

# Effects of Chemical Reaction on MHD and Radiative Viscous Flow past an Impulsively Started Infinite Vertical Plate

P. Srikara Reddy<sup>1</sup>, J. Girish Kumar<sup>2</sup>, R.V.S. Prasad<sup>3</sup>

Lecturer, Dept. of Mathematics, Krishna Chaithanya Degree College, Nellore, A.P, India

Lecturer, Dept. of Mathematics, Govt. Degree College, Jammalamdugu, Kadapa, A.P, India

Lecturer, Dept. of Statistics, S.V.G.S. Degree College, Nellore, A.P, India

**ABSTRACT:** This paper studies the effects of chemical reaction on unsteady MHD flow of a viscous incompressible fluid past an impulsively started infinite vertical plate with variable temperature and uniform diffusion, in the presence of thermal radiation. The fluid considered is gray, absorbing-emitting radiation but a non-scattering medium. The dimensionless governing equations for this study are solved numerically using finite difference method. The velocity, temperature and concentration distributions are studied for different parameters like radiation parameter, Schmidt number, Thermal Grashof number, mass Grashof number, magnetic field parameter, Prandtl number, chemical reaction parameter

**KEYWORDS:** MHD, impulsively started, vertical plate, chemical reaction etc.

## I. INTRODUCTION

The magnetic and electrical fields must satisfies a set of physical laws, which are represented by Maxwell's equations. The solution of such problems needs the simultaneous solution of the equations of fluid mechanics and electromagnetism. One special case of this type of combining is called magneto hydrodynamics (MHD). Magneto Hydrodynamics taken considerable attention for the past decades due to its numerous scientific and industrial applications. An exact analysis of MHD Stokes problem for the flow of incompressible, viscous and electrically conducting fluid past an impulsively started vertical plate, in the presence of transversely applied magnetic field was considered by Soundelgekar et al. (1) and the same problem was extended for mass transfer also (2). Soundalgekar et al (3) discussed the MHD Stokes problem for a vertical infinite plate with variable temperature.

The effects of heat transfer on MHD radiative flow problems has become more important in the field of industries. Many such processes arise at high temperature, and the knowledge of radiative heat transfer has plays a vital role in the design of pertinent equipment. Free convection heat transfer due to the action of buoyancy, transverse magnetic field and radiative flow for a semi-infinite vertical plate is investigated by Takhar et al. (4). Radiation effects on magnetohydrodynamic unsteady free-convection flow past a semi-infinite vertical plate with variable surface temperature taking into the account of transversal uniform magnetic field was studied numerically by Abd El-Naby et al. (5). Perdikis and Rapti (6) studied the magnetohydrodynamic unsteady free convection flow in the presence of radiation. Ghaly (7) investigated the radiation effects on a certain MHD free-convection flow.

While considering the chemical reaction effect many transport processes involving the combined action of buoyancy forces due to both thermal and mass diffusion. These processes are plays a significant role in the nuclear reactor safety and combustion systems, solar collectors, as well as metallurgical and chemical engineering. Tripathy et al (8) investigated the chemical reaction effect on MHD free convective surface over a moving vertical plate embedded in a porous medium. Al-Qadat and Al-Azab (9) studied the influence of chemical reaction on transient MHD free

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

convective flow over a moving vertical plate. Kandaswamy et al. (10) given the lie group analysis for the effects of temperature dependent fluid viscosity and chemical reaction on MHD free convective heat and mass transfer with variable stream conditions. Raju et al (11) discussed the analytical study of free convective, dissipative boundary layer MHD fluid flow past a porous surface in the consideration of thermal radiation, chemical reaction and constant suction. Manivannan (12) examined the radiation and chemical reaction effects on isothermal vertical oscillating plate taking into the account of variable mass diffusion. Sharma et al (13) investigated the influence of chemical reaction and radiation on unsteady MHD free convection flow and mass transfer through viscous incompressible fluid past a heated vertical plate embedded in porous medium in the presence of heat source.

In spite of all the above discussions, the unsteady MHD free convective, chemically reacting flow of a incompressible viscous fluid past an infinite vertical plate with variable temperature and uniform mass diffusion, in the presence of thermal radiation has little attention. Hence, the main objective of present chapter is to study the effects of radiation and chemical reaction on an electrically conducting viscous incompressible fluid past an impulsively started infinite vertical plate through variable temperature with uniform mass diffusion and considering the account of viscous dissipation. The equations of continuity, momentum, energy and diffusion, which governing the flow field, are numerically solved by using explicit finite difference method.

## II. MATHEMATICAL FORMULATION

Here the unsteady, chemically reacting and electrically conducting flow of a viscous incompressible fluid past an impulsively started infinite vertical plate with variable temperature and uniform mass diffusion, in the presence of thermal radiation is considered. The fluid considered here is gray, absorbing – emitting radiation but a non – scattering medium. The x – axis is taken along the plate in the vertically upward direction and the y – axis is taken normal to the plate. It is also assumed that the radiation heat flux in the x – direction is negligible as compared to that in the y – direction. Initially, the plate and the fluid are the same temperature and concentration in a stationary condition. At time  $t' > 0$ , the plate is given impulsive motion in the vertical direction against gravitational fluid with constant velocity  $u_0$ , the plate temperature is raised linearly with time and the concentration level near the plate is raised to  $C'_w$ . Under the usual Boussinesq's approximation, the flow of the fluid governed by the following equations are:

Continuity equation

$$\frac{\partial v}{\partial y} = 0 \tag{1}$$

Momentum equation

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

Energy equation

$$\rho C_p \frac{\partial T}{\partial t'} = \kappa \frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y} \tag{3}$$

Diffusion equation

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y^2} - k_r(C' - C'_\infty) \tag{4}$$

Initial and boundary conditions are as follows:

$$\left. \begin{aligned} t' \leq 0: & \quad u = 0, \quad T = T_\infty, \quad C' = C'_\infty \quad \text{for all } y \\ t' > 0: & \quad u = u_0, \quad T = T_\infty + (T_w + T_\infty)At', \quad C' = C'_w \quad \text{at } y = 0 \\ & \quad u \rightarrow 0, \quad T \rightarrow T_\infty, \quad C' \rightarrow C'_\infty \quad \text{as } y \rightarrow \infty \end{aligned} \right\} \tag{5}$$

Where  $A = \frac{u'_0}{\nu}$

where x, y and  $t'$  are the dimensional distances along and perpendicular to the plate and dimensional time, respectively,  $u$  and  $v$  are the components of dimensional velocities along  $x$  and  $y$  directions respectively.  $T$  and  $C'$  are the dimensional temperature and concentration,  $\rho$  is the fluid density,  $\nu$  is the kinematic viscosity,  $C_p$  is the specific heat at constant pressure,  $\sigma$  is fluid electrical conductivity,  $g$  is the acceleration due to gravity,  $\beta$  and  $\beta^*$  are the thermal and

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

concentration expansion coefficients,  $B_0$  is the magnetic induction,  $D$  is the chemical molecular diffusivity,  $k'_r$  is the chemical reaction parameter and  $\kappa$  is the fluid thermal conductivity. The viscous dissipation is neglected in this study. The first and second terms on the right hand side of the momentum equation (2) denote the thermal and concentration buoyancy effects respectively.

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

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

We assume that the temperature difference 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  $T^4$  as a Taylor series about  $T_\infty$  and neglecting the higher – order terms, thus

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

By using equations (6) and (7), equation (3) reduces to

$$\rho C_p \frac{\partial T}{\partial t'} = \kappa \frac{\partial^2 T}{\partial y^2} + 16a^* \sigma T_\infty^3 (T_\infty - T) \quad (8)$$

On introducing the following non-dimensional quantities:

$$\left. \begin{aligned} U &= \frac{u}{u_0}, Y = \frac{y u_0}{v}, t = \frac{t' u_0^2}{v}, \theta = \frac{T - T_\infty}{T_w - T_\infty}, C = \frac{c' - c'_\infty}{c'_w - c'_\infty} \\ Sc &= \frac{v}{D}, R = \frac{16a^* \sigma v^2 T_\infty^3}{\kappa u_0^2}, Gr = \frac{v g \beta (T_w - T_\infty)}{u_0^3}, Pr = \frac{v \rho C_p}{\kappa} \\ Gc &= \frac{v g \beta^* (c'_w - c'_\infty)}{u_0^3}, M = \frac{\sigma B_0^2 v}{\rho u_0^2}, Kr = \frac{Kr v}{u_0^2} \end{aligned} \right\} \quad (9)$$

In equations (2), (3) and (8), leads to

$$\frac{\partial U}{\partial t} = \frac{\partial^2 U}{\partial Y^2} + Gr\theta + GcC - MU \quad (10)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial Y^2} - \frac{R\theta}{Pr} \quad (11)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial Y^2} - KrC \quad (12)$$

Initial and boundary conditions in non-dimensional form are:

$$\left. \begin{aligned} t \leq 0: & U = 0, \theta = 0, C = 0 \text{ for all } Y \\ t > 0: & U = 1, \theta = t, C = 1 \text{ at } Y = 0 \\ & U \rightarrow 0, \theta \rightarrow 0, C \rightarrow 0 \text{ as } Y \rightarrow \infty \end{aligned} \right\} \quad (13)$$

### III. METHOD OF SOLUTION

The unsteady and coupled partial differential equations (10), (11) and (12) along with their initial and boundary conditions (13) have been solved numerically using an explicit finite difference technique.

The equivalent finite difference scheme of equations for (10), (11) and (12) are as follows:

$$\frac{U_{i,j+1} - U_{i,j}}{\Delta t} = \frac{U_{i+1,j} - 2U_{i,j} + U_{i-1,j}}{(\Delta Y)^2} + Gr\theta_{i,j} + GcC_{i,j} - MU_{i,j} \quad (14)$$

$$\frac{\theta_{i,j+1} - \theta_{i,j}}{\Delta t} = \frac{1}{Pr} \frac{\theta_{i+1,j} - 2\theta_{i,j} + \theta_{i-1,j}}{(\Delta Y)^2} - \frac{R\theta_{i,j}}{Pr} \quad (15)$$

$$\frac{C_{i,j+1} - C_{i,j}}{\Delta t} = \frac{1}{Sc} \frac{C_{i+1,j} - 2C_{i,j} + C_{i-1,j}}{(\Delta Y)^2} - KrC_{i,j} \quad (16)$$

Here, index  $i$  refers to  $y$  and  $j$  refers to time, the mesh system is divided by taking  $\Delta y = 0.1$ .

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

From the initial conditions in (13) we have the following equivalent

$$U(i, 0) = 0, \theta(i, 0) = 0, C(i, 0) = 0 \text{ for all } i \tag{17}$$

The boundary conditions from (13) are expressed in finite-difference form as follows

$$U(0, j) = 1, \quad \theta(0, j) = t, \quad C(0, j) = 1 \text{ for all } j$$

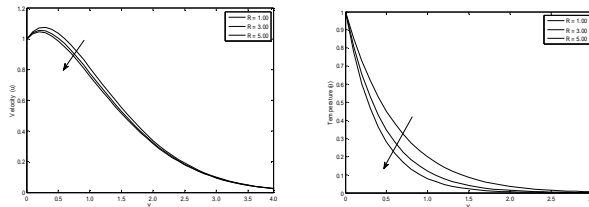
$$U(i_{max}, j) = 0, \quad \theta(i_{max}, j) = 0, \quad C(i_{max}, j) = 0 \text{ for all } j \tag{18}$$

Here  $i_{max}$  was taken as 50

Here infinity is taken as  $y = 4.1$ . First the velocity at the end of the time step namely  $U(i, j + 1)$ ,  $i = 1$  to 200 is computed from the equation (14) and temperature  $\theta(i, j + 1)$ ,  $i = 1$  to 200 from equation (15) and concentration  $C(i, j + 1)$ ,  $i = 1$  to 200 from equation (16). The procedure is repeated until  $t = 1$  (i.e.,  $j = 400$ ). During computation  $\Delta t$  was chosen as 0.0025. To judge the accuracy of the convergent of the finite difference scheme, the same programmed was run with similar values of  $\Delta t$  i.e.,  $\Delta t = 0.0009, 0.001$ , and no significant change was observed. Hence we conclude that the finite-difference scheme is stable and convergent.

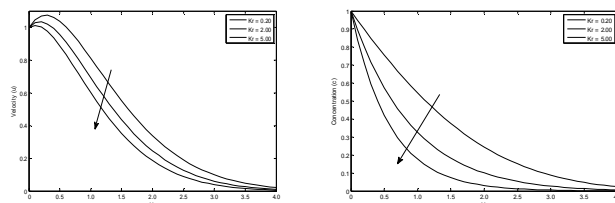
## IV. EXPERIMENTAL RESULTS

In order to obtain the physical significance of the problem, a representative set of numerical results is shown graphically in Fig. 1-6, to illustrate the influence of physical parameters embedded in the flow system.



1. (a & b) Velocity and Temperature profiles for different values of Radiation parameter (R)

Figs. 1(a) and 1(b) represents the influence of radiation parameter R on velocity and temperature. It is noticed that an increase in R leads to decrease in the velocity and temperature fields.



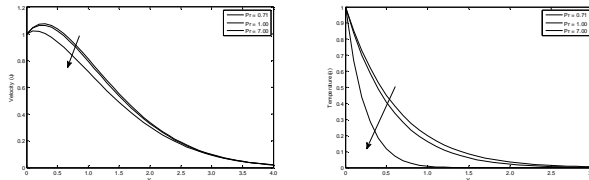
2. (a & b) Velocity and Concentration profiles for different values of Chemical reaction parameter (Kr)

Figs. 2(a) and 2(b) displays the influence of chemical reaction parameter Kr on the velocity and concentration. It is seen, that the effect of increasing values of the chemical reaction parameter Kr results in a decreasing velocity distribution as well as concentration also.

# International Journal of Innovative Research in Science, Engineering and Technology

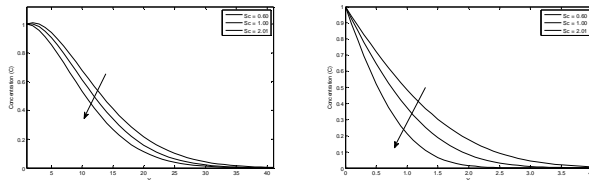
(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016



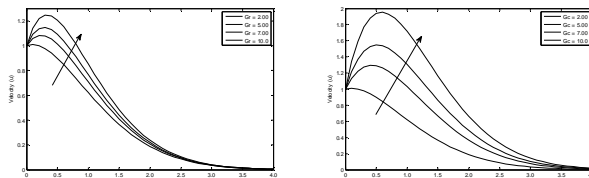
3. (a & b) Velocity and Temperature profiles for different values of Prandtl number (Pr)

In Figs. 3(a) and 3(b) we depict the effect of Prandtl number Pr, on the velocity and temperature fields. It is observed that the velocity and temperature both are decreasing with increasing Prandtl number Pr.



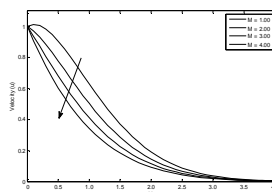
4. (a & b) Velocity and Concentration profiles for different values of Schmidt number (Sc)

Fig. 4(a) and 4(b) illustrate the influence of the Schmidt number Sc on the velocity and concentration fields. It is evident that the velocity and concentration both are decreasing with increasing values of Schmidt number Sc.



5 (a & b). Velocity profiles for different values of Grashof and solutal Grashof number (Gr & Gc)

The velocity profiles for different values of Grashof number Gr and solutal Grashof number Gc are described in Figs. 5(a) and 5(b). It is easily says that velocity increases with increasing values of Grashof number or solutal Grashof number. Here the positive values of Gr correspond to a cooling of the surface by natural convection.



6. Velocity profiles for different values of magnetic parameter

For various values of the magnetic parameter M the velocity profiles are depict in Fig.6. The impact of the magnetic parameter M on the velocity profiles is an expected. velocity decreases with increasing values of M.

## V. CONCLUSION

We summarize below the following results of physical interest on the velocity, temperature and concentration distribution of the flow field.

1. A growing radiation or chemical reaction parameter or Prandtl number or Schmidt number or magnetic parameter retards the velocity of the flow field at all points.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

2. The effect of increasing Grashof number or solutal Grashof number is to accelerate velocity of the flow field at all points.
3. A growing radiation or Prandtl number decreases temperature of the flow field at all points
4. The growing chemical reaction parameter or Schmidt number decreases the concentration of the flow field at all points.

### REFERENCES

- [1] Soundalgekar V.M., Gupta S.K., and Aranake R.N., Free convection effects on MHD Stokes problem for vertical plate, Nuclear Engineering Design, 51, pp. 403-407, 1979.
- [2] Soundalgekar V.M., Gupta S.K., and Birajdar N.S., Effects of mass transfer and free convection currents on MHD Stokes problem for a vertical plate, Nuclear Engineering Design, 53, pp.339-349, 1979.
- [3] Soundalgekar V.M. Patil. M.R., and Jahagirdar M.D., MHD Stokes problem for a vertical infinite plate with variable temperature, Nuclear Engineering Design, 64, pp.39-42, 1981.
- [4] Takhar H.S., Gorla R.S.R., and Soundalgekar V.M., Radiation effects on MHD free convection flow of a gas past a semi-infinite vertical plate, International. J. Numer. Methods Heat Fluid Flow 6, pp.77-83, 1996.
- [5] Abd El-Naby M.A., Elsayed M.E., Elbarbary and Nade Y. Abdelazem., Finite difference solution of radiation effects on MHD unsteady free convection flow over vertical plate with variable surface temperature, Journal of Applied Mathematics 2, pp.65-86, 2003.
- [6] Perdakis C., and Rapti E., Unsteady MHD flow in the presence of radiation, Int. J. of Applied Mechanics and Engineering, vol.11, No.2, pp.383-390, 2006.
- [7] Ghaly A.Y., Radiation effects on a certain MHD free-convection flow. – Chaos, Solitons and Fractals, vol.13, pp.1843-1850, 2002.
- [8] Tripathy P.S., Dash G.S., Mishra S.R., and Baag S., Chemical reaction effect on MHD convective surface over a moving vertical plate through porous medium, Alexandria Engineering Journal, 54, pp.673-679, 2015.
- [9] M.Q. Al-Qadat, T.A. Al-Azab, Influence of chemical reaction on transient MHD free convective flow over a moving vertical plate, Emirates J. Eng. Res. 12 (3), pp.15-21, 2007.
- [10] Kandaswamy R. Muhaimin I., Hashim B.S., Lie group analysis for the effects of temperature dependent fluid viscosity and chemical reaction on MHD free convective heat and mass transfer with variable stream conditions, Nuclear Engineering and Design 240, pp.39-46, 2010.
- [11] Raju M.C. Ananda Reddy N and Varma S.V.K., Analytical study of MHD free convective, dissipative boundary layer flow past a porous surface in the presence of thermal radiation, chemical reaction and constant suction, Ain Shams Engineering Journal, 5, pp.1361-1369, 2014.
- [12] Manivannan K, Muthucumarswamy R, Thangaraj V. Radiation and chemical reaction effects on isothermal vertical oscillating plate with variable mass diffusion. Therm Sci, 13(2), pp.155-162, 2009.
- [13] Sharma PR, Kumar N, Sharma P. 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, Appl Math Sci, 5(46), pp.2249-2260, 2011.