HEAT AND MASS TRANSFER ON MHD FLOW OF A VISCOUS FLUID THROUGH POROUS MEDIUM WITH THE EFFECT OF RADIATION AND CHEMICAL REACTION

A.Haritha[1], A. Leela Ratnam[2]

Abstract— The effect of chemical reaction and radiation on heat and mass transfer in the MHD flow of a viscous fluid through porous medium in the presence of transverse magnetic field is investigated. The governing equations are reduced to non-linear ordinary differential equations by means of similarity transformations. These equations are then solved numerically by applying Runge Kutta fourth order method along with shooting technique. The velocity, temperature and concentration distributions are discussed numerically through graphs for different parameters. It has been observed that with increase of chemical reaction and radiation parameters the concentration and temperature increases respectively. The results for local skin friction, Nusselt number and Sherwood number are tabulated and discussed.

Index Terms— Heat and Mass transfer, MHD flow, viscous fluid, Porous medium, Radiation, chemical reaction.

1 INTRODUCTION

In recent years the study of heat and mass transfer of the boundary layer flow has gained interest because of their numerous technological applications in various fields like polymer technology related to the stretching of plastic sheets. The study of free convective mass transfer flow has become the object of extensive research as the effects of heat transfer along with mass

transfer effects are dominant features in many engineering applications such as rocket nozzles, cooling of nuclear reactors, high sinks in turbine blades, high speed aircrafts and their atmospheric re-entry, chemical devices and process equipments. Sakiadis [1] analyzed the boundary layer flow over a solid surface moving with a constant velocity. The study of convective heat transfer mechanisms through porous media in relation to the applications to the above areas has been made by Nield and Bejan [2]. As presence of suction being more important and appropriate from the technological point of view, Nanda and Sarma [3], Schetz and Eichhorn [4], Soundalgekar [5],[6] and Kafousias [7] have studied unsteady free convective flow past vertical plates with suction. Magnetohydrodynamics(MHD) is the study of the flow of electrically conducting fluids in a magnetic field.. In fluid dynamics the effects of extern-al magnetic field on magnetohydro-dynamic (MHD) flow over a stretching sheet are very important due to its applications in many engineering problems, such as glass manufacturing, geophysics, paper producti-on and purification of crude oil. Pavlov [8] studied the effect of external magnetic field on the MHD flow over a stretching sheet. Andersson [9] discussed the MHD flow of viscous fluid on a stretching sheet, Unsteady effect on MHD free convective and mass transfer flow through porous medium with constant suction and constant heat flux in rotating system studied by Sharma [10]. Flows through porous medium are very prevalent in nature and therefore in the theory of flow through a porous medium, the role of momentum equation is occupied by the numerous experimental observation summarized mathematically as the Darcy's law. Saffman [11] employing statistical method derived a general governing equation for the flow in porous medium which takes in to account as viscous stress. Chemical reactions usually accompany a large amount of exothermic and endothermic reactions. These characteristics can be easily seen in a lot of industrial processes. Chamkha [12] studied the MHD flow of a numerical of uniformly stretched vertical permeable surface in the presence of heat generation and chemical reaction. Cess (13) presented radiation effects on the boundary layer flow of an absorbing fluid past a vertical plate, by using the Rosseland diffusion model.

In view of the above discussion, in this paper the effect of chemical reaction and radiation on heat and mass transfer in the MHD flow of a viscous fluid through porous medium in the presence of transverse magnetic field is investigated.

1. School of Engineering and Technology, SPMVV, Tirupati. (arigalaharitha@gmail.com)
2. Professor, Dept. of Applied Mathematics, SPMVV, Tirupati.

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2 Mathematical Formulation

In view of the present physical situation a two-dimensional flow of a viscous, electrically conducting fluid past a semi-infinite vertical permeable moving plate embedded in a uniform porous medium is considered. The flow is assumed to be in the x-direction, which is taken along the vertical plate in the upward direction and the y-axis is taken to be normal to the plate. A temperature dependent heat source is assumed to be present in the flow. A uniform transverse magnetic field of strength B_0 is applied parallel to the y-axis and the chemical reaction is taking place in the flow. It is also assumed that the magnetic Reynolds number Re_m is very small so that the induced magnetic field is negligible. The surface of the plate is maintained at a uniform constant temperature Tw and a uniform constant concentration Cw of a foreign fluid, which are higher than the corresponding values Tw and Cw respectively, sufficiently far away from the flat surface. Under these assumptions, the governing Equations for the problem are :

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad (1)$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}-\left(\frac{\sigma B_0^2 u}{\rho}\right)-\frac{\upsilon}{k'}u \quad (2)$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{K}{\rho c_p}\frac{\partial^2 T}{\partial y^2}+\frac{Q_0}{\rho c_p}(T-T_\infty)-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y} \quad (3)$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2}-k_1\,(c-c_\infty) \quad (4)$$

Where (u, v) are the velocity components in x- and y- directions respectively, υ is the kinematic viscosity, K is the thermal conductivity, k' is the permeability of the porous medium, ρ is the density, B_0 is the magnetic induction, T and T_∞ are the temperature of the fluid inside the thermal boundary layer and the fluid temperature in the free stream respectively, while C is the concentration, σ is the electrical conductivity of the fluid, c_p is the specific heat at constant pressure, q_r is the radiation heat flux, Q_0 the heat generation constant, D is the coefficient of mass diffusivity, k_1 is the reaction rate.

The appropriate boundary conditions for the problem are given by

$$u=0,\ v=-v_w(x),\ T=T_w,\ C=C_w \quad at\ \ y=0$$
$$u=U_\infty,\ T=T_\infty,\ C=C_\infty \quad as \quad y\to\infty \quad (5)$$

$$f'''+\frac{1}{2}ff''-(M+k)f'=0 \quad (9)$$

$$(1+\frac{4}{3}R)\theta''+\frac{1}{2}\Pr f\theta'+Q\Pr\theta=0 \quad (10)$$

$$\phi''+Scf\phi'+ScK^*\phi=0 \quad (11)$$

Where v_w is the suction velocity, T_w is the temperature of the sheet.

The radiative heat flux term is simplified by using Rosseland approximation as

$$q_r=-\frac{4\sigma^*}{3k^*}\frac{\partial(T^4)}{\partial y} \quad (6)$$

Where q_r represents the radiative heat flux in the y-direction, σ^* is the Stefan-Boltzmann constant and k^* is the mean absorption coefficient. We assume that the temperature difference with in the flow is sufficiently small such that T^4 may be expressed as a linear function of the temperature .This is accomplished by expanding T^4 in a Taylors series about T_∞ and neglecting higher order terms so that

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

Introducing the similarity variables

$$\eta=y\sqrt{\frac{U_\infty}{\nu x}},\ f(\eta)=\frac{\psi}{\sqrt{\nu x U_\infty}},\ \ \theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty},$$
$$\phi(\eta)=\frac{C-C_\infty}{C_w-C_\infty},\ M=\frac{\sigma B_0^2 x}{\rho U_\infty},\Pr=\frac{\nu\rho c_p}{k},$$
$$Q=\frac{Q_0 x}{\rho c_p U_\infty},\ Sc=\frac{\nu}{D},\quad R=\frac{4\sigma^* T_\infty^3}{k^* k}$$

(8)

Where ψ is the stream function with $u=\frac{\partial\psi}{\partial y}$, $v=-\frac{\partial\psi}{\partial x}$

and η is the stream variable.

using equation (8), the equations (2), (3), and (4) reduce to

The corresponding boundary conditions are

$$f = f_w,\ f' = 0,\ \theta = 1,\ \phi = 1 \quad at \quad \eta = 0$$

$$f' = 1,\ \theta = 0,\ \phi = 0 \quad as \quad \eta \to \infty \qquad (12)$$

Where $f_w = -2\nu_w(x)\sqrt{\frac{x}{\upsilon U_\infty}}$ is the suction parameter.

Knowing the velocity field, temperature field, concentration field the Skin- friction, Nusselt number and Sherwood number, can be calculated by

$$(\mathrm{Re}_x)^{\frac{1}{2}} c_f = 2f''(0), \qquad (\mathrm{Re}_x)^{-\frac{1}{2}} Nu = -\theta'(0)$$

$$and \quad (\mathrm{Re}_x)^{-\frac{1}{2}} Sh = -\phi'(0)$$

Where $\mathrm{Re}_x = \frac{u_0 L}{\nu}$ (stretching Reynold's number).

3 Results and Discussions

In this paper the effect of chemical reaction and radiation on heat and mass transfer in the MHD flow of a viscous fluid through porous medium in the presence of transverse magnetic field is investigated.

Fig(1) presents the velocity profiles for different values of magnetic field parameter. The presence of magnetic field reduces the velocity. This result qualitatively agrees with the expectations, since the magnetic field exerts a retarding force on the flow. In fig.(2) the effect of suction is shown. In the presence of suction the velocity decreases and increasing values of suction parameter results in further reduction in velocity and hence the thickness of boundary layer decreases. Fig.(3) shows the effect of permeability parameter *K* on the velocity profiles. It is seen that the velocity decreases as the permeability parameter increases.

The temperature profiles are presented in figures (4-7) . From fig(4) it is noticed that the presence of radiation increases the temperature and hence leads to an increase in thickness of thermal boundary layer. Fig.(5). shows that with increase of porous parameter the temperature increases. From fig.(6) it is observed that increasing values of Prandtl number leads to significant reduction of temperature. This is due to the fact that larger Prandtl number indicates low thermal conductivity. The effect of suction parameter *fw* on the temperature profiles is shown in Fig.(7). It is observed that the temperature decreases as *fw* increases.

The concentration profiles are presented in figures (8-10). The presence of porous medium parameter (fig.8) increases the concentration however, its effect is not very significant. Fig.(9) shows the presence of Suction parameter decreases the concentration. Increase in suction parameter leads to significant reduction in concentration.Fig.(10) illustrates the influence of Cemical reaction parameter K* on concentraton profile. It shows that with increase of Chemical reaction the concentration increases.

The effect of various physical parameters on the skin-friction, Nusselt number and Sherwood number are depicted in Table. It is seen that as magnetic parameter *M* or permeability parameter *K* increases, there is a fall in the skin-friction coefficient. Also, it is noticed that as the suction parameter *fw* increases, the skin-friction coefficient decreases, while the Nusselt number and Sherwood number increases. It is observed that as the radiation parameter *R* increases, the Nusselt number increases, but the Sherwood number remains unchanged. It is also noticed that an increase in Chemical reaction parameter leads to a rise in the Sherwood number.

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