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Chemical Reaction and Thermal Radiation Effects on Unsteady MHD Flow over an Infinite Vertical Oscillating Porous Plate with Heat Source

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Abstract-In this paper, unsteady MHD flow over an infinite vertical oscillating porous plate with chemical reaction and thermal radiation effects in presence of heat source is investigated. The governing equations are solved numerically by using Finite difference method and MATLAB coding is developed for the finite difference method for different values of governing flow parameters. The effects of various parameters such as Radiation parameter (R), chemical reaction parameter (k_r), heat source parameter (Q) etc. on the velocity field, temperature field and concentration distribution have been studied and results are presented graphically.

Keywords-Chemical Reaction, thermal radiation, heat source, MHD, oscillating porous plate and finite difference method.

I. INTRODUCTION

The study of heat and mass transfer with chemical reaction is of great practical importance to engineers and scientists because of its almost universal occurrence in many branches of science and engineering. Possible applications of this type of flow can be found in many industries like power industry and chemical process industries.

A comprehensive review of the studies of convective heat transfer mechanism through porous media has been made by Neild and Bejan [1]. Rajeswari, Jothiram and Nilson [2] studied chemical reaction, heat and mass transfer on nonlinear MHD boundary layer flow through a vertical porous surface in the presence of suction. Pal and Talukdar [3] have studied perturbation analysis of unsteady MHD convective heat and mass transfer in boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. The effect of thermal radiation and heat and mass transfer flow of a variable viscosity fluid past a vertical porous plate in presence of transverse magnetic field was investigated by Makinde and Ogulu[4]. Rajesh et al. [5] have studied the chemical reaction and radiation effects on MHD flow past an infinite vertical plate with variable temperature.

At higher operating temperature, the effects of thermal radiation and heat transfer play a pivotal role on the fluid flow problem of boundary layer. The application of controlled heat transfer in polymer industries is very important to get final product of desired parameters. The modern system of electric power generation, plasma, space vehicles, astrophysical flows and cooling of nuclear reactors are governed by applications of thermal radiation and heat transfer of fluid flow.

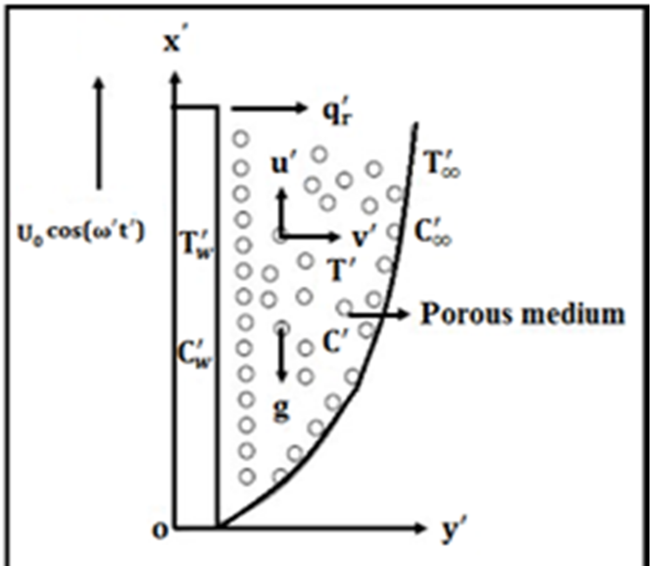
Makinde[6] discussed radiation and mass transfer effects on free convection flow past a moving vertical porous plate. Effect of radiation on free convection flow past a moving plate is established by Raptis and Perdikis [7]. G. Charan Kumar and G. V. Ramana Reddy [8] studied Radiation and chemical reaction effects on MHD flow fluid over an infinite vertical oscillating porous plate. England and Emery [9] studied the thermal radiation effect of an optically thin gray gas bounded by a stationary vertical plate. Raptis et al [10] studied the effects of radiation on two dimensional steady MHD optically thin gray gas flow along an infinite vertical plate taking into account the induced magnetic field.

In this paper we investigate the influence of Chemical Reaction and thermal radiation effects on Unsteady MHD flow fluid over an infinite vertical oscillating porous plate with heat source. The dimensionless governing equations involved in the present analysis are solved using a finite difference method and discussed graphically.

II. MATHEMATICAL FORMULATION OF THE PROBLEM

Thermal radiation and chemical reaction effects on unsteady MHD flow of a viscous incompressible fluid past along a vertical oscillating plate with heat source in the presence of transverse applied magnetic field has been studied. The plate is taken along x'

axis in vertically upward direction and y' axis is taken normal to the plate. Initially it is assumed that the plate and fluid are at the same temperature T'_∞ in the stationary condition with concentration level C'_∞ at all the points. At time $t' > 0$, the plate is given an oscillatory motion in its own plane with velocity $U_0\cos(\omega' t')$. At the same time the plate temperature is raised linearly with time and also mass is diffused from the plate linearly with time. The fluid considered here is gray, absorbing/emitting radiation but a non-scattering medium.



Physical configuration and coordinate system

Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations:

$$\frac{\partial u'}{\partial t'} = \upsilon \frac{\partial^2 u'}{\partial y'^2} + g\beta\,(T'-T'_\infty) + g\beta^*(C'-C'_\infty) - \frac{u'}{K'} - \frac{\sigma}{\rho} B_0^2 u' \qquad (1)$$

$$\frac{\partial T'}{\partial t'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_p}\frac{\partial q'_r}{\partial y'} + \frac{Q_0}{\rho C_p}(T'-T'_\infty) \qquad (2)$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} - k_r{}'(C'-C'_\infty) \qquad (3)$$

The initial and boundary conditions for the velocity, temperature and concentration fields are

$$\left.\begin{array}{ll} u' = 0,\ T' = T'_\infty,\ C' = C'_\infty & \forall\ y', t' \leq 0 \\ u' = U_0\cos(\omega' t'),\ T' = T'_\infty + \epsilon(T'_w + T'_\infty)e^{n't'},\ C' = C'_\infty + \epsilon(C'_w - C'_\infty)e^{n't'} & \text{at } y' = 0\ , t' > 0 \\ u' \to 0,\ T' \to T'_\infty,\ C' \to C'_\infty & \text{as } y' \to \infty\ , t' > 0 \end{array}\right\} \qquad (4)$$

where u' is the velocity in the x' direction, K' is the permeability parameter, β is the volumetric coefficient of thermal expansion , β^* is the volumetric coefficient of expansion for concentration, ρ is the density, σ is the electrical conductivity , k is the thermal conductivity, g is the acceleration due to gravity, T' is the temperature, T'_w is the fluid temperature at the plate, T'_∞ is the fluid temperature in the free stream, C' is the species concentration, C_p is the specific heat at constant pressure, C'_∞ is the species concentration in the free stream, C'_w is the species concentration at the surface, D is the chemical molecular diffusivity, q'_r is the radiative flux and Q_0 is the volumetric rate of heat generation.

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

$$\frac{\partial q'_r}{\partial y'} = -\,4a'\sigma'\,(\,T'^4_w - T'^4\,) \qquad (5)$$

where σ' and a' are the Stefan-Boltzmann constant and the Mean absorption coefficient, respectively. We assume that the temperature differences within the flow are sufficiently small so that T'^4 can be expressed as a linear function of T' after using Taylor's series to expand T'^4 about the free stream temperature T'_∞ and neglecting higher-order terms. This results in the following approximation:

$$T'^4 \cong 4T'^3_\infty T' - 3T'^4_\infty \tag{6}$$

$$\frac{\partial T'}{\partial t'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{16a'\sigma'}{\rho C_p} T'^3_\infty (T' - T'_\infty) + \frac{Q_0}{\rho C_p}(T' - T'_\infty) \tag{7}$$

In order to write the governing equations and the boundary conditions in dimensionless from, the following non-dimensional quantities are introduced.

$$\left.\begin{array}{l} u = \dfrac{u'}{u_0},\ y = \dfrac{u_0 y'}{\upsilon},\ t = \dfrac{{u_0}^2 t'}{\upsilon},\ \theta = \dfrac{T' - T'_\infty}{T'_w - T'_\infty},\ \phi = \dfrac{C' - C'_\infty}{C'_w - C'_\infty},\ \omega = \dfrac{\omega'\upsilon}{u_0^2},\ K = \dfrac{K' u_0^2}{\upsilon^2},\ Pr = \dfrac{\upsilon\rho C_p}{k},\ Sc = \dfrac{\upsilon}{D}, \\ M = \dfrac{\sigma B_0^2 \upsilon}{\rho u_0^2},\ Gr = \dfrac{\upsilon\beta g(T'_w - T'_\infty)}{u_0^3},\ Gm = \dfrac{\upsilon\beta^* g(C'_w - C'_\infty)}{u_0^3},\ k_r = \dfrac{k'_r\upsilon}{u_0^2},\ R = \dfrac{16a'\sigma'\upsilon^2 T'^3_\infty}{k u_0^2},\ Q = \dfrac{Q_0 \upsilon^2}{k u_0} \end{array}\right\} \tag{8}$$

Using the transformations (8), the non-dimensional forms of (1), (3) and (7) are

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + Gm\phi - (M + \frac{1}{K})u \tag{9}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} + \frac{1}{Pr}(Q - R)\theta \tag{10}$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - k_r\phi \tag{11}$$

The corresponding boundary conditions are

$$\left.\begin{array}{ll} u = \cos(\omega t),\ \theta = t,\ \phi = t & \text{at } y = 0 \\ u \to 0,\ \theta \to 0,\ \phi \to 0 & \text{as } y \to \infty \end{array}\right\} \tag{12}$$

where M is the magnetic parameter, K is the permeability parameter, Gr is the Grashof number for heat transfer, Gc is the Grashof number for mass transfer, Pr is the Prandtl number, k_r is the Chemical reaction parameter, Sc is the Schmidt number, ω is the frequency of oscillation, R is the radiation parameter, ωt is the phase angle and Q is the heat source parameter respectively.

III. METHOD OF SOLUTION

The dimensionless governing differential equations (9)-(11) subject to the initial and boundary conditions (12) are reduced to a system of difference equations using the following finite difference scheme, and then the system of difference equations is solved numerically by an iterative method. The scheme for a variable u is given by

$$\frac{\partial u}{\partial y} = \frac{u_{i+1,j} - u_{i,j}}{\Delta y},\ \frac{\partial u}{\partial t} = \frac{u_{i,j+1} - u_{i,j}}{\Delta t},\ \frac{\partial^2 u}{\partial y^2} = \frac{u_{i+1,j} - 2u_{i,j} + u_{i-1,j}}{(\Delta y)^2}$$

IV. RESULT AND DISCUSSION

Chemical reaction, thermal radiation and heat source effects on the velocity, temperature and concentration profiles are studied then by supplying various values of the parameters. Numerical calculations have been carried out for different values of t, k_r, R, Q and for fixed values of Pr, Sc, Gr, Gm, ωt and M. The values are taken for computation K= 1, Gr = 1, Gm = 1, M = 1, Pr =0.71, Q = 1, Sc = 0.66, R = 1, k_r = 1, $\omega t = \frac{\pi}{6}$.

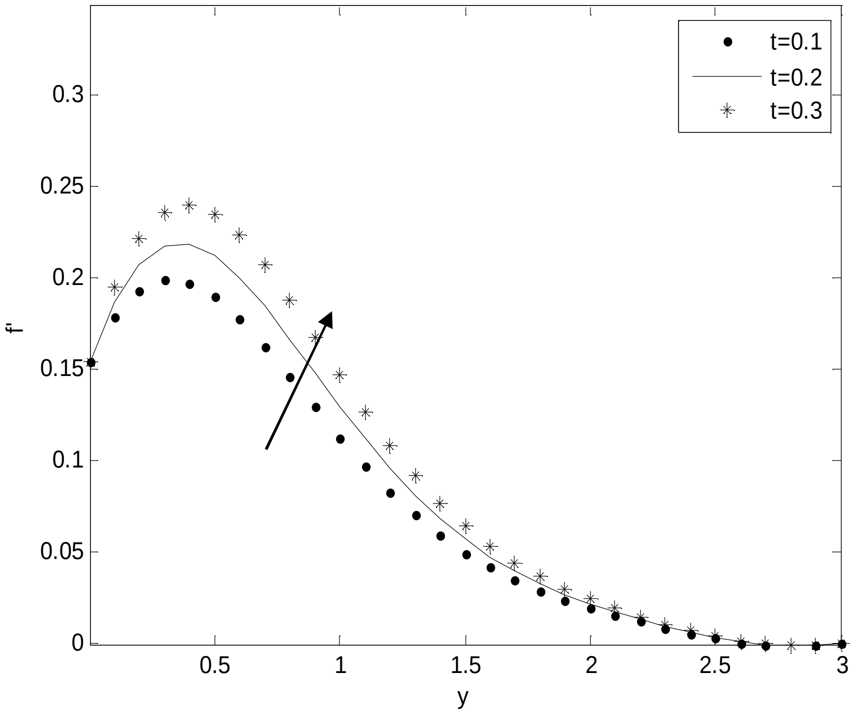


Fig. 1: Velocity profile for variation of t.

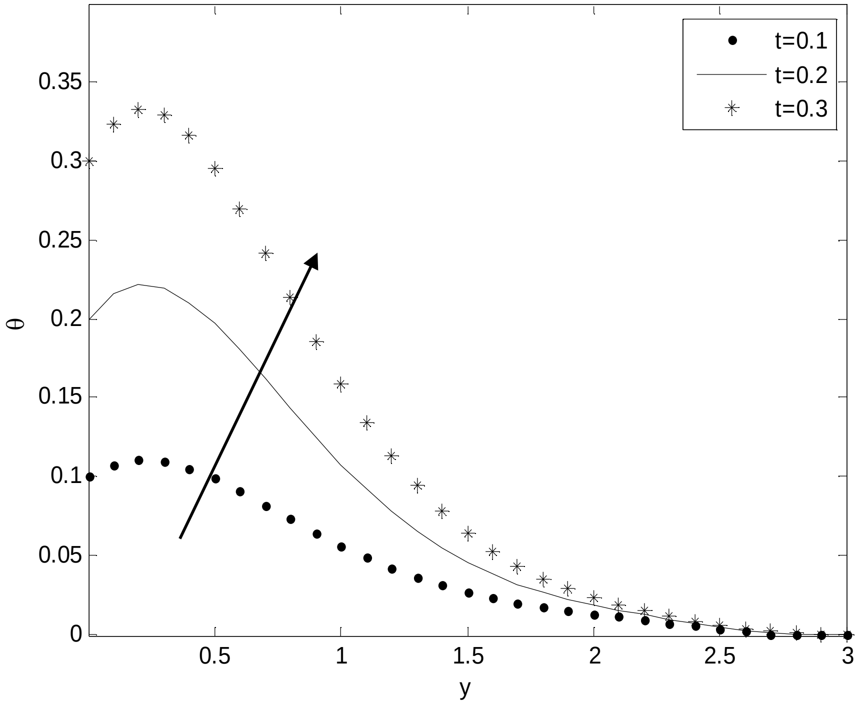


Fig. 2: Temperature profile for variation of t.

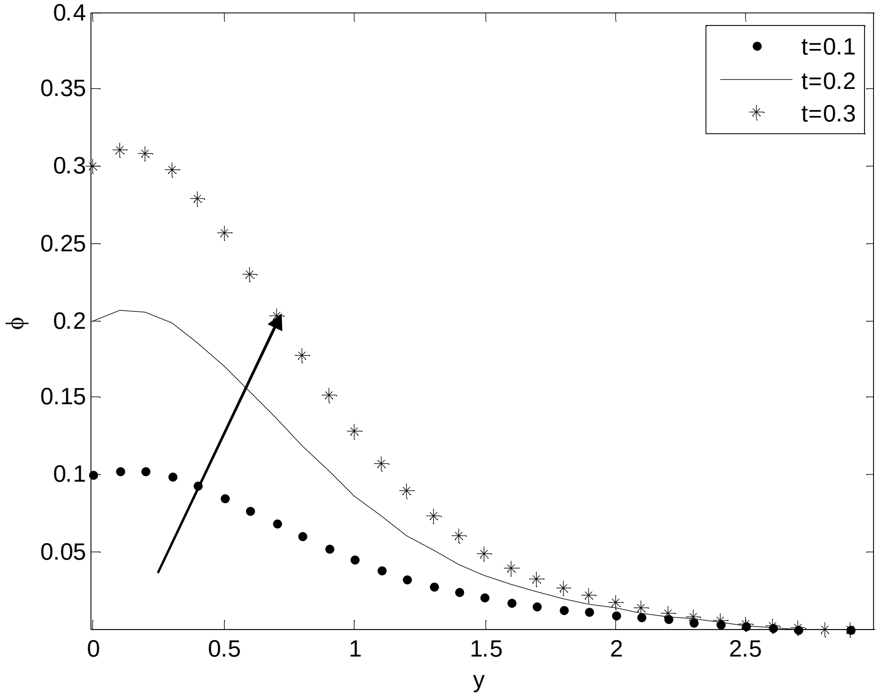


Fig. 3: Concentration profile for variation of t.

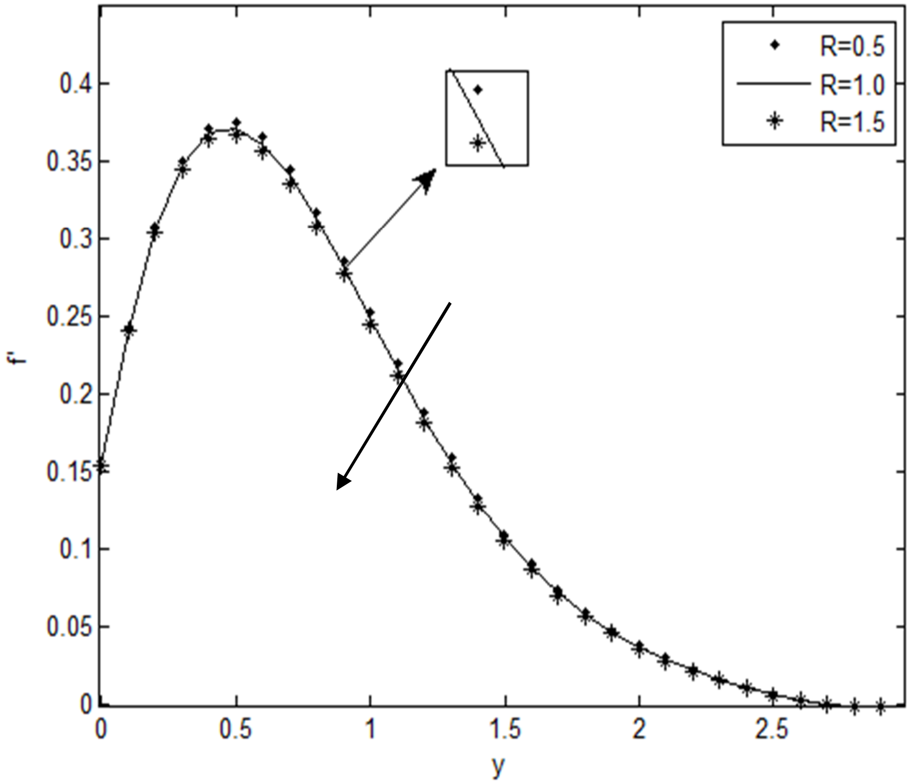


Fig.4: Velocity profile for variation of R.

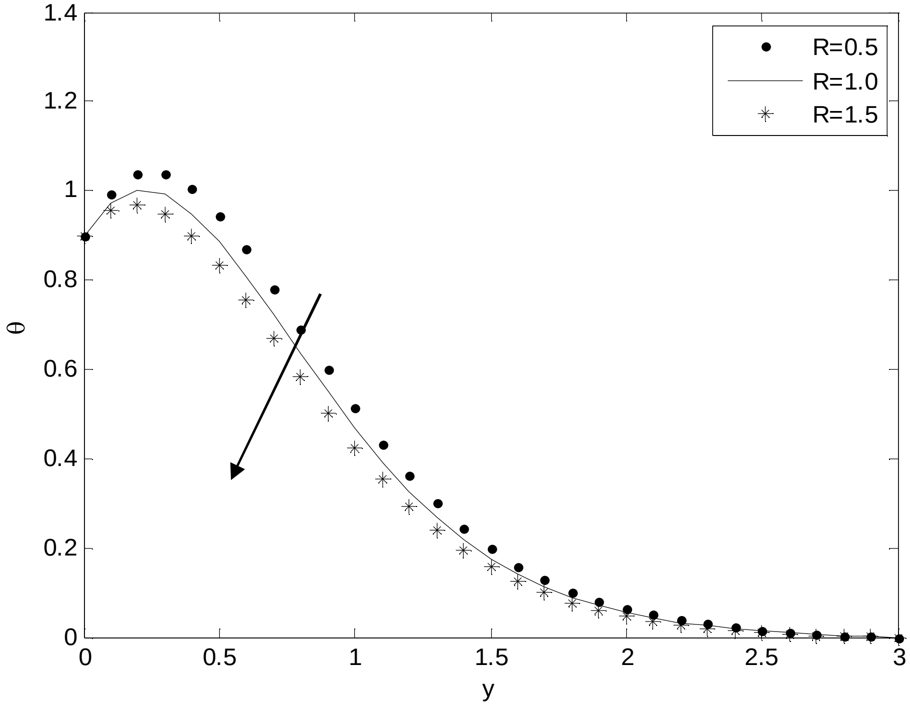


Fig. 5: Temperature profile for variation of R.

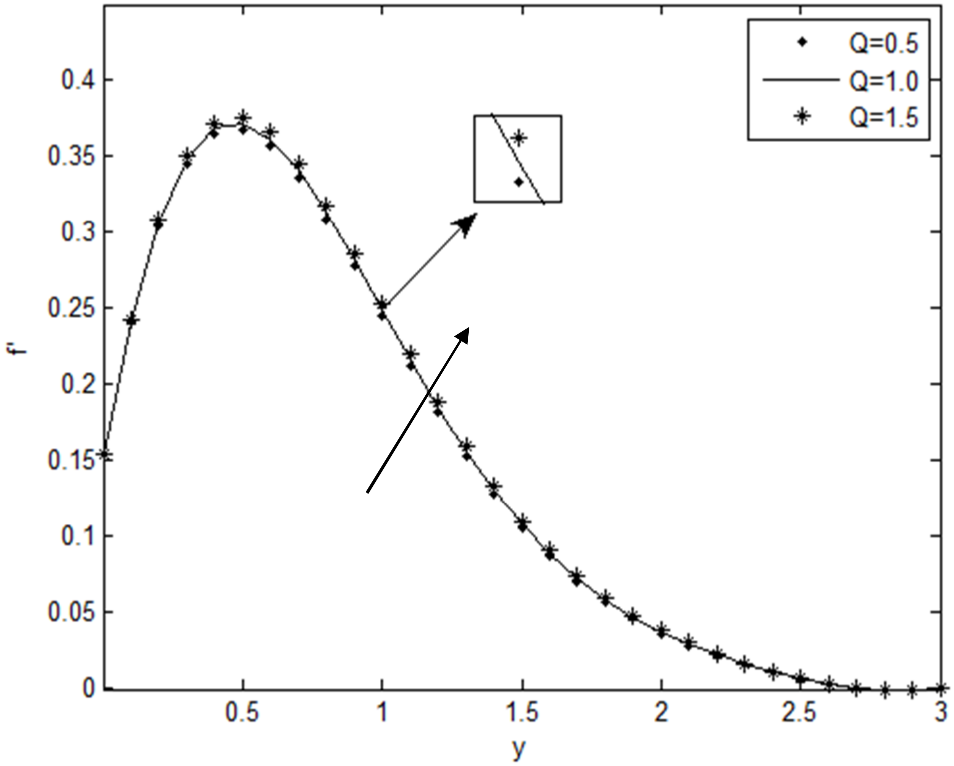


Fig. 6: Velocity profile for variation of Q.

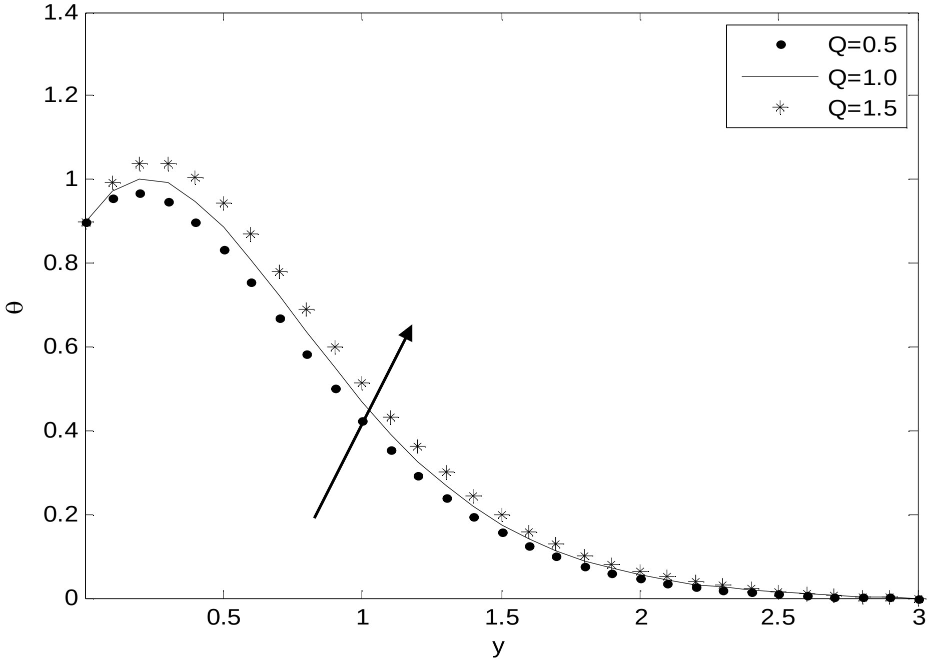


Fig. 7: Temperature profile for variation of Q.

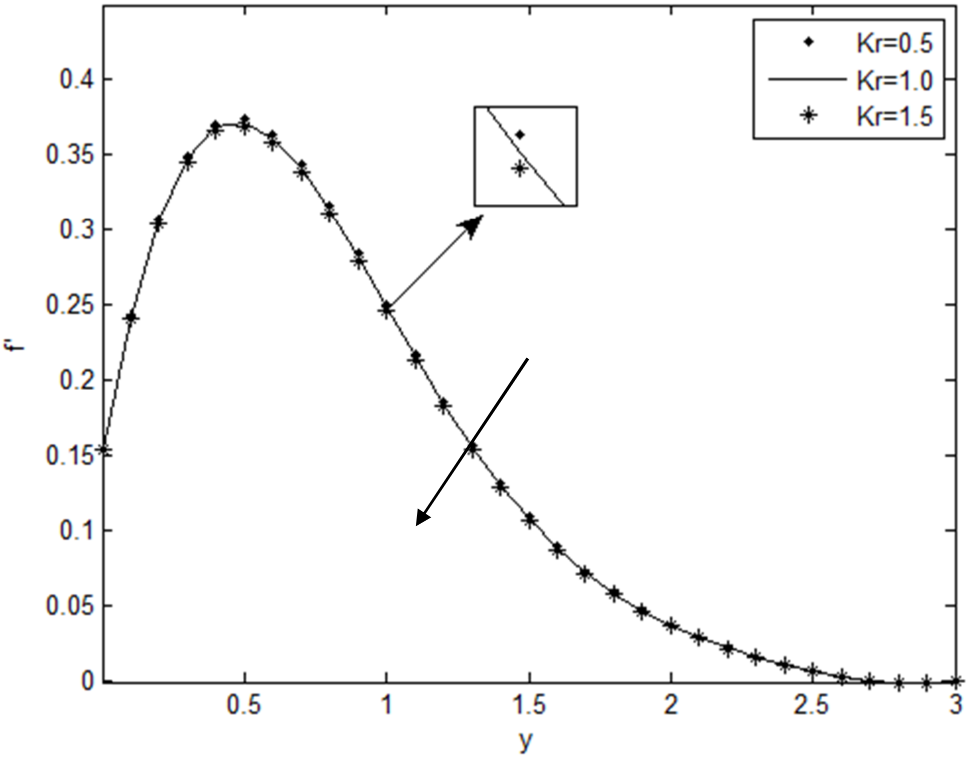


Fig. 8: Velocity profile for variation of k_r

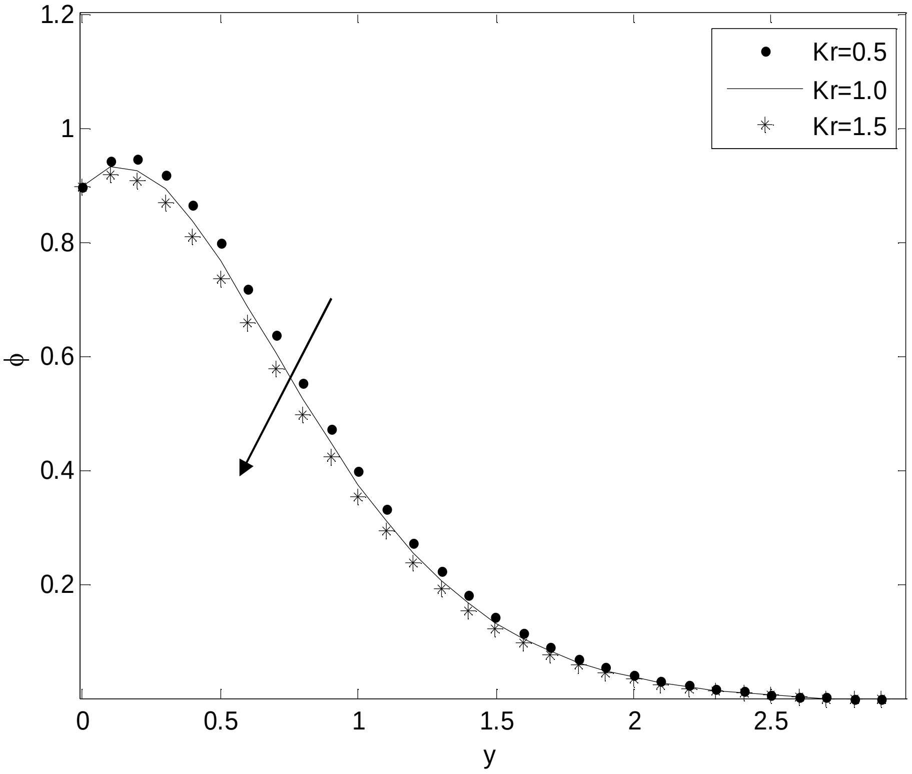


Fig. 9: Concentration profile for variation of k_r

Effect of time (t): Figure 1, 2, 3 shows the velocity, temperature and concentration profiles against y for several values of the time t. It is observed that an increase in t leads to an increase in the values of velocity, temperature and concentration.

Effect of Radiation parameter (R): The effect of R on velocity and temperature profile is depicted in Figs. 4 and 5. It is observed that the velocity and temperature decreases with the increasing values of R.

Effect of Heat source parameter (Q): The effect of Q on velocity and temperature profile is depicted in Figs.6 and 7. It is observed that the velocity and temperature increases with the increasing values of Q.

Effect of Chemical reaction parameter (k_r): The effect of k_r on velocity and Concentration profile is depicted in Figs. 8 and 9. It is observed that the velocity and Concentration decreases with the increasing values of k_r. As the fluid flow is subjected to a first order chemical reaction it reduces the fluid concentration i.e. concentration profile decreases with increase in chemical reaction parameter.

V. CONCLUSION

The effects of Chemical Reaction and thermal radiation on Unsteady MHD flow fluid over an infinite vertical oscillating porous plate with heat source are investigated numerically using Finite difference method. The effects of time, Radiation, Heat source and Chemical reaction parameters on the velocity field, temperature field and concentration fields are summarized as follows:

Velocity, temperature and concentration profiles increases with increase in time (t).
Velocity and temperature profiles decreases with increase in radiation parameter (R) and there is no variation of Concentration profile for R.
Velocity and temperature profiles increases with increase in heat source parameter (Q) and there is no variation of Concentration profile for Q.

Velocity and concentration profiles decreases with increase in chemical reaction parameter (k_r) and there is no variation of temperature profile for k_r.

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