RADIATION AND CHEMICAL REACTION EFFECTS ON TRANSIENT MHD FREE CONVECTIVE FLOW OVER A VERTICAL PLATE THROUGH POROUS MEDIUM

M.VENKATESWARLU, D.V.LAKSHMI

Abstract: This paper analyze the Magneto hydrodynamic, Radiation and chemical reaction effects on unsteady MHD flow, heat and mass transfer characteristics in a viscous, incompressible and electrically conduction fluid over a semi-infinite vertical porous plate through porous medium. The porous plate is subjected to a transverse variable suction velocity. The governing equations for the flow are transformed into a system of non-linear ordinary differential equations are solved by a perturbation technique. The effects of the various parameters on the velocity, temperature, concentration and skin-friction profiles are presented graphically and discussed qualitatively.

Keywords: Chemical reaction, MHD, Radiation Parameter, Transient velocity.

Introduction: Transient MHD flows with and without heat transfer in electrically conducting fluids have attracted substantial interest in the context of metallurgical fluid dynamics, re-entry aerothermodynamics, astronautics, geophysics, nuclear engineering and applied mathematics. An early study was presented by Carrier and Greenspan [1] who considered unsteady hydromagnetic flows past a semi-infinite flat plate moving impulsively in its own plane. Gupta [2] considered unsteady magneto-convection under buoyancy forces. Singer [3] further assessed the unsteady free convection heat transfer with magnetohydrodynamic effects in a channel regime. Pop [4] reported on transient buoyancy-driven convective hydromagnetic from a vertical surface. Yu and Yang [5] investigated the influence of channel wall conductance on hydromagnetic convection. Rao [6] analyzed the unsteady magnetohydrodynamic convection heat transfer past an infinite plane. Further excellent studies of unsteady free convection magnetohydrodynamic flows were reported by Antimirov and Kolyshkin [7] for a vertical pipe and Rajaram and Yu for a parallel-plate channel [8].

Tokis [9] used Laplace transforms to analyze the three dimensional free-convection hydromagnetic flows near an infinite vertical plate moving in a rotating fluid when the plate temperature undergoes a thermal transient. The influence of oscillatory pressure gradient on transient rotating hydromagnetic flow was considered by Ghosh [10]. Other transient MHD studies include the papers by Sacheti et al. [11], Attia [12] who included viscosity variation effects, Al-Nimr and Alkam [13] who considered open-ended vertical annuli, and Takhar et al. [14] who employed a numerical method to study flat-plate magnetohydrodynamic unsteady convection flow. Chamkha [15] has analyzed the unsteady MHD free three-dimensional con vection over an inclined permeable surface with heat generation/absorption.

Mathematical Model: Consider the unsteady two dimensional MHD free convective flow of a viscous incompressible, electrically conducting and radiating fluid in an optically thin environment past an infinite heated vertical porous plate embedded in a porous medium in presence of thermal and concentration buoyancy effects . Let the $x-$axis be taken in vertically upward direction along the plate and $y-$axis is normal to the plate. It is assumed that there exist a homogeneous chemical reaction of first order with constant rate Kr between the diffusing species and the fluid. A uniform magnetic field is applied in the direction perpendicular to the plate.

The viscous dissipation and the Joule heating effects are assumed to be negligible in the energy equation. The transverse applied magnetic field and magnetic Reynolds number are assumed to be very small, so that the induced magnetic field is negligible. Also it is assumed that there is no applied voltage, so that the electric field is absent. The concentration of the diffusing species in the binary mixture is assumed to be very small in comparison with the other chemical species, which are present, and hence the Soret and Dufour effects are negligible and the temperature in the fluid flowing is governed by the energy concentration equation involving radiative heat temperature. Under the above assumptions as well as Boussinesq's approximation, the equations of conservation of mass, momentum, energy and concentration governing the free convection boundary layer flow over a vertical porous plate in porous medium can be expressed as:

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

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

$$\frac{\partial T'}{\partial t'}+v'\frac{\partial T'}{\partial y'}=\frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y'^2}-\frac{1}{\rho c_p}\frac{\partial q'_r}{\partial y'} \quad (3)$$

$$\frac{\partial C'}{\partial t'}+v'\frac{\partial C'}{\partial y'}=D\frac{\partial^2 C'}{\partial y'^2}-K'_r\left(C'-C'_\infty\right) \quad (4)$$

$$q'_r=-\frac{4\sigma^*}{3k'_1}\frac{\partial T'^4_w}{\partial y'} \quad (5)$$

$$T'^4_w\cong 4T'^3_\infty T'_w-3T'^4_\infty \quad (6)$$

$$v'=-V_0\left(1+\varepsilon A\exp^{i\omega' t'}\right) \quad (7)$$

$$\frac{1}{4}\frac{\partial u}{\partial t}-\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial u}{\partial y}= \frac{\partial^2 u}{\partial y^2}+Gr\theta+Gc\phi-\left(M+\frac{1}{K}\right)u \quad (8)$$

$$\frac{1}{4}\frac{\partial \theta}{\partial t}-\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial \theta}{\partial y}=\frac{1}{\Pr}\left(1+\frac{4}{3R}\right)\frac{\partial^2\theta}{\partial y^2} \quad (9)$$

$$\frac{1}{4}\frac{\partial \phi}{\partial t}-\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial \phi}{\partial y}=\frac{1}{Sc}\frac{\partial^2\phi}{\partial y^2}-Kr\phi \quad (10)$$

Solution Of Problem:

$$u(y,t)=N_8e^{-m_4y}+N_6e^{-m_1y}+N_7e^{-m_2y}+ \varepsilon\left[\begin{array}{l}N_{13}e^{-m_5y}+N_9e^{-m_1y}+N_{10}e^{-N_1y}\\+N_{11}e^{-m_3y}+N_{12}e^{-m_2y}\end{array}\right]e^{i\omega t} \quad (11)$$

$$\theta(y,t)=e^{-N_1y}+\varepsilon\left[N_2e^{-N_1y}+N_3e^{-m_1y}\right]e^{i\omega t} \quad (12)$$

$$\phi(y,t)=e^{-m_2y}+\varepsilon\left[N_5e^{-m_3y}+N_4e^{-m_2y}\right]e^{i\omega t} \quad (13)$$

$$\tau^*_w=\mu\left(\frac{\partial u'}{\partial y'}\right)_{y'=0} \quad (14)$$

$$q^*_w=-k\left(\frac{\partial T'}{\partial y'}\right)_{y'=0}-\frac{4\sigma^*}{3k^*_1}\left(\frac{\partial T'^4}{\partial y'}\right)_{y'=0} \quad (15)$$

$$Nu=\frac{xq^*_w}{k\left(T'_w-T'_\infty\right)} \quad (16)$$

Results And Discussion: In order to obtain a physical insight of the problem and to observe that the effects of various physical hydrodynamics parameters on the velocity, numerical calculations have been performed for different values of magnetic parameter M ,thermal Grashof number Gr, Soluta Grashof number Gc, Permeability parameter K, Radiation Parameter R and Permeability parameter Pr.

For various values of the thermal Grashof number Gr the velocity profiles 'u' are plotted in Figs. (1). The thermal Grashof number Gr signifies the relative effect of the thermal buoyancy force to the viscous hydrodynamic force in the boundary layer. As expected, it is observed that there is a rise in the velocity due to the enhancement of thermal buoyancy force. Also, as Gr increases, the peak values of the velocity increases rapidly near the porous plate and then decays smoothly to the free stream velocity.

For various values of the Solutal Grashof number Gc , the velocity profiles 'u' are plotted in Figs.(2). The Solutal Grashof number Gc defines the ratio of the species buoyancy force to the viscous hydrodynamic force. As expected, the fluid velocity increases and the peak value is more distinctive due to increase in the species buoyancy force. The velocity distribution attains a distinctive maximum value in the vicinity of the plate and then decreases properly to approach the free stream value. It is noticed that the velocity increases with increasing values of the Solutal Grashof number.

The effect of the magnetic parameter M is shown in Fig.3. It is observed that the tangential velocity of the fluid decreases with the increase of the magnetic field number values. The decrease in the tangential velocity as the magnetic parameter M increases is because the presence of a magnetic field in an electrically conducting fluid introduces a force called the Lorentz force, which acts against the flow if the magnetic field is applied in the normal direction, as in the present study. This resistive force slows down the fluid velocity component as shown in Fig.3.

Fig.4 shows the effect of the permeability of the porous medium parameter K on the velocity distribution. It is found that the velocity increases with an increase in K .

For different values of thermal radiation R the velocity profiles are shown in Fig.5. It is noticed that an increase in the thermal radiation results a decrease in the velocity.

Fig.6. shows the behavior of velocity for different values of Prandtl number. The numerical results show that the effect of increasing values of Prandtl

number results a decreasing velocity.

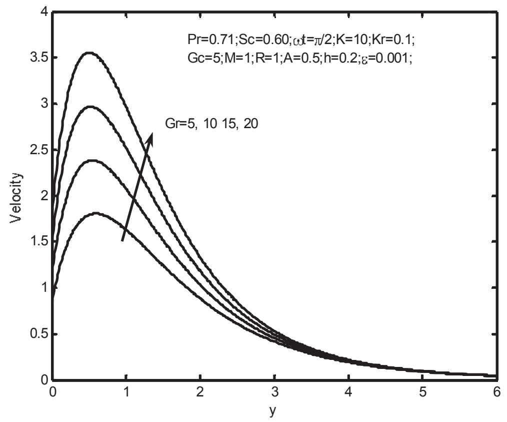

Fig.1. Velocity profiles for different values of Grashof number.

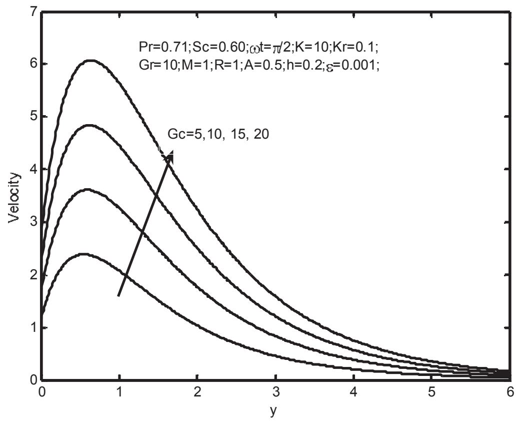

Fig.2. Velocity profiles for different values of Solutal Grashof number.

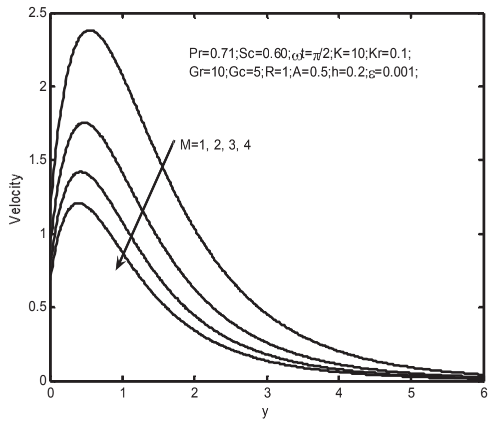

Fig.3. Velocity profiles for different values of magnetic parameter.

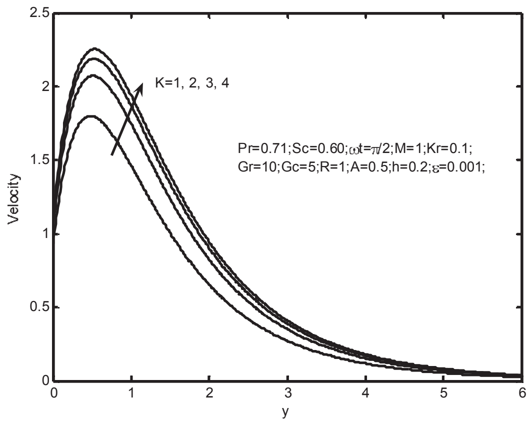

Fig.4. Velocity profiles for different values of permeability parameter.

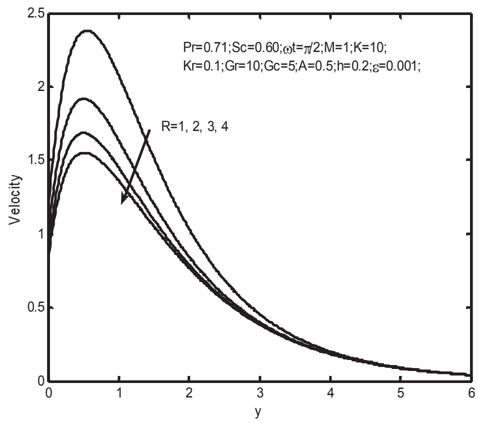

Fig.5. Velocity profiles for different value of radiation parameter.

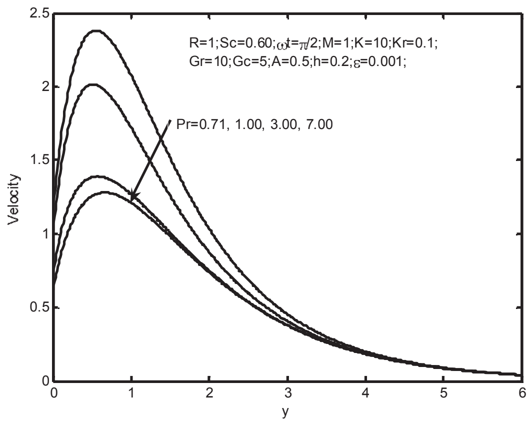

Fig.6. Velocity profiles for different values of Prandtl number.

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Department of Mathematics, V. R. Siddhartha Engineering College,
Kanuru, Krishna (Dist),A.P,India, Pin-520 007.
Department of Mathematics, Bapatla Women's, Engineering, Bapatla,
Guntur (Dist), A.P, India, Pin-522 101.
mvsr2010@gmail.com