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RESEARCH ARTICLE

CHEMICAL REACTION EFFECT ON MHD RADIATING FLOW OVER AN INFINITE VERTICAL SURFACE BOUNDED BY A POROUS MEDIUM WITH HEAT SOURCE

***Sidda Reddy, K. and Raju, G.S.S.**

Department of Mathematics, JNTUA College of Engineering, Pulivendula-516390, A.P., India

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ABSTRACT

The present study of non-linear MHD flow with heat and mass transfer characteristics of an incompressible, viscous, electrically conducting and Newtonian fluid over a vertical oscillating porous plate embedded in a porous medium in the presence of homogeneous chemical reaction of first order, thermal radiation and heat source effects have been analyzed. The dimensionless governing coupled, non-linear boundary layer partial differential equations are solved by the Laplace Transform technique.

Key words: Chemical reaction, porous medium, heat source, porosity parameter, MHD.

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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. An analytical solution for heat and mass transfer by laminar flow of a Newtonian, viscous, electrically conducting fluid and heat generation/absorption studied and analyzed by Chamkha (Chamkha, 2003).The exact solution for hydrodynamic boundary layer flow and heat transfer over a continuous, moving horizontal flat surface with uniform suction and internal heat generation/absorption analyzed by Vajravelu (Vajravelu, 1986). An approximate solution to the problem of an unsteady flow past an infinite vertical plate with constant suction and embedded in a porous medium with oscillating plate temperature investigated by Jaiswal and Soundalgekar (Jaiswal *et al.,* 2001). Raptis and Perdikis (Raptis and Perdikis, 2004) discussed by the unsteady flow through a highly porous medium in the presence of radiation. If the temperature of surrounding fluid is rather high, radiation effects play an important role and this situation does not exist in space technology. In such cases one has to take into account the effect of thermal radiation and mass diffusion. The radiation free convection flow of an optically thin gray-gas past a semi-infinite vertical plate discussed by Soundalgekar and Takhar (Soundalgekar and Takhar, 1993). Hossain and Takhar (Hossain and Takhar, 1996) analyzed by Radiation effects on mixed convection along isothermal vertical plate. Recently, Sahin (Ahmed, 2001) discussed and studied by the effects of radiation and chemical reaction on a steady mixed convective heat and mass transfer past an infinite vertical permeable plate with constant suction taking into account the induced magnetic field. Chamkha (Chamkha, 2001) analyzed byan unsteady laminar hydromagnetic flow and heat transfer in a porous channel with temperaturedependent properties was presented by.

Magneto hydrodynamic mixed free forced heat and mass convective steady incompressible laminar boundary layer flow of a gray optically thick electrically conducting viscous fluid past a semi-infinite vertical plate for high temperature and concentration differences have studied by Emad and Gamal (Aboeldahab and Azzam, 2005). The natural convection flow from an inclined, semi-infinite, impermeable flat plate embedded in a variable porosity porous medium due to solar radiation and in the presence of an externally applied magnetic field studied by Chamkha *et al.* (2002). For unsteady convection in porous media studied by Ghosh and Bég (Ghosh and Bég, 2008). An exact solution for the hydromagnetic natural convection boundary layer flow past an infinite vertical flat plate under the influence of a transverse magnetic field with magnetic induction effects and the transformed ordinary differential equations are solved exactly analyzed by Ghosh *et al.* (2009). For coupled species and heat diffusion in nonlinear porous media studied and analyzed by Bég *et al.* (2009). The thermal radiation effects on flow past an impulsively started infinite vertical plate with uniform temperature and variable mass diffusion in the presence of transverse applied magnetic field analyzed by Muthucumaraswamy and Janakiraman (2006). Zueco and Bég (2009) for hydromagnetic gas flow from a two-dimensional wedge in porous media.

****Corresponding author:*** **Sidda Reddy, K.,**
Department of Mathematics, JNTUA College of Engineering, Pulivendula-516390, A.P., India.

The governing equations are solved by the Laplace-transform technique. Ahmed and Kalita (2013) studied and analyzed by the magneto hydrodynamic transient convective radiative heat transfer in an isotropic, homogenous porous regime adjacent to a hot vertical plate using the Laplace transform technique. Rajput and Kumar (2012) presented the radiation effects on MHD flow past an impulsively started vertical plate with variable heat and mass transfer by Laplace transform technique. The objective of the present paper is to analyze the effects of chemical reaction as well as magnetic field on the heat and mass transfer of Newtonian fluids over an infinite vertical oscillating plate with variable mass diffusion. The magnetic field is imposed transversely to the plate. The temperature and concentration of the plate is oscillating with time about a constant non-zero mean value. The conservation equations are solved by using the Laplace Transform technique.

Mathematical Analysis

Thermal radiation and mass transfer effects on unsteady MHD flow of a viscous incompressible fluid past along a vertical oscillating plate with variable temperature and also with variable mass diffusion in the presence of transverse applied magnetic field and chemical reaction of first order have been studied. The $\bar{x}$ axis is taken along the plate in the vertical upward direction and the $\bar{y}$ axis is taken normal to the plate. Initially it is assumed that the plate and fluid are at the same temperature $\overline{T}_\infty$ in the stationary condition with concentration level $\overline{C}_\infty$ at all the points. At time, $\bar{t} > 0$ the plate is given an oscillatory motion in its own plane with velocity $u_0\, t$ .At the same time the plate temperature is raised linearly with time $\bar{t}$ and also mass is diffused from the plate linearly with time. A transverse magnetic field of uniform strength B_0 is assumed to be applied normal to the plate. The induced magnetic field and viscous dissipation is assumed to be negligible as the magnetic Reynolds number of the flow is taken to be very small. The fluid considered here is gray, absorbing/emitting radiation but a non-scattering medium. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations.

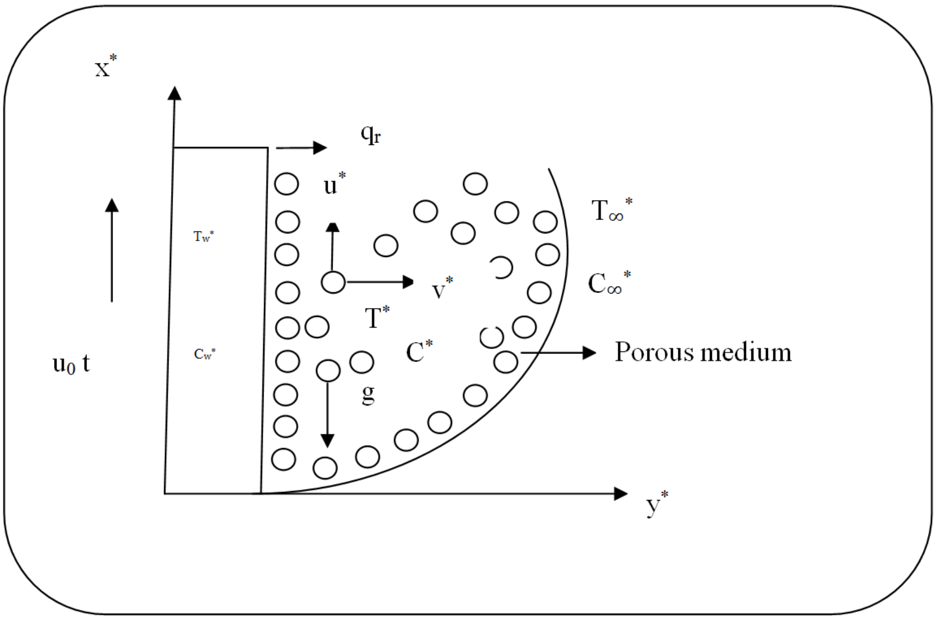

Fig. 1. Physical configuration and coordinate system

The unsteady flow is governed by the following equations:

$$\frac{\partial \bar{u}}{\partial \bar{t}} = g\beta(\overline{T} - \overline{T}_\infty) + g\bar{\beta}(\overline{C} - \overline{C}_\infty) + \upsilon \frac{\partial^2 \bar{u}}{\partial \bar{y}^2} - \frac{\sigma B_0^2\, \bar{u}}{\rho} - \frac{\upsilon}{\overline{Kr}}\bar{u} \qquad \text{.......... (1)}$$

$$\rho Cp \frac{\partial \overline{T}}{\partial \bar{t}} = k \frac{\partial^2 \overline{T}}{\partial \bar{y}^2} - \frac{\partial qr}{\partial \bar{y}} - Q^*(\overline{T} - \overline{T}_\infty) \qquad \text{.......... (2)}$$

$$\frac{\partial \overline{C}}{\partial \bar{t}} = D \frac{\partial^2 \overline{C}}{\partial \bar{y}^2} - \overline{C}r(\overline{C} - \overline{C}_\infty) \qquad \text{.......... (3)}$$

The initial and boundary conditions are:

$$\bar{t} \le 0: \ \bar{u} = 0, \ \bar{T} = \bar{T}_\infty, \ \bar{C} = \bar{C}_\infty \quad \forall y$$
$$\bar{t} > 0: \ \bar{u} = u_0 t, \ \bar{T} = \bar{T}_w, \bar{C} = \bar{C}_w \ at \ y=0$$
$$\bar{t} > 0: \ \bar{u} \to 0, \ \bar{T} \to \bar{T}_\infty, \ \bar{C} \to \bar{C}_\infty \quad as \ y \to \infty \qquad \text{(4)}$$

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

$$\frac{\partial q_r}{\partial \bar{y}} = -4\overline{a\sigma}(\bar{T}_\infty^4 - \bar{T}^4) \qquad \text{(5)}$$

Where $\bar{\sigma}$ and $\bar{a}$ 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 $\bar{T}^4$ can be expressed as a linear function of $\bar{T}$ after using Taylor's series to expand $\bar{T}^4$ about the free stream temperature $\bar{T}_\infty$ and neglecting higher-order terms. This results in the following approximation:

$$\bar{T}^4 \cong 4\bar{T}_\infty^3 - 3\bar{T}_\infty^4 \qquad \text{(6)}$$

$$\rho Cp \frac{\partial \bar{T}}{\partial \bar{t}} = k\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - 16\overline{a\sigma}\bar{T}_\infty^3 (\bar{T} - \bar{T}_\infty) \qquad \text{(7)}$$

Introducing the following non-dimensional quantities:

$$t = \frac{\bar{t}\,u_0^2}{\upsilon}, \ y = \frac{\bar{y}\,u_0}{\upsilon}, u = \frac{\bar{u}}{u_0}, \theta = \frac{\bar{T} - \bar{T}_\infty}{\bar{T}_w - \bar{T}_\infty}, \phi = \frac{\bar{C} - \bar{C}_\infty}{\bar{C}_w - \bar{C}_\infty}, Sc = \frac{\upsilon}{D}, \ \Pr = \frac{\rho Cp\,\upsilon}{k}, \ M = \frac{\sigma B_0^2\,\upsilon}{\rho u_0^2}$$

$$Gr = \frac{g\beta\upsilon(\bar{T}_w - \bar{T}_\infty)}{u_0^3}, Grm = \frac{g\bar{\beta}\upsilon(\bar{C}_w - \bar{C}_\infty)}{u_0^3}, \ Ra = \frac{16\overline{a\sigma}\upsilon^2\bar{T}_\infty^3}{k\,u_0^2}, Cr = \frac{\overline{Cr}\,\upsilon}{u_0^2}, \ K = \frac{\overline{Kr}\,u_0^2}{\upsilon^2}$$

$$A = \frac{u_0^2}{\upsilon}, \ w = \frac{\bar{w}\,\upsilon}{u_0^2}, \ Q = \frac{Q^*\,\upsilon}{\rho Cp u_0^2} \qquad \text{(8)}$$

The non-dimensional forms are

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\,\theta + Grm\,\phi - N\,u \qquad \text{(9)}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} - S_1\,\theta \qquad \text{(10)}$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - Cr\,\phi \qquad \text{(11)}$$

Where $N = M + \frac{1}{K}, \ S_1 = \frac{Ra}{\Pr} + Q$

The corresponding initial and boundary conditions are transformed to:

$$t \le 0: \ u = 0, \ \theta = 0, \ \phi = 0 \quad \forall y$$

$$t > 0 : u = t,\ \theta = 1,\ \phi = 1 \quad at\ \ y = 0$$
$$t > 0 :\ u \to 0,\ \theta \to 0,\ \phi \to 0 \quad as\ \ y \to \infty \qquad \text{(12)}$$

METHOD OF SOLUTION

Applying Laplace transform technique to equations (09) to (11) along with their boundary conditions eq. (12) we get

$$\theta(y,t) = \frac{1}{2}\left[e^{-y\sqrt{\Pr S_1}}\ erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}} - \sqrt{S_1\, t} \right) + e^{y\sqrt{\Pr S_1}}\ erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}} + \sqrt{S_1\, t} \right) \right] \qquad \text{(13)}$$

$$\phi(y,t) = \frac{1}{2}\left[e^{-y\sqrt{Sc\ Cr}}\ erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}} - \sqrt{Cr\, t} \right) + e^{y\sqrt{Sc\ Cr}}\ erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}} + \sqrt{Cr\, t} \right) \right] \qquad \text{(14)}$$

$$u(y,t) = \left(\frac{t}{2} - \frac{y}{4\sqrt{N}} \right)\left[e^{-y\sqrt{N}}\ erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{N\, t} \right) \right] + \left(\frac{t}{2} + \frac{y}{4\sqrt{N}} \right)\left[e^{y\sqrt{N}}\ erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{N\, t} \right) \right]$$
$$- \frac{A_5}{2}\left[e^{-y\sqrt{N}}\ erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{N\, t} \right) + e^{y\sqrt{N}}\ erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{N\, t} \right) \right]$$
$$+ \frac{A_5\, e^{-A_2 t}}{2}\left[e^{-y\sqrt{(N-A_2)}}\ erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{(N-A_2)\,t} \right) + e^{y\sqrt{(N-A_2)}}\ erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{(N-A_2)\,t} \right) \right]$$
$$- \frac{A_6}{2}\left[e^{-y\sqrt{N}}\ erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{N\, t} \right) + e^{y\sqrt{N}}\ erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{N\, t} \right) \right]$$
$$+ \frac{A_6\, e^{-A_4 t}}{2}\left[e^{-y\sqrt{(N-A_4)}}\ erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{(N-A_4)\,t} \right) + e^{y\sqrt{(N-A_4)}}\ erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{(N-A_4)\,t} \right) \right]$$
$$+ \frac{A_5}{2}\left[e^{-y\sqrt{\Pr S_1}}\ erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}} - \sqrt{S_1\, t} \right) + e^{y\sqrt{\Pr S_1}}\ erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}} + \sqrt{S_1\, t} \right) \right]$$
$$- \frac{A_5\, e^{-A_2 t}}{2}\left[e^{-y\sqrt{\Pr S_1}}\ erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}} - \sqrt{S_1\, t} \right) + e^{y\sqrt{\Pr S_1}}\ erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}} + \sqrt{S_1\, t} \right) \right]$$
$$+ \frac{A_6}{2}\left[e^{-y\sqrt{Sc\ Cr}}\ erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}} - \sqrt{Cr\, t} \right) + e^{y\sqrt{Sc\ Cr}}\ erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}} + \sqrt{Cr\, t} \right) \right]$$
$$+ \frac{A_6\, e^{-A_4 t}}{2}\left[e^{-y\sqrt{Sc\ Cr}}\ erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}} - \sqrt{Cr\, t} \right) + e^{y\sqrt{Sc\ Cr}}\ erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}} + \sqrt{Cr\, t} \right) \right] \qquad \text{(15)}$$

The Non-dimensional **skin friction** at the surface is given by

$$\tau = \left(\frac{\partial u}{\partial y} \right)_{y=0} = -\frac{1}{4\sqrt{N}}\, erfc\left(-\sqrt{Nt}\right) + \frac{t}{2}\left[(-\sqrt{N})\, erfc\left(-\sqrt{Nt}\right) - \frac{1}{\sqrt{\pi t}}\, e^{-N t} \right] + \frac{1}{4\sqrt{N}}\, erfc\left(\sqrt{Nt}\right)$$
$$+ \frac{t}{2}\left[\sqrt{N}\, erfc\left(\sqrt{Nt}\right) - \frac{1}{\sqrt{\pi t}}\, e^{-N t} \right]$$

$$-\frac{A_5}{2}\left[(-\sqrt{N})\,erfc\left(-\sqrt{Nt}\right)-\frac{1}{\sqrt{\pi t}}e^{-Nt}+\sqrt{N}\,erfc\left(\sqrt{Nt}\right)-\frac{1}{\sqrt{\pi t}}e^{-Nt}\right]$$

$$+\frac{A_5\,e^{-A_2 t}}{2}\left[(-\sqrt{(N-A_2)})\,erfc\left(-\sqrt{(N-A_2)t}\right)-\frac{1}{\sqrt{\pi t}}e^{-(N-A_2)t}\right.$$

$$\left.+\sqrt{(N-A_2)}\,erfc\left(\sqrt{(N-A_2)t}\right)-\frac{1}{\sqrt{\pi t}}e^{-(N-A_2)t}\right]$$

$$-\frac{A_6}{2}\left[(-\sqrt{N})\,erfc\left(-\sqrt{Nt}\right)-\frac{1}{\sqrt{\pi t}}e^{-Nt}+\sqrt{N}\,erfc\left(\sqrt{Nt}\right)-\frac{1}{\sqrt{\pi t}}e^{-Nt}\right]$$

$$+\frac{A_6\,e^{-A_4 t}}{2}\left[(-\sqrt{(N-A_4)})\,erfc\left(-\sqrt{(N-A_4)t}\right)-\frac{1}{\sqrt{\pi t}}e^{-(N-A_4)t}\right.$$

$$\left.+\sqrt{(N-A_4)}\,erfc\left(\sqrt{(N-A_4)t}\right)-\frac{1}{\sqrt{\pi t}}e^{-(N-A_4)t}\right]$$

$$+\frac{A_5}{2}\left[(-\sqrt{\Pr S1})\,erfc\left(-\sqrt{S1t}\right)-\frac{1}{\sqrt{\pi t}}e^{-S1t}+\sqrt{\Pr S1}\,erfc\left(\sqrt{S1t}\right)-\frac{1}{\sqrt{\pi t}}e^{-S1t}\right]$$

$$-\frac{A_5\,e^{-A_2 t}}{2}\left[(-\sqrt{\Pr S1})\,erfc\left(-\sqrt{S1t}\right)-\frac{1}{\sqrt{\pi t}}e^{-S1t}+\sqrt{\Pr S1}\,erfc\left(\sqrt{S1t}\right)-\frac{1}{\sqrt{\pi t}}e^{-S1t}\right]$$

$$+\frac{A_6}{2}\left[(-\sqrt{Sc\ Cr})\,erfc\left(-\sqrt{Cr\,t}\right)-\frac{1}{\sqrt{\pi t}}e^{-Cr\,t}+\sqrt{Sc\ Cr}\,erfc\left(\sqrt{Cr\,t}\right)-\frac{1}{\sqrt{\pi t}}e^{-Cr\,t}\right]$$

$$+\frac{A_6\,e^{-A_4 t}}{2}\left[(-\sqrt{Sc\ Cr})\,erfc\left(-\sqrt{Cr\,t}\right)-\frac{1}{\sqrt{\pi t}}e^{-Cr\,t}+\sqrt{Sc\ Cr}\,erfc\left(\sqrt{Cr\,t}\right)-\frac{1}{\sqrt{\pi t}}e^{-Cr\,t}\right]$$

The **rate of heat transfer** in terms of the Nusselt number is given by

$$Nu=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0}=-\frac{1}{2}\left[(-\sqrt{\Pr S1})\,erfc\left(-\sqrt{S1t}\right)-\frac{1}{\sqrt{\pi t}}e^{-S1t}+\sqrt{\Pr S1}\,erfc\left(\sqrt{S1t}\right)-\frac{1}{\sqrt{\pi t}}e^{-S1t}\right]$$

The **rate of mass transfer** in the form of Sherwood number is given by

$$S_h=-\left(\frac{\partial\phi}{\partial y}\right)_{y=0}=-\frac{1}{2}\left[(-\sqrt{Sc\ Cr})\,erfc\left(-\sqrt{Cr\,t}\right)-\frac{1}{\sqrt{\pi t}}e^{-Cr\,t}+\sqrt{Sc\ Cr}\,erfc\left(\sqrt{Cr\,t}\right)-\frac{1}{\sqrt{\pi t}}e^{-Cr\,t}\right]$$

RESULTS AND DISCUSSION

The non linear coupled equations (09)-(11) subject to boundary conditions (12), which illustrate the non-linear MHD flow with heat and mass transfer characteristics of an incompressible, viscous, electrically conducting and Newtonian fluid over a vertical oscillating porous plate embedded in a porous medium in presence of homogeneous chemical reaction of first order and thermal radiation effects have been analyzed.The dimensionless governing coupled, non-linear boundary layer partial differential equations are solved by the Laplace Transform technique and the expressions for the velocity, temperature, concentration were obtained. In order to get a physical insight of the problem, the above physical quantities are computed for different values of the governing parameters The velocity profile for the different values of Hartmann number parameter (M), thermal Grashof number (Gr), MassGrashof number (Grm), Prandtl number (Pr), Schmidt number (Sc), Porosity parameter (K), Radiation-Conduction parameter (Ra), and dimensionless time (t) are shown in the figures 2 -7 respectively. From these figures it is observed that the velocity increases as Gr, Grm, Kand t increases. While velocity decreases as K increases. Figure 8 - figure 10 shows that the temperature profile for the different values of the Prandtl number (Pr), Radiation-Conduction parameter (Ra) and Heat source parameter (Q). It is noticed that temperature decreases as Pr, Ra and Q increases. The concentration profile for different values of the Schmidt number (Sc) and the Chemical reaction parameter (Cr) are shown in figures 11-12 respectively. It is noticed that the concentration decreases as Sc and Cr increases. From table 1 it is noticed that an increasing the thermal Grashof number (Gr), Mass Grashof number (Grm), Porosity parameter (K), Heat source parameter (Q) and dimensionless time (t) results an increasing Skin friction. While it decreases with increase of Prandtl number (Pr), Hartmann number parameter (M), Radiation-Conduction parameter (Ra), the Schmidt number (Sc) and the Chemical reaction parameter (Cr) respectively. Tables 2 discuss the effects of Prandtl number (Pr), the Radiation-Conduction parameter (Ra) and the Heat source parameter (Q) numerically on rate of heat transfer (Nu). It is noticed that the rate of heat transfer increases with increasing of Pr, Ra and Q. Table 3 shows the effects of the Schmidt number (Sc), the Chemical reaction parameter (Cr) and dimensionless time (t) on rate of mass transfer (Sh) numerically. It is observed that the rate of mass transfer increases with increasing Sc and Cr.While it decrease with increase of time(t).

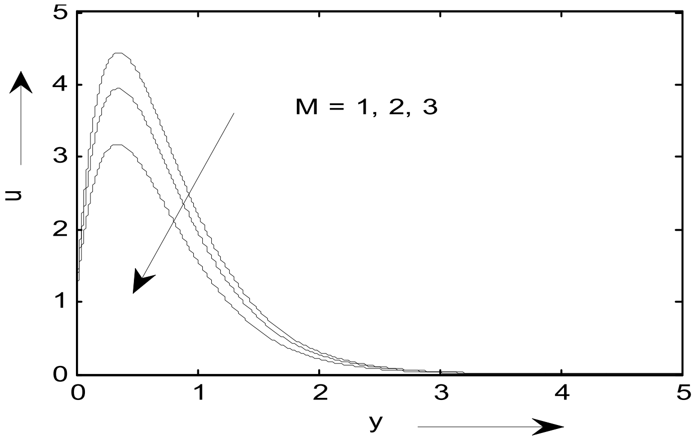

Fig 2: Velocity distribution for various values of M

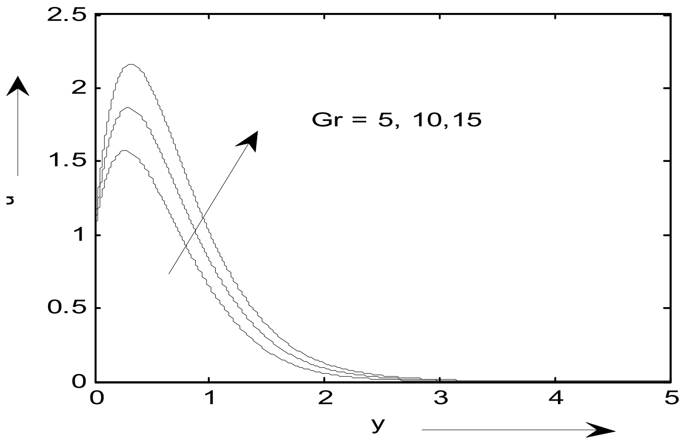

Fig3: Velocity distribution for various values of Gr

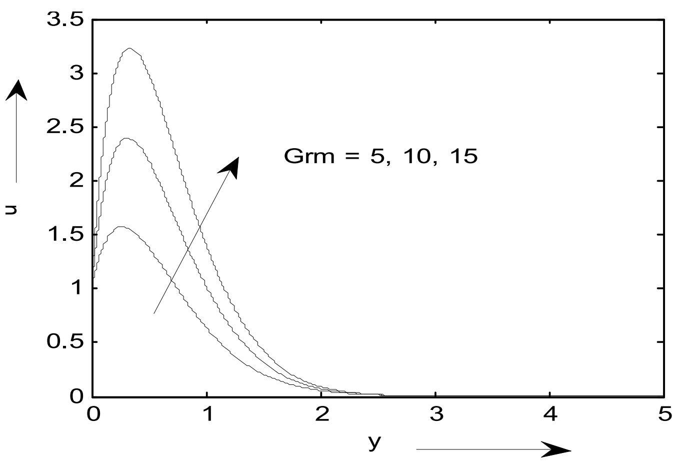

Fig4: Velocity distribution for various values of Grm

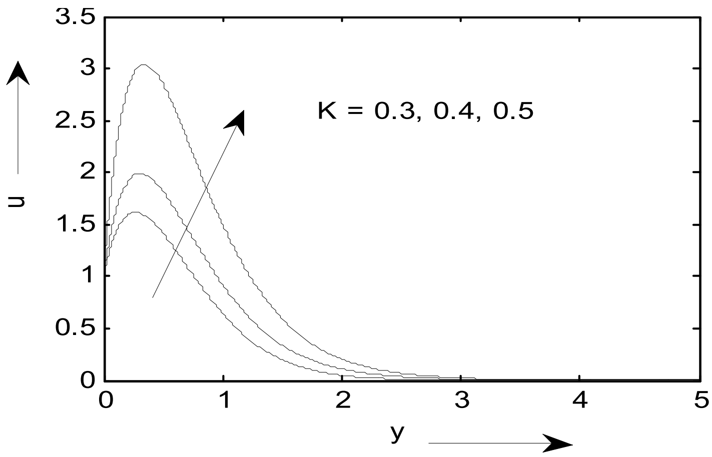

Fig 5: Velocity distribution for various values of K

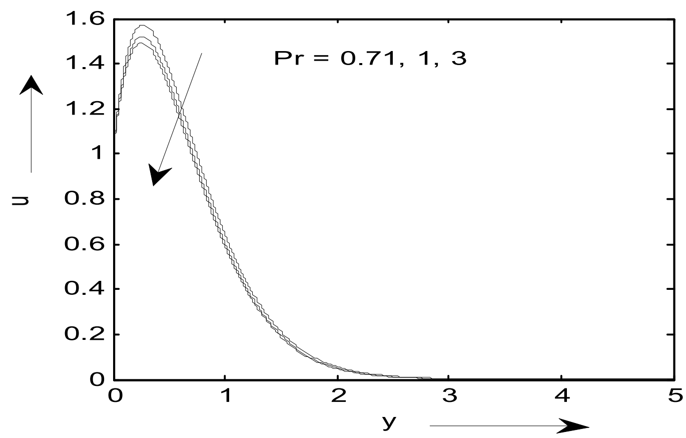

Fig6: Velocity distribution for various values of Pr

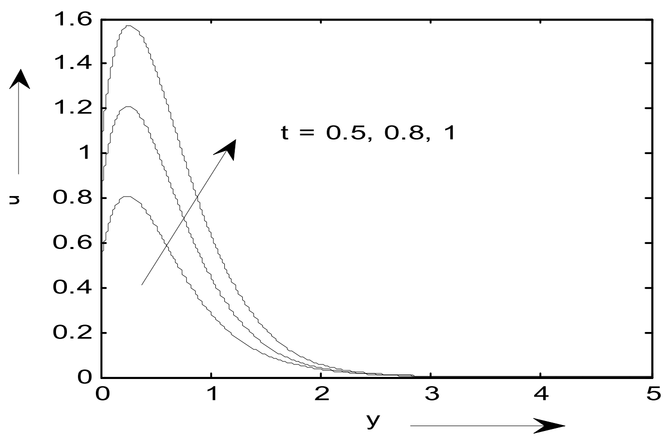

Fig7: Velocity distribution for various values of t

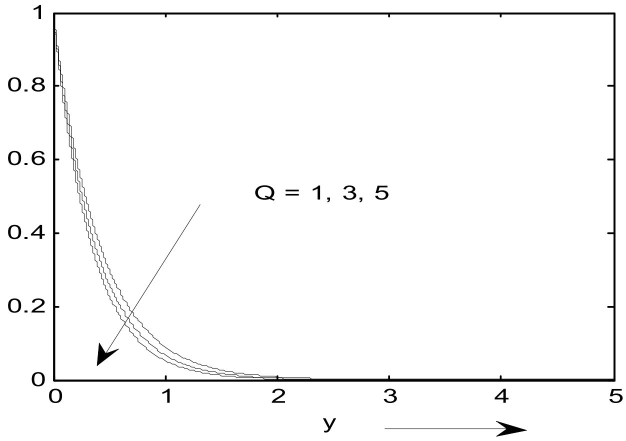

Fig8: Temperature distribution for various values of Q

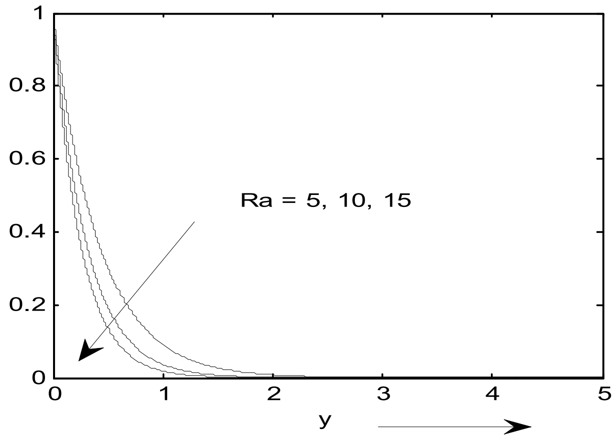

Fig9: Temperature distribution for various values of Ra

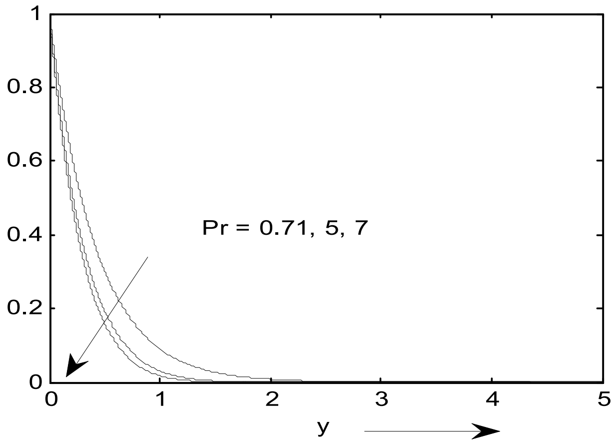

Fig10: Temperature distribution for various values of Pr

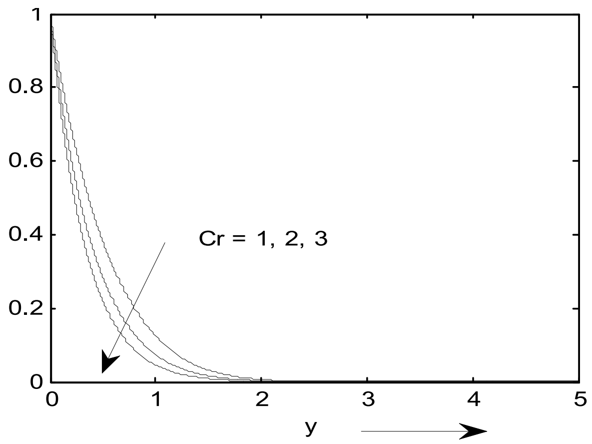

Fig11: Concentration distribution for various values of Cr

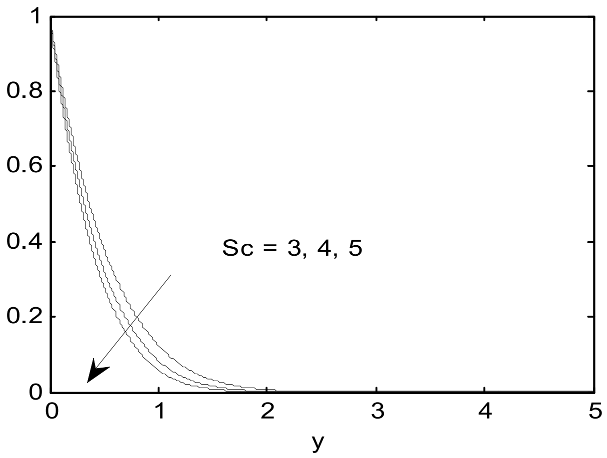

Fig12: Concentration distribution for various values of Sc

Table 1. Skin friction (τ) for different parameter

M	Pr	Gr	Grm	Q	Sc	Cr	K	Ra	t	Sf
4.00	0.71	5.00	5.00	1.00	3.00	1.00	0.50	5.00	1.00	6.0519
5.00	0.71	5.00	5.00	1.00	3.00	1.00	0.50	5.00	1.00	6.0112
4.00	5.00	5.00	5.00	1.00	3.00	1.00	0.50	5.00	1.00	4.4574
4.00	0.71	10.00	5.00	1.00	3.00	1.00	0.50	5.00	1.00	8.0580
4.00	0.71	5.00	10.00	1.00	3.00	1.00	0.50	5.00	1.00	12.7512
4.00	0.71	5.00	5.00	10.00	3.00	1.00	0.50	5.00	1.00	14.9472
4.00	0.71	5.00	5.00	1.00	4.00	1.00	0.50	5.00	1.00	1.3163
4.00	0.71	5.00	5.00	1.00	3.00	1.50	0.50	5.00	1.00	1.8119
4.00	0.71	5.00	5.00	1.00	3.00	1.00	0.60	5.00	1.00	7.0406
4.00	0.71	5.00	5.00	1.00	3.00	1.00	0.50	6.00	1.00	6.0491
4.00	0.71	5.00	5.00	1.00	3.00	1.00	0.50	5.00	2.00	9.5776

Table 2. The rate of heat transfer Nu for different parameters

Pr	Ra	Q	Nu
0.71	5.00	1.00	2.3896
5.00	5.00	1.00	3.0947
0.71	10.00	1.00	3.2726
0.71	5.00	3.00	2.3902

Table 3. The rate of mass transfer Sh for different parameters

Sc	Cr	t	Sh
3.00	1.00	1.00	1.6672
5.00	1.00	1.00	2.0919
3.00	3.00	1.00	2.9852
3.00	1.00	2.00	1.6657

Conclusion

The analysis is focused on the study of non-linear MHD flow with heat and mass transfer characteristics of an incompressible, viscous, electrically conducting and Newtonian fluid over a vertical oscillating porous plate embedded in a porous medium in presence of homogeneous chemical reaction of first order and thermal radiation, heat source effects have been analyzed. The most interesting points can be summarized as follows:

- The velocity increases with increasing values of thermalGrashof number (Gr), mass Grashof number (Grm), porosity parameter (K) and t, while it decreases with increasing values of Prandtl number (Pr) and Hartmann number parameter (M).
- The temperature decreases with increasing the values of Prandtl number (Pr), heat absorption parameter (Q) and radiation parameter (Ra).
- The concentration decreases with increasing values of chemical reaction parameter (Cr) and Schmidt number (Sc).
- Skin friction increases with increasing values of thermal Grashof number (Gr), mass Grashof number (Grm), heat absorption parameter (Q), porosity parameter (K), and t, while it decreases with increasing values of Prandtl number (Pr), Hartmann number parameter (M), Schmidt number (Sc), chemical reaction parameter (Cr) and radiation parameter (Ra).
- The rate of heat transfer increases with increasing values of Prandtl number (Pr), heat absorption parameter (Q) and radiation parameter (Ra).
- The rate of mass transfer in terms of Sherwood number increases with increasing values of Schmidt number (Sc) and chemical reaction parameter (Cr).

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