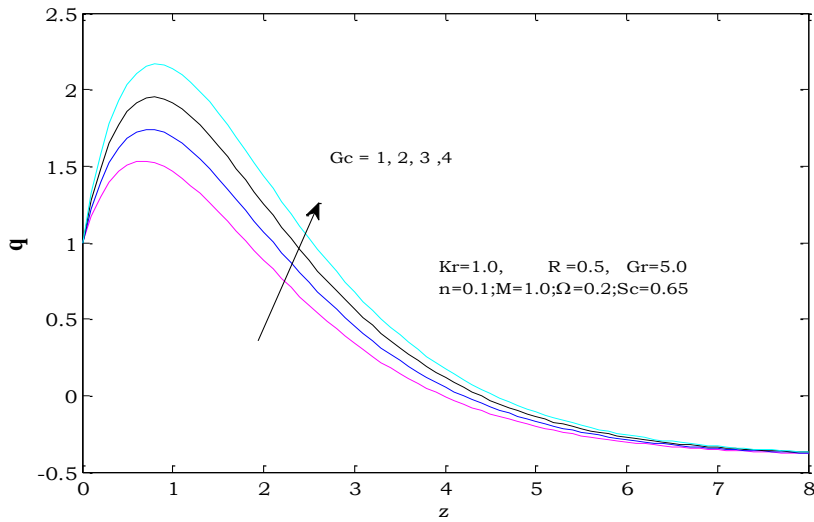


Figure 4 (b): Primary Velocity Profiles for different values of  $Gc$

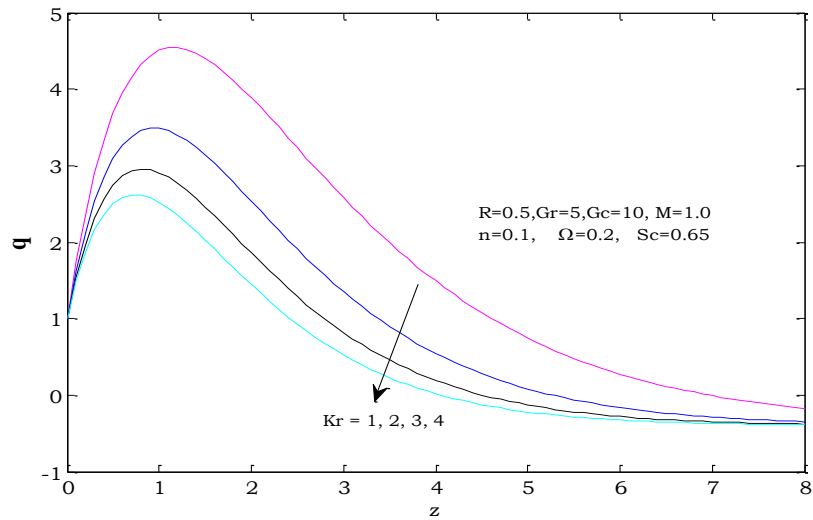


Figure (5): Primary Velocity profiles for different values of  $Kr$



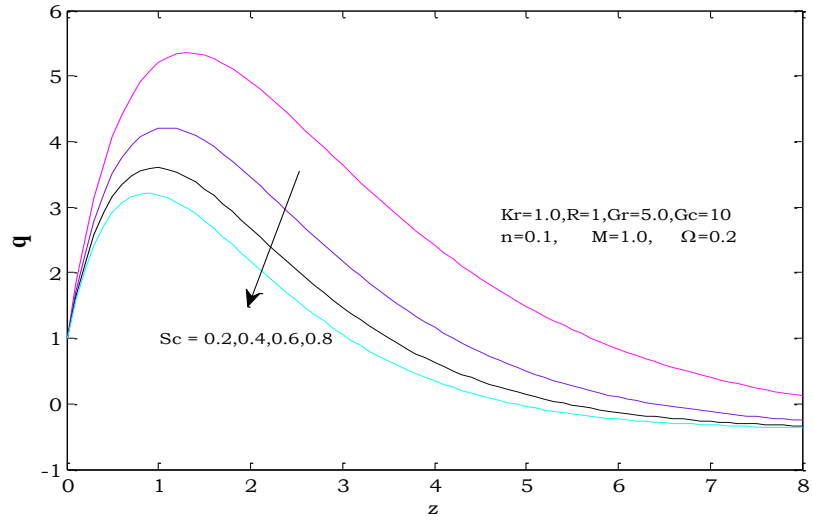


Figure (6): Primary velocity profiles for different values of  $Sc$

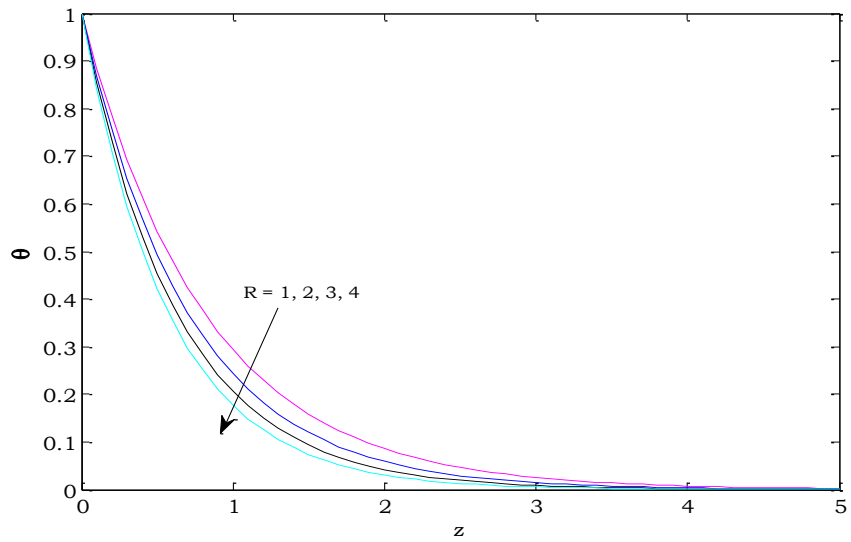


Figure (7): Temperature profiles for different values of  $R$

RADIATION AND CHEMICAL REACTION EFFECTS ON MHD ROTATING FLUID  
PAST A MOVING VERTICAL PLATE

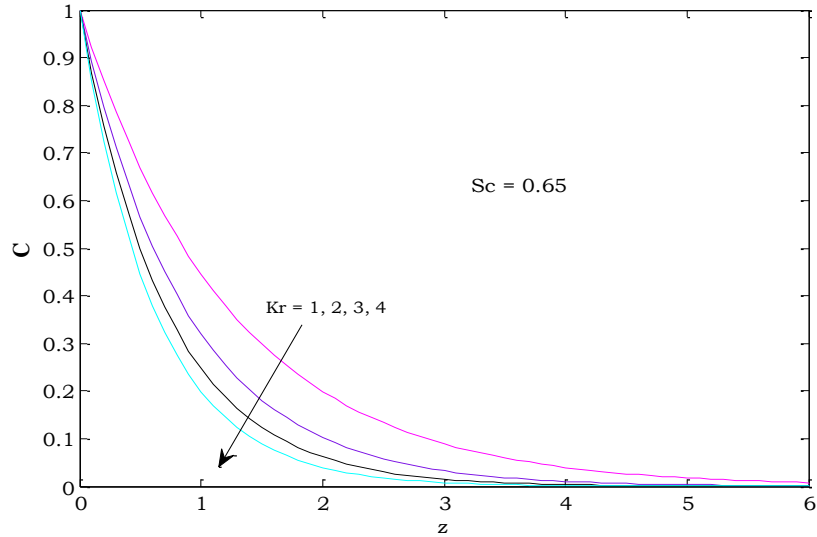


Figure 8(a): Concentration profiles for different values of  $Kr$

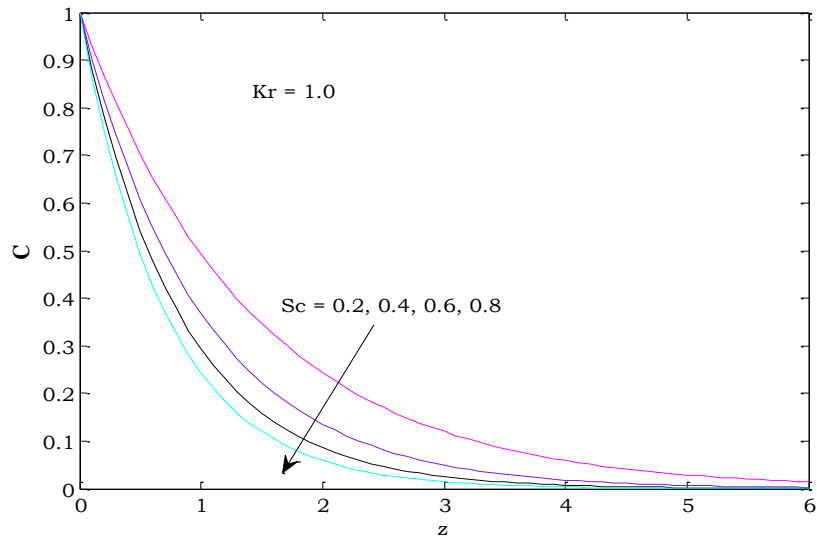


Figure 8(b): Concentration profiles for different values of  $Sc$

### References

1. Viskanta, R. and Grosch, R.J., Boundary layer in thermal radiation absorbing and emitting media, *Int. J. Heat Mass Transfer*, 1962, 5, pp.795–805.
2. Arpaci, V.S., Effect of thermal radiation on the laminar free convection from a heated vertical plate, *Int. J. Heat Mass Transfer*, 1968, 11, pp. 871–881.
3. Greenspan, H.P., *The theory of rotating fluids*. Cambridge University Press, UK, 1968.
4. England, W.G. and Emery, A.F., Thermal radiation effects on the laminar free convection boundary layer of an absorbing gas, 1969, *J. Heat Transfer*, 91, pp. 37–44.
5. Debnath, L., On unsteady magnetohydrodynamics boundary layers in a rotating flow, *Z. Angew. Math. Mech.*, 1972, 52, pp. 623–626.
6. Debnath, L., Exact solution of the unsteady hydrodynamic and hydromagnetic boundary layer equations in a rotating fluid system, *Z. Angew. Math. Mech.*, 1975, 55, pp. 431–438.
7. Puri, P. and Kulshrestha, P.K., Unsteady hydro-magnetic boundary layer in a rotating medium, *J. Appl. Mech. Trans. ASME*, 1976, 98, pp. 205–208.
8. Soundalgekar, V.M., Effects of mass transfer and free-convection currents on the flow past an impulsively started vertical plate, *Trans. ASME. J. Appl. Mech.*, 1979, 46, pp.757–760.
9. Soundalgekar, V.M., Gupta, S.K. and Aranake, R.N. (1979), Free convection effects on MHD Stokes problem for a vertical plate, *Nucl. Eng. Des.*, 1979, 51, pp. 403–407.
10. Singh, A.K., Hydromagnetic free convection flow past an impulsively started vertical infinite plate in a rotating fluid, *Int. Comm. Heat Mass Transfer*, 1984, 11, pp. 399–406.

11. Bestman, A.R. and Adjepong, S.K., Unsteady hydromagnetic free-convection flow with radiative heat transfer in a rotating fluid, *Astrophys., Space Sci.*, 143, pp. 73–80, 1988.
12. Das, U.N., Deka, R.K. and Soundalgekar, V.M., Radiation effects on flow past an impulsively started vertical infinite plate, *J. Theo., Mech.*, 1, pp. 111–115, 1996.
13. Raptis, A. and Massalas, C.V., Magnetohydrodynamic flow past a plate by the presence of radiation, *Int. J. Heat Mass Transfer.* 34, pp.107–109, (1998).
14. Basant Kumar Jha (1998), Effects of applied magnetic field on transient free-convective flow in a vertical channel, *Indian J. Pure appl. Math.*, 29, pp. 441–445, (1998).
15. Greenspan H P (1968): The theory of rotating fluids. *Cambridge University Press, UK.*
16. Debnath L, Exact solution of the unsteady hydrodynamic and hydromagnetic boundary layer equations in a rotating fluid system, *Z. Angew. Math. Mech.*, 1975, 55, pp. 431–438.
17. D Chenna Kesavaiah, P V Satyanarayana, A Sudhakaraiah, S Venkataramana, Natural convection heat transfer oscillatory flow of an elasto-viscous fluid from vertical plate, *International Journal of Research in Engineering and Technology*, 2013, Vol. 2 (6), pp. 959-966
18. Narahari, Effects of thermal radiation and free convection currents on the unsteady Couette flow between two vertical parallel plates with constant heat flux at one boundary, *WSEAS TRANSACTIONS on HEAT and MASS TRANSFER I*, 1, V 5, 2010, pp. 21-30
19. Srinathuni Lavanya, B Devika and D Chenna Kesavaiah, Radiation effect on unsteady free convective MHD flow of a viscoelastic fluid past a tilted porous plate with heat source, *Journal of Xidian University*, 2020, Vol. 14 (4), pp. 2298 - 2312.
20. D Chenna Kesavaiah, and B Devika, Free convection and heat transfer of a Couette flow an infinite porous plate in the presence radiation effect, *Journal of Xi'an University of Architecture & Technology*, 2020, Vol. XII, (V), pp. 525-543.
21. V. M. Soundalgekar, H. S. Takhar and N. V. Vighnesam, The combined free and forced convection flow past a semi-infinite plate with variable surface temperature, *Nuclear Engineering and Design*, 1960, Vol. 110, pp. 95-98
22. D Kumar, A K Singh and D Kumar, Influence of heat source/sink on MHD flow between vertical alternate conducting walls with Hall effect, *Physica A*, Vol. 544, p. 123562, 2020.
23. B Mallikarjuna Reddy, D Chenna Kesavaiah and G V Ramana Reddy, Radiation and diffusion thermo effects of viscoelastic fluid past a porous surface in the presence of magnetic field and chemical reaction with heat source, *Asian Journal of Applied Sciences*, 2019, Vol. 7 (5), pp. 597-607
24. Chenna Kesavaiah DAMALA, Venkateswarlu BHUMARAPU, Oluwole Daniel MAKINDE, Radiative MHD Walter's Liquid-B flow past a semi-infinite vertical plate in the presence of viscous dissipation with a heat source, *Engineering Transactions*, Vol. 69(4), pp. 373–401, 2021.
25. G Rami Reddy , D Chenna Kesavaiah , Venkata Ramana Musala and G Bkaskara Reddy, Hall effect on MHD flow of a visco-elastic fluid through porous medium over an infinite vertical porous plate with heat source, *Indian Journal of Natural Sciences*, 2021, Vol. 12 (68), pp. 34975-34987.
26. D Chenna Kesavaiah and B Venkateswarlu, Chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, *International Journal of Fluid Mechanics Research*, 2020, Vol. 47 (2), pp. 153-169.
27. V Nagaraju, K Hemalatha and V Srihari Babu, MHD Viscoelastic Fluid flow Past an Infinite Vertical Plate in the Presence of Radiation and Chemical Reaction." *International Journal of Applied Engineering Research*, 2019, Volume 14(5): 1062-1069.
28. L Panigrahi, D Kumar and J P Panda (2021): Impact of chemical reaction, hall current and radiation on MHD flow between vertical walls, *J. Engin. Thermophys.*, Vol. 30, pp. 122-144
29. D Ch Kesavaiah, P V Satyanaryana and S Venkatarama, Studied Effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction, *Int. J. of Appl. Math and Mech.*, 2011, 7(1), pp. 52-69.
30. M Raju, K Venkateswara Raju, P Chandra Reddy, M Changaal Raju, and G Sankara Sekhar Raju , Heat generation and Chemical reaction impact on MHD Rotating flow past a Vertical Porous plate, *Turkish Journal of Computer and Mathematics Education*, 2021, Vol.12 (13), pp. 3101-3111
31. D Chenna Kesavaiah and B Venkateswarlu, Chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, *International Journal of Fluid Mechanics Research*, 2020, Vol. 47 (2), pp. 153-169
32. V Nagaraju, K Hemalatha and V Srihari Babu, Radiation effects on MHD convective heat and mass transfer flow past a semi-infinite vertical moving porous plate in the presence of chemical reaction." *International journal of engineering sciences and research technology*, 2018, 7(8): 146-161.

V SRI HARI BABU: Department of Mathematics, Usha Rama College of Engineering & Technology, Telaprolu 521109, Andhra Pradesh, India.  
 Email: [srihari.veeravalli@gmail.com](mailto:srihari.veeravalli@gmail.com)

RADIATION AND CHEMICAL REACTION EFFECTS ON MHD ROTATING FLUID  
PAST A MOVING VERTICAL PLATE

NAGARAJU VELLANKI: Department of Basic Sciences & Humanities, Vignan Institute of Technology and Science, Deshmukhi (V), Pochampally (M), Yadadri-Bhuvangiri (Dist)-508284, TS, India.

Email: [vellanki.nagsra@gmail.com](mailto:vellanki.nagsra@gmail.com)

G RAMI REDDY: Department of Mathematics, Mallareddy Engineering College (Autonomous), Dulapally (V), Kompally (M), Medchal Malkajgiri (Dist), Pin: 500100, TS, India.

Email: [dr.g.ramireddy76@gmail.com](mailto:dr.g.ramireddy76@gmail.com)

V OMESWAR REDDY: Department of Basic Sciences & Humanities, Vignan Institute of Technology and Science, Deshmukhi (V), Pochampally (M), Yadadri-Bhuvangiri (Dist)-508284, TS, India.

Email: [Omesh.reddy1110@gmail.com](mailto:Omesh.reddy1110@gmail.com)