MHD Flow past a Vertical Oscillating Plate with Radiation and Chemical Reaction in Porous Medium-Finite Difference Method

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Abstract: – In this paper we analyze the effect of thermal radiation and chemical reaction on unsteady natural Convective flow of a viscous incompressible conducting fluid past over an infinite isothermal vertical oscillating plate in Porous medium. The non dimensional governing equations are solved using the 'finite difference technique'. The effects of the different physical parameters like Radiation parameter, Schmidt number, Magnetic field parameter, Chemical reaction parameter, thermal Grashof number, Phase angle and time on temperature, concentration and velocity profiles are discussed graphically.

Index Terms: - Chemical reaction, magnetic field, oscillating vertical plate, porous medium, radiation finite difference method.

1. 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, technology and also industries. In particular, the study of chemical reaction, heat and mass transfer with radiation is of considerable free convection flows that occur in nature and in engineering practice is very large and has been extensively considered by many authors. Chaudhary et.al. [1] have discussed the MHD flow past an infinite vertical oscillating plate through porous medium, taking account of the presence of free convection and mass transfer. Anjalidevi and Kandasamy [2] have studied the effect of a chemical reaction on the flow in the presence of heat transfer and magnetic field. Rajasekhar et al. [3] discussed unsteady magnetohydrodynamic free convective flow past a semi-infinite vertical porous plate. Muthucumaraswamy and Ganesan [4] examined the radiation effects on flow past an impulsively started infinite vertical plate with variable temperature. Mohammed Ibrahim et.al [5] analyzed the effects on the radiation and chemical reaction effects on MHD convective flow past a moving vertical porous plate. Chemical reaction effects on the flow past an infinite vertical plate in porous medium with constant heat flux have been studied by R.K.Tripathi et.al [6]. Radiation effects on MHD flow through a porous medium with variable temperature or variable mass diffusion was studied by Rajesh and Verma[7] . Rajput and Sahu [8] have investigated effects of rotation and magnetic field on the flow past an exponentially accelerated vertical plate with constant temperature. Radiation effects on MHD free convection flow over a vertical plate with heat and mass flux was studied by Sivaiah et al. [9]. Ramana Reddy et.al [10] analyses the mass transfer and radiation effects of unsteady MHD free convective fluid flow embedded in porous medium with heat generation/absorption.

The objective of this paper is to study the effects of radiation and chemical reaction on hydro magnetic flow past an oscillating vertical plate under the assumption of first order chemical reaction.

2. MATHEMATICAL ANALYSIS

An unsteady natural convection flow of a viscous incompressible electrically conducting fluid past an infinite vertical plate in porous medium. The x^* axis is taken along the vertical plate in the upward direction and the flow is assumed to be in x^* axis direction and y^*- axis normal to the plate and the fluid fills the region $y^* \geq 0$. Initially, the fluid and the plate are kept at the same constant temperature T_∞^* and species concentration C_∞^*. At time $t^* > 0$, the plate is given an oscillatory motion in its own plane with a velocity $U_0 \cos \omega^* t^*$. At the same time the plate temperature is raised to T_w^* and concentration is raised to C_w^* and a magnetic field of uniform strength B_0 is applied normal to the plate. It is assumed that the magnetic Reynolds number is very small and the induced magnetic field is negligible in comparison to the transverse magnetic field. It is also assumed that the effect of viscous dissipation is negligible in the energy equation and the level of species concentration is very low so the Soret and Dufour effects are negligible.

Under the above assumptions and following Boussinesq approximation, the unsteady flow field is governed by the following set of equations:

Momentum equation:

$$\frac{\partial u^*}{\partial t^*}=v\frac{\partial^2 v^*}{\partial y^{*2}}+g\beta(T^*-T_\infty^*)+g\beta^*(C^*-C_\infty^*)-\frac{v}{K^*}u^*-\frac{\sigma B_0^2}{\rho}u^* \quad \text{--- (1)}$$

Energy equation:

$$\frac{\partial T^*}{\partial y^*}=\frac{k}{\rho c_p}\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y^*} \quad \text{--- (2)}$$

Diffusion equation:

$$\frac{\partial C^*}{\partial t^*}=D\frac{\partial^2 C^*}{\partial y^{*2}}-K_r^*C^* \quad \text{--- (3)}$$

Under these assumptions, the approximate boundary conditions for the velocity, temperature and concentration fields are

$$\left.\begin{array}{l} t^*\le 0: u^*=0, T^*=T_\infty^*, C^*=C_\infty^* \quad for\ all\ \ y^* \\ t^*>0:\begin{cases} u^*=U_0\cos\omega^* t^*, T^*=T_w^*, C^*=C_w^* & at\ \ y^*=0 \\ u^*=U_\infty^*, T^*\to T_\infty^*, C^*\to C_\infty^* & as\ \ y^*\to\infty \end{cases}\end{array}\right\} \quad \text{--- (4)}$$

In order to write the governing equations and the boundary conditions in dimensionless form, we introduce the following non-dimensional quantities.

$$\left.\begin{array}{l} y=\frac{U_0 y^*}{\nu}, u=\frac{u^*}{U_0}, t=\frac{U_0^2 t^*}{\nu}, \theta=\frac{T^*-T_\infty^*}{T_w^*-T_\infty^*}, \\ C=\frac{C^*-C_\infty^*}{C_w^*-C_\infty^*}, Sc=\frac{v}{D}, K=\frac{K^*U_0^2}{v^2}, M=\frac{\sigma B_0^2 v}{\rho U_0^2}, \\ Gm=\frac{g\beta^* v\left(C_w^*-C_\infty^*\right)}{U_0^3}, Gr=\frac{g\beta v\left(T_w^*-T_\infty^*\right)}{U_0^3}, \\ R=\frac{vK^*}{U_0^2}, \Pr=\frac{\mu C_p}{k}, Kr=\frac{K_r^* v}{v_0^2}, \omega=\frac{\omega^* v}{U_0^2}, \\ F=\frac{4I_1 v^2}{KU_0^2}, \frac{\partial q_r}{\partial y^*}=(4I_1\Delta T^*)\theta, \end{array}\right\} \quad \text{--- (5)}$$

In view of equations (4) and (5), equations (1), (2) and (3) reduce to the following dimensionless form

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}+Gr\theta+GmC-\left(M+\frac{1}{K}\right)u \quad \text{--- (6)}$$

$$\frac{\partial \theta}{\partial y}=\frac{1}{\Pr}\frac{\partial^2\theta}{\partial y^2}-\frac{F}{\Pr}\theta \quad \text{--- (7)}$$

$$\frac{\partial C}{\partial t}=\frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}-RC \quad \text{--- (8)}$$

and the initial and boundary conditions are as follows:

$$\left.\begin{array}{l} t\le 0:\ u=0, \theta=0, C=0 \ \ for\ all\ \ y \\ t>0:\begin{cases} u=\cos\omega t, \theta=1, C=1 & at\ \ y=0 \\ u\to 0, \theta\to 0, C\to 0 & as\ \ y\to\infty \end{cases}\end{array}\right\} \quad \text{--- (9)}$$

3. METHOD OF SOLUTION

The dimensionless governing differential equations (6)-(8) subject to the initial and boundary conditions (9) 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,

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

4. RESULTS AND DISCUSSION

The numerical values of the velocity, temperature and concentration fields are computed for different parameters like, thermal Grashof number(Gr) and mass Grashof number(Gm), radiation parameter(F), chemical reaction parameter(R), magnetic field parameter(M), Schmidt number(Sc), Prandtl number(Pr) and phase angle and they are presented graphically in figure.

Figure 1 represents the temperature profiles for different values of $Pr=0.71,7$ and $F=0.5,5$. It is observed that the increase of Prandtl number (Pr) and radiation parameter (F) lead to decrease in temperature. In figures 2 concentration profiles are presented for different values of $Sc=0.6,3.5$ and $R=2,5$. From this figure it is clear that concentration decreases with increase of Schmidt number (Sc) and chemical reaction parameter(R).

For different values of the parameters, the velocity profiles are depicted in figures 3-5. Effects of $R=2,5$ and $K=1,5,10$ are shown in figure 3 for some fixed values of the other parameters. Influence of $Gr=5,10$ $Gm=2,5$ and $M=0.5,1$ are presented in figure 4 for some fixed values of other parameters and in figure 5 velocity MHD flow past a vertical oscillating plate with radiation and chemical reaction in porous medium profiles are presented for different values of $\frac{\pi}{6},\frac{\pi}{4},\frac{\pi}{3},\frac{\pi}{2}$. It is clear from these figures that velocity increases with the increase of $Gr, Gm\ and\ K$. Further, velocity decreases with the increase of M,F,Sc,R M, F, Sc, R and ωt.

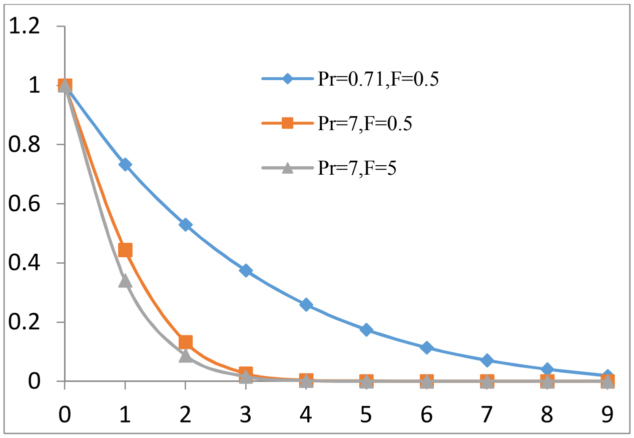

Fig.1 Temperature Profile showing the effect of Pr and F.

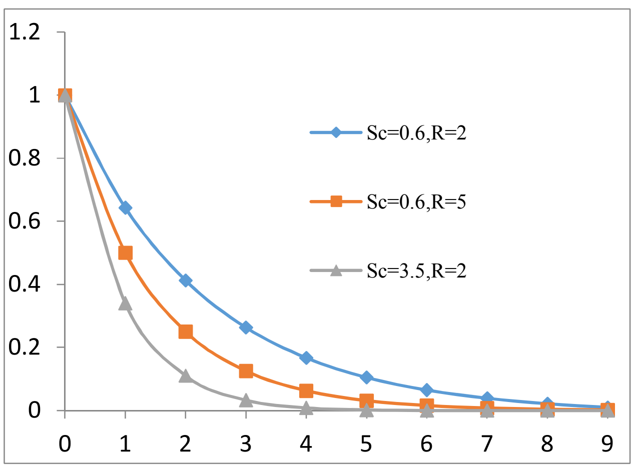

Fig.2 Concentration Profile showing the effect of Sc and R.

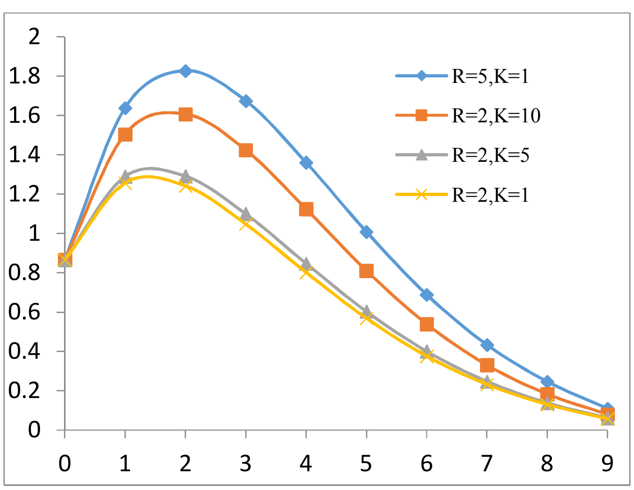

Fig.3 Velocity Profile showing the effect of R and K

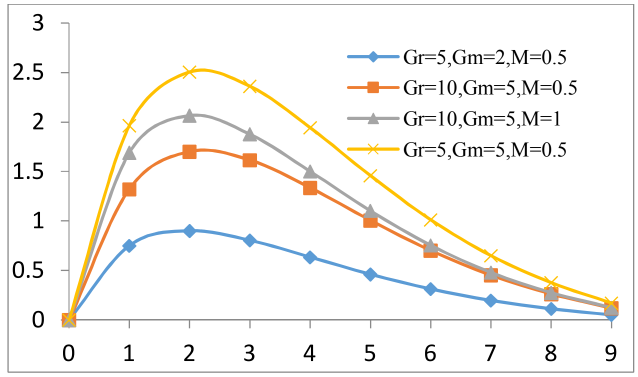

Fig.4 Velocity Profile showing the effect of Gr, Gm and M.

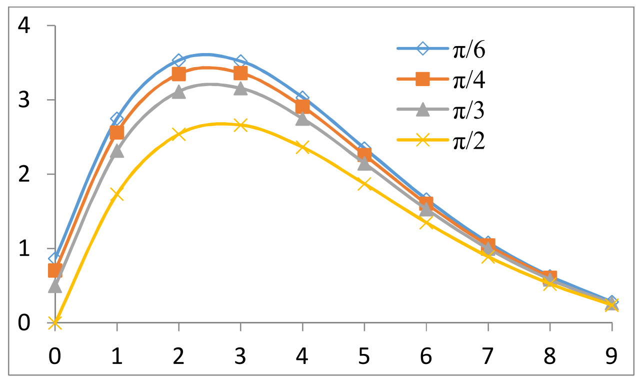

Fig.5 Velocity Profile showing the effect of phase angle ωt .

5. CONCLUSIONS

In this paper, we analyze the influence of the thermal radiation and chemical reaction on unsteady natural convective flow of a viscous incompressible conducting fluid past over an infinite vertical oscillating plate in Porous medium. The governing equations of the fluid are solved by using finite difference technique. In the analysis of the flow the following conclusions are made:

- Velocity increases with increasing Gr, Gm and K and with decreasing M and F
- Increase in Sc, R and ωt lead to decrease in velocity.
- Temperature decreases with the increase of Pr and F.
- Also concentration decreases as Sc and R increase.

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