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Effect Of Mass Transfer On Hydromagnetic Free Convective Rivlin-Ericksen Flow Through A Porous Medium With Time Dependent Suction

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Abstract: *The aim of the present work is to study the effect of mass transfer on unsteady hydromagnetic free Convective Rivlin-Ericksen flow of incompressible and electrically conducting fluids past an infinite vertical porous plate subjected to a periodic suction is presented under the influence of a uniform transverse magnetic field. The governing equations of the flow field are solved analytically and the expressions for velocity,temperature mass concentration, skin-friction and the rate of heat transfer in terms of Nusselt number are obtained.The effects of the important flow parameters such as magnetic parameter,permeability parameter,Grashoff number,modified Grashoff number ,Prandtl number,Schmidt number are discussed quantitativily with the help of figures.*
Keywords:*Rivlin-Ericksen fluid, free convection,porous medium, suction.*

I. INTRODUCTION

The study of the effect of mass transfer on Newtonian and non-Newtonian fluids has become important in the last few years. This importance is due to a number of industrial processes. For instance the food processing, biochemical operations and transport polymers. Flowing over deformable boundaries has also gained importance because of its immediate practical application in lubrication technology,biophysical flows and many other transportation types. Besides, the characteristics of the flow of blood through artiries and veins are of considerable medical interest.

Both steady and unsteady flows have been investigated at length in diverse range of geometries using a wide spectrum of analytical and computational methods. Siddappa and Khapata (1975) studied the second order Rivlin-Ericksen viscolastic boundary layer flow along a stretching surface. Rochelle and Peddieson (1980) used an implicit difference scheme to analyze the steady boundary layer flow of a non linear Maxwell viscolastic fluid past a parabola and paraboloid. Ji et al.(1990) studied the Von Karman Oldroyd-B viscolastic flow from a rotating disk using the Galerkin method with B-test functions. Rao and Finlayson (1990) used adoptive finite element technique to analyze viscolastic flow of Maxwell fluid. Muthur and Bhatnager (1967) have studied the steady axial flow of a Rivlin-Ericksen fluid in a wavy annulus with heat transfer.They found that the non -Newtonian parameter affect the velocity field, the stresses, and the temperature field. They also found that the streamlines near the boundaries run parallel to them and there is no change in their deformity as a result of the slip conditions. Kawase and Ulbrecht (1983) investigated the heat and mass transfer in a non-Newtonian fluid flow with different velocity profiles. They considered a laminer as well as turbulent non-Newtonian fluid. They found a reasonable agreement between their results and the available experimental data. Hung and Perng (1991) discussed the flow of a non-Newtonian fluid in the entrance region of a tube with porous walls. They solved the modified Navier-Stokes equations numerically. Their analysis resulted in velocity distributions,pressure drops and skin-friction coefficients in the cases of blowing and suction.Away from the entrance their results agree well with previous works.

The requirements of modern technology have stimulated interest in fluid flow studies which involve the interaction of several phenomena. One such study is related to the effects of free convective flow with mass transfer,which plays an important role in geophysical sciences and in cosmical studies. In view of these applications several investigators have given much attention towards free convective flows of viscous incompressible fluid past an infinite plate.Ramanamurthy et al. (2007) have discussed the MHD unsteady free convective Walter's memory flow with constant suction and heat sink.Mustafa et al. (2008) obtained the analytical solution of unsteady MHD memory flow with oscillatory sucton, variable free stream and heat source.Numerical study of transient free convective mass transfer in Walter-B viscolastic flow with wall suction was analysed by Chang et al. (2011). Effects of the chemical reaction and radiation absorption on free convective flow through porous medium with variable suction in the presence of uniform magnetic field were studied by Sudhear Babu and Satyanarayanta (2009). Gireesh Kumar et al. (2009) analysed the effects of the chemical and mass transfer on MHD unsteady free convective flow past an infinite vertical plate with constant suction and heat sink.

Kafousias and Raptis (1981) have discussed the mass transfer and free convective effects on the flow past an accerelated vertical infinite plate with variable suction of injection. Chowdhury and Islam (2000) studied the MHD free convective flow of viscoelastic fluid past an infinite vertical porous plate. Raptis et al. (1981) have studied the flow of Walter's liquid B model in the presence of constant heat flux between the fluid and the plate and taking into account the influence of the memory fluid on the energy equation.

Motivated by the above referenced works and the numerous possible industrial applications of the engineering fields, it is of paramount interest in this study to investigate the unsteady fully developed Effect of mass transfer problem on hydromagnetic free convective Rivlin-Ericksen flow through a porous medium with variable permeability. The expressions for velocity,temperature,mass concentration,the local wall shear stress,the local surface heat,and mass flux are obtained by solving analytically the governing equations of the flow field and the effects of the pertinent parameters.

II. Formulation Of The Problem

Consider unsteady hydromagnetic free convective Rivlin-Ericksen flow of a viscous, incompressible and electrically conducting fluid past an infinite vertical plate through a porous medium in the presence of periodic suction and transverse magnetic field. Let $u \; and \; v$ be the velocity components of $x- \; and \; y-$ directions respectively.All the physical variables are functions of $y \; and \; t$ only.The magnetic Reynolds number is much less than unity, therefore, the induced magnetic field is neglected in comparison with the applied magnetic field following Sparrow and Cess (1962). The pressure in the flow field is assumed to be constant. Boussineq's approximation for the equations of the flow is governed as :

The Continuity Equation :

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

The Momentum Equation :

$$\frac{\partial u}{\partial t} + v^* \frac{\partial u}{\partial y} = g\beta(T - T_\infty) + v\frac{\partial^2 u}{\partial y^2} + \beta_1\left(\frac{\partial^3 u}{\partial t \partial y^2} + V\frac{\partial^3 u}{\partial y^3}\right) - v\frac{u}{k} - \frac{\sigma u e^2 H_0{}^2 u}{\rho} + g\beta^*(C - C_\infty) \tag{2}$$

The Energy Equation :

$$\frac{\partial T}{\partial t} + v^* \frac{\partial T}{\partial y} = \left(\frac{k}{\rho C_p}\right)\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho C_p}\left(\frac{\partial q_r}{\partial y}\right) \tag{3}$$

The Concentration Equation:

$$\frac{\partial C}{\partial t} + v^* \frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} - K\left(C - C_\infty\right) \tag{4}$$

The appropriate boundary conditions to the problem for the velocity, temperature, and concentration fields are

$$\left.\begin{array}{l} u = 0, \quad T = T_\omega, \quad C = C_\omega \quad at \;\; y = 0 \\ u = 0, \; T = T_\infty, \quad C = C_\infty \quad as \;\; y \to \infty \end{array}\right\} \tag{5}$$

Where u is the velocity of the fluid in the x - direction and v in the y - direction. T is the temperature of the fluid, C is the concentration of the fluid, g the acceleration due to gravity, β is the coefficient of the volume expansion, $\beta_1 \; and \; \beta^*$ are the kinematic viscosity, k is the thermal conductivity and C_P is the specific heat capacity of the fluid at constant pressure. t is the time, σ is the electrical conductivity of the fluid and μ is the magnetic permeability. T_ω is the temperature of the plate, and T_∞ is the temperature of the fluid far away from the plate. C_ω is the concentration of the plate and C_∞ is the concentration of the fluid far away from the plate. It is clear from equation (1) that the suction velocity at the plate is either a constant or a function of time. Therefore the suction velocity normal to the plate is assumed in the form

$$v^* = V_0\left(1 + \varepsilon A e^{n^* t^*}\right) \tag{6}$$

Where A is a real positive constant, $\varepsilon \; and \; \varepsilon A$ is small values less than unity, V_0 is scale of suction velocity which is non-zero positive constant. The negative sign implies that the suction is towards the plate.

The term $\frac{\partial qr}{\partial y}$ in (3) represent the local radiant. For a case optically thin gray gas: $\frac{\partial qr}{\partial y}$ is expressed as:

$$\frac{\partial qr}{\partial y} = -4Q_R\sigma^*(T_\infty{}^4 - T^4) \qquad (7)$$

Assume that the temperature differences within the flow as small such that T^4 may be expressed as linear function of the temperature. This is established by expanding T^4 in a Taylor series about T_∞ and neglecting higher order terms.

$$T^4 \approx 4T_\infty{}^3T - 3T_\infty{}^4) \qquad (8)$$

By substituting equation (8) into equation (7) to obtain

$$\frac{\partial q_r}{\partial y} = 16a_R\sigma^* T_\infty{}^3\left[T - T_\infty\right] \qquad (9)$$

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

$$\left.\begin{array}{l} \bar{y} = \frac{yV_0}{\nu};\ \bar{t} = \frac{tV_0{}^2}{4\nu};\ \bar{\omega} = \frac{4\nu\omega}{V_0{}^2};\ \bar{u} = \frac{u}{V_0};\ \bar{\theta} = \frac{T - T\infty}{T_\omega - T_\infty};\ \bar{C} = \frac{C - C_\infty}{C_\omega - C_\infty} \\ Gr = \frac{\nu g\beta(T_\omega - T_\infty)}{V_0{}^3};\ Pr = \frac{\mu Cp}{K} : K = \frac{KV_0{}^2}{\nu^2};\ M = \frac{\sigma\mu e^2 H_0{}^2\nu}{\rho V_0{}^2} \\ Rm = \frac{\beta_1 V_0{}^2}{\nu^2} :\ Gc = \frac{\nu g\beta^*(C_\omega - C_\infty)}{V_0{}^3} :\ Sc = \frac{\nu}{D} \end{array}\right\} \qquad (10)$$

Then substituting equation (10) into equations (2) - (4) taking into consideration equations (6) and (9) to get

$$\frac{\partial u}{4\partial \bar{t}} - (1 + \varepsilon e^{i\omega t})\frac{\partial u}{\partial y} = Gr\theta + \frac{\partial^2 u}{\partial y^2} + Rm\left[\frac{\partial^3 u}{4\partial t\partial y^2} - \frac{\partial^3 u}{\partial y^3}\right] - ku - Mu - GcC \qquad (11)$$

$$\frac{\partial \theta}{4\partial t} - (1 + \varepsilon e^{i\omega t})\frac{\partial \theta}{\partial y} = \frac{1}{\Pr}\frac{\partial^2\theta}{\partial y^2} - \frac{R}{\Pr}\theta \qquad (12)$$

$$\frac{\partial C}{4\partial \bar{t}} - (1 + \varepsilon e^{i\omega t})\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 u}{\partial y^2} - K_r C \qquad (13)$$

Where $M = N - \frac{1}{k}$ *and* Gr, Gc, M, Pr, Sc, R, K *and* K_r are the thermal Grsshof number, the solutal Grashof number, the magnetic parameter, the Prandt number, the Schmidt number, the radiation parameter, the viscoelastic parameter and chemical reaction parameter respectively.

The transform boundary conditions become

$$\left.\begin{array}{ll} u = 0,\ \ \theta = 1 + \varepsilon e^{i\omega t},\ \ C = 1 + \varepsilon e^{i\omega t} & at\ \ y = 0 \\ u \to 0,\ \ \theta \to 0,\ \ C \to 0 & as\ \ y \to \infty \end{array}\right\} \qquad (14)$$

To solve equations (11) - (13), we assume ω to be very small and the velocity, temperature and concentration in the neighbourhood of the plate as

$$U(y,t) = U_0(y) + \varepsilon e^{i\omega t}U_1(y)$$

(15)

$$\theta(y,t) = \theta_0(y) + \varepsilon e^{i\omega t}\theta_1(y)$$

(16)

$$C(y,t) = C_0(y) + \varepsilon e^{i\omega t}C_1(y) \qquad (17)$$

Where u_0, θ_0 *and* C_0 are the mean velocity,mean temperature and mean concentration respectively.

By substituting equations (15) - (17) into (11) - (13) and equating the harmonic and non-harmonic terms we obtain the following pairs of equations for $\left(u_{0,}\theta_{0,}C_0\right)$ *and* $\left(u_{1,}\theta_{1,}C_1\right)$

$$RmU_0''' - U_0'' - U_0' + L_1U_0 = Gre^{-m_{1y}} + Gce^{-m_2 y} \qquad (18)$$

$$RmU_1''' - U_1'' - i\omega RmU_1'' - U_1' + D_1U_1 = Gc\theta_1 + GcC_1 + U_0' \quad (19)$$

$$\theta_0'' + \Pr\theta_0' - R\theta = 0 \quad (20)$$

$$\theta_1'' + \Pr\theta_1' - D_2\theta_1 = -\Pr\theta_0' \quad (21)$$

$$C_0'' + ScC_0' - KScC_0 = 0 \quad (22)$$

$$C_1'' + ScC_1' - C_1D_3 = -ScC_0' \quad (23)$$

Where the primes denote differentiation with respect to y.

The corresponding boundary conditions can be written as

$$\left.\begin{array}{l} U_0 = U_1 = 0,\ \theta_0 = \theta_1 = 1,\ \ C_0 = C_1 = 1 \quad at\ \ y = 0 \\ U_0 = U_1 \to 0,\ \theta_0 = \theta_1 \to 0,\ \ C_0 = C_1 \to 0 \quad as\ \ y \to \infty \end{array}\right\} \quad (24)$$

Equation (18) and (19) are third order differential equations due to the presence of viscoelasticity.Therefore , u_0, u_1 is expanded using Beard and Walters rule (1964) in terms of Rm

$$\left.\begin{array}{l} u_0 = u_{00} + Rmu_{01} \\ u_1 = u_{11} + Rmu_{12} \end{array}\right\} \quad (25)$$

Zeroth – order

$$U_{00}'' + U_{00}' - L_1U_{oo} = -\left(Gre^{-m_1y} + Gce^{-m_2y}\right) \quad (26)$$

$$u_{11}'' + u_{11}' - D_1u_{11} = -\left(Gr\theta_1 + GcC_1 + u_{00}'\right) \quad (27)$$

First – order

$$u_{01}'' + u_{01}' - L_1u_{01} = u_{00}''' \quad (28)$$

$$u_{12}'' + u_{12}' - D_1u_{12} = u_{11}''' - i\omega u_{11}'' - u_{01}' \quad (29)$$

The corresponding boundary conditions are

$$\left.\begin{array}{l} u_{00} = u_{01} = u_{11} = u_{12} = 0 \quad at\ \ y = 0 \\ u_{00} = u_{01} = u_{11} = u_{12} \to 0 \quad as\ \ y \to \infty \end{array}\right\} \quad (30)$$

Solving equations (26) - (29) satisfying boundary conditions (30), we obtain the velocity, temperature and concentration distribution in the boundary layer as

$$U(y,t) = A_6e^{-m_3y} - A_7e^{-m_1y} - A_8e^{-m_2y} + Rm\left[\left(A_{10} + A_{11}y\right)e^{-m_3y} + A_{12}e^{-m_1y} + A_{13}e^{-m_2y}\right] + \varepsilon e^{i\omega t}\left\{\begin{array}{l} B_2e^{-m_6y} - B_3e^{-m_4y} - B_5e^{-m_5y} + B_{10}e^{-m_2y} + B_{11}e^{-m_1y} + B_7e^{-m_3y} + \\ Rm[(H_2 + H_{21}y)e^{-m_6y} + H_{22}e^{-m_4y} + H_{23}e^{-m_5y} + H_{24}e^{-m_2y} + \\ H_{25}e^{-m_1y} + (H_{26} + H_{20}y)e^{-m_3y} \end{array}\right\} \quad (31)$$

$$\theta(y,t) = e^{-m_1y} + \varepsilon e^{i\omega t}\left(A_{15}e^{-m_4y} + A_{16}e^{-m_1y}\right) \quad (32)$$

$$C(y,t) = e^{-m_2y} + \varepsilon e^{i\omega t}\left(A_{18}e^{-m_5y} + A_{19}e^{-m_2y}\right) \quad (33)$$

$$where\ \ m_1 = \frac{1}{2}\left(Pr + \sqrt{P^2r + 4R}\right),\ \ m_2 = \frac{1}{2}\left(Sc + \sqrt{S^2c + 4KSc}\right),\ \ m_3 = \frac{1}{2}\left(1 + \sqrt{1 + 4L_1}\right),$$

$$m_4 = \frac{1}{2}\left(Pr + \sqrt{P^2r + 4D_2}\right),\ \ m_5 = \frac{1}{2}\left(Sc + \sqrt{S^2c + 4D_3}\right),\ \ m_6 = \frac{1}{2}\left(1 + \sqrt{1 + 4D_1}\right)$$

$$A_6 = A_7 + A_8,\ \ A_7 = \frac{Gr}{m_1^2 - m_1 - L_1},\ A_8 = \frac{Gc}{m_2^2 - m_2 - L_1}\ \ A_{10} = -\left(A_{12} + A_{13}\right),$$

$$A_{11} = \frac{m_3^3A_6}{1 - 2m_3},\ A_{12} = \frac{m_1^3A_7}{m_1^2 - m_1 - L_1},\ A_{13} = \frac{m_2^3A_8}{m_2^2 - m_2 - L_1},\ A_{10} = -\left(A_{12} + A_{13}\right)$$

$$A_{16} = \frac{m_1Pr}{m_1^2 - m_1 - D_1},\ \ A_{18} = 1 - A_{19},\ \ A_{19} = \frac{m_2Sc}{m_2^2 - m_2 - D_3}$$

$$B_2 = B_3 + B_5 - (B_7 + B_{10} + B_{11}), \quad B_3 = \frac{Gr}{m_4^2 - m_4 - D_1}, \quad B_4 = \frac{Gr}{m_1^2 - m_1 - D_1}$$

$$B_5 = \frac{GcA_{18}}{m_5^2 - m_5 - D_1}, \; B_6 = \frac{GcA_{19}}{m_2^2 - m_2 - D_1}, \; B_7 = \frac{m_3 A_6}{m_3^2 - m_3 - D_1},$$

$$B_8 = \frac{m_1 A_7}{m_1^2 - m_1 - D_1}, \; B_9 = \frac{m_2 A_8}{m_2^2 - m_2 - D_1}, \; B_{10} = B_9 - B_6, \; B_{11} = B_8 - B_4,$$

$$H_2 = -(H_{22} + H_{23} + H_{24} + H_{25} + H_{26}), \; H_3 = \frac{m_6^2 B_2}{1 - 2m_6}, \; H_4 = \frac{m_4^3 B_3}{m_4^2 - m_4 - D_1}$$

$$H_5 = \frac{m_5^3 B_5}{m_5^2 - m_5 - D_1}, \; H_6 = \frac{m_2^3 B_{10}}{m_2^2 - m_2 - D_1}, \; H_7 = \frac{m_1^3 B_{11}}{m_1^2 - m_1 - D_1}, \; H_8 = \frac{m_3^3 B_7}{m_3^2 - m_3 - D_1},$$

$$H_9 = \frac{i\omega m_6^2 B_2}{1 - 2m_6}, \; H_{10} = \frac{i\omega m_4^2 B_3}{m_4^2 - m_4 - D_1}, \; H_{11} = \frac{i\omega m_5^2 B_5}{m_5^2 - m_5 - D_1}, \; H_{12} = \frac{i\omega m_2^2 B_{10}}{m_2^2 - m_2 - D_1},$$

$$H_{17} = \frac{m_1 A_{12}}{m_1^2 - m_1 - D_1}, \; H_{18} = \frac{m_2 A_{13}}{m_2^2 - m_2 - D_1}, \; H_{19} = \frac{-(1 - 2m_3) H_{20}}{m_3^2 - m_3 - D_1}, \; H_{20} = \frac{m_3 A_{11}}{m_3^2 - m_3 - D_1},$$

$$H_{21} = H_9 - H_3, \; H_{22} = H_4 + H_{10}, \; H_{23} = H_5 + H_{11}, \; H_{24} = H_{18} - H_{12} - H_6,$$

$$H_{25} = H_{17} - H_{13} - H_7, \; H_{26} = -(H_8 + H_{14} + H_{15} + H_{19}).$$

It is important to calculate the physical parameters of primary interest for this type of boundary layer flow. They are the local wall shear stress, the local surface heat and mass flux.

Skin-friction :

Knowing the velocity field, the skin-friction at the plate becomes

$$S_k = \left(\frac{\partial u_0}{\partial y} + \varepsilon e^{i\omega t} \frac{\partial u_1}{\partial y} \right)_{y=0}$$

$$-C_f = -m_3 A_6 + m_1 A_7 + m_2 A_8 - m_3 A_6 + Rm(-m_3 A_{10} - A_{11} - m_1 A_{12} - m_2 A_{13}) + \varepsilon e^{i\omega t} \begin{Bmatrix} -m_6 B_2 + -m_4 B_3 + -m_5 B_5 - m_2 B_{10} - m_1 B_{11} - m_3 B_7 + \\ Rm(H_{21} - m_6 H_2 - m_4 H_{22} - m_5 H_{23} - m_2 H_{24} - m_1 H_{25} + H_{20} - m_3 H_{26}) \end{Bmatrix} \quad (34)$$

Nusselt number :

Similarly, the Nusselt number at the plate in non-dimensional form is given as

$$N_u = \left(\frac{\partial \theta_0}{\partial y} + \varepsilon e^{i\omega t} \frac{\partial \theta_1}{\partial y} \right)_{y=0}$$

$$N_u = -\{ m_1 + \varepsilon e^{i\omega t} (m_4 A_{15} + m_1 A_{16}) \} \quad (35)$$

Sherwood number is given by

$$S_h = \left(\frac{\partial C_0}{\partial y} + \varepsilon e^{i\omega t} \frac{\partial C_1}{\partial y} \right)_{y=0}$$

$$S_h = -\{ m_2 + \varepsilon e^{i\omega t} (m_5 A_{18} - m_2 A_{19}) \} \quad (36)$$

III. Results And Discussion

The problem of effects of mass transfer on unsteady hydromagnetic free convective Rivlin-Ericksen flow of imcompressible and electrically conducting fluids through a porous medium with time dependent suction and heat radiation has been formulated, analysed and solved by using multi-parameter perturbation technique. In order to get physical insight into the problem, factors such as velocity,temperature,concentration, skin-friction,Nusselt number,and Sherwood number have been discussed by assigning numerical values to various parameters obtained in the mathematical formulaion of the problem and the results are graphically shown in Figures 1-14. Throughout the computation we assign $Gc = 2.0, Gr = 1.0, M = 5.0, K = 0.1, k_1 = 0.3, R = 0.5, Rm = 0.05,$

$Pr = 0.71, Sc = 0.20, \omega = \frac{\pi}{8}, \omega = 4.0, \varepsilon = 0.02$, unless otherwise stated.

The velocity distribution is shown in figures 1-10 for different values for solutal Grashof number ($Gc = 1.0, 2.0, 3.0, 4.0$), thermal Grashof number ($Gr = 1.0, 2.0, 3.0, 4.0$),Schmidt number ($Sc = 0.21, 0.30, 0.35, 0.40$), Prandtl number ($Pr = -1.0, 0.0, 0.71$), Radiation parameter ($R = 0.0, 0.2, 0.5, 1.0$), Hartmann number ($M = 1.0, 3.0, 5.0, 7.0$), viscoelastic parameter ($K = 0.0, 0.3, 0.5, 1.0$), magnetic Reynold number ($Rm = 0.1, 0.2, 0.3, 0.4$), chemical reaction parameter ($k_1 = 0.3, 0.6, 0.9, 1.2$) and epsilon ($\varepsilon = 0.04, 0.08, 0.12, 0.16$) respectively.

It is observed that the velocity increases with increase of solutal Grashof number,thermal Grashof number and epsilon but decreases with increase in Schmidt number,Prandtl number,radiation parameter,Hartmann number,viscoelastic parameter,magnetic Reynold number and chemical reaction parameter respectively.

The temperature profiles have been studied and presented in figures 11 and 12. It is observed that an increase in Prandtl number decreases the temperature as shown in figure 11 while an increase in radiation parameter influence in decreasing the temperature as shown in figure 12.

The variation of the mass concentration along $y-axis$ is shown in figures 13 and 14 respectively for different varying values of Schmidt number and chemical reaction parameter. It is found that increasing Schmidit number and chemical reaction parameter results in decrease in concentration of the boundary layer.

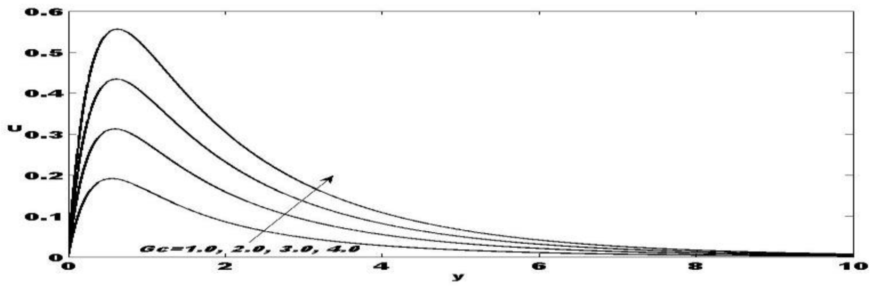

Fig 1:Velocity profiles for different values of solutal Grashof number

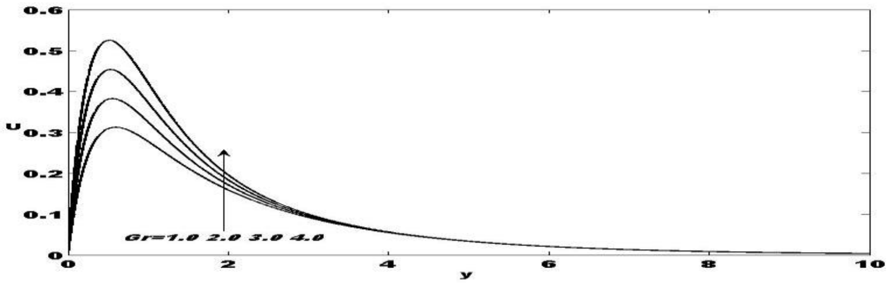

Fig2: Velocity profiles for different values of thermal Grashof number

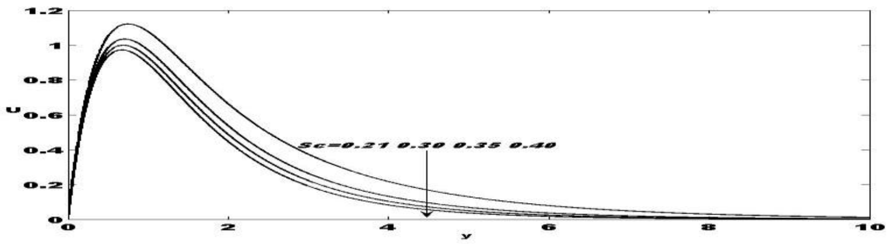

Fig3: Velocity profiles for different values of Schmidt number

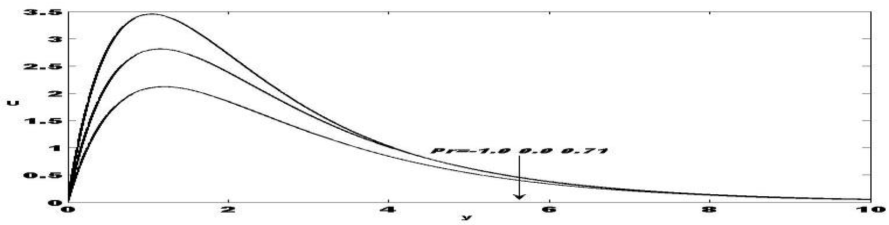

Fig4: Velocity profiles for different values of Prandtl number

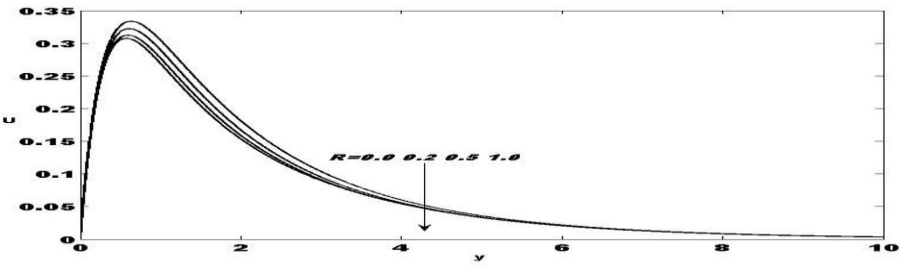

Fig5: Velocity profiles for different values of radiation parameter

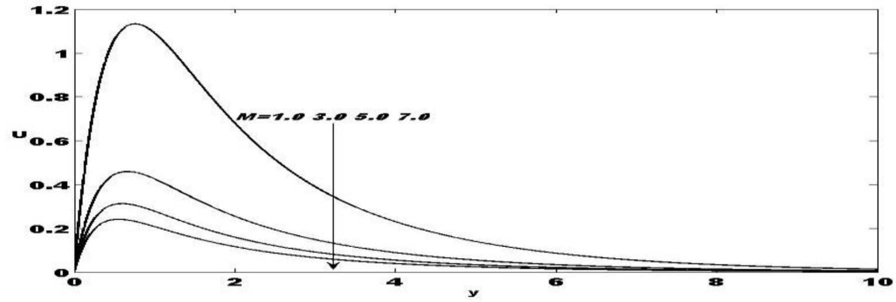

Fig6: Velocity profiles for different values of Magnetic parameter

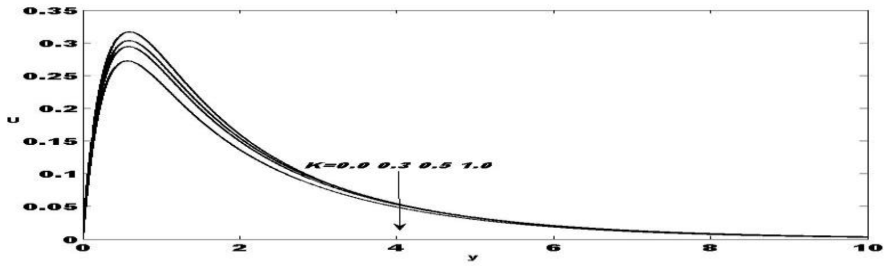

Fig7: Velocity profiles for different values of viscoelastic paramete

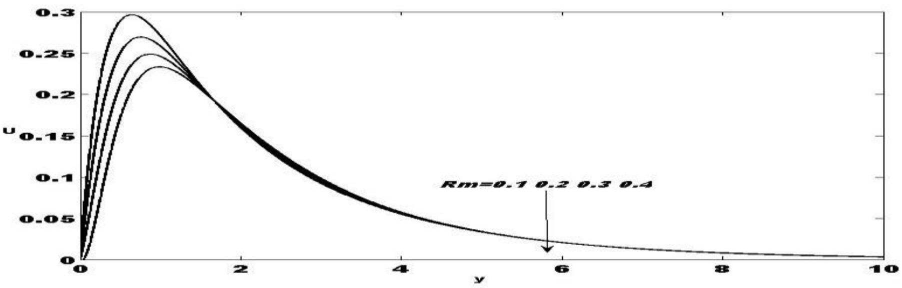

Fig8: Velocity profiles for different values of Reynolds number

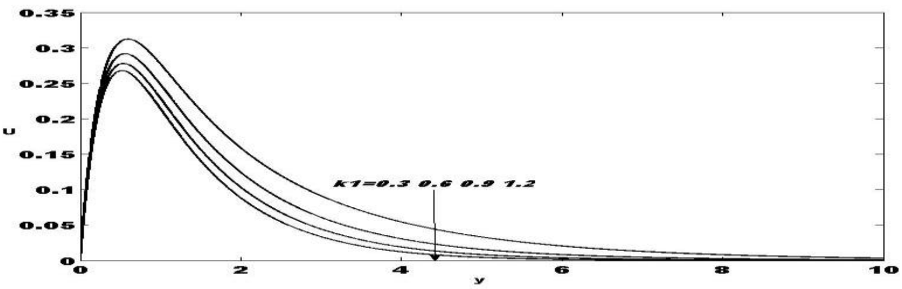

Fig9: Velocity profiles for different values of Chemical reaction parameter

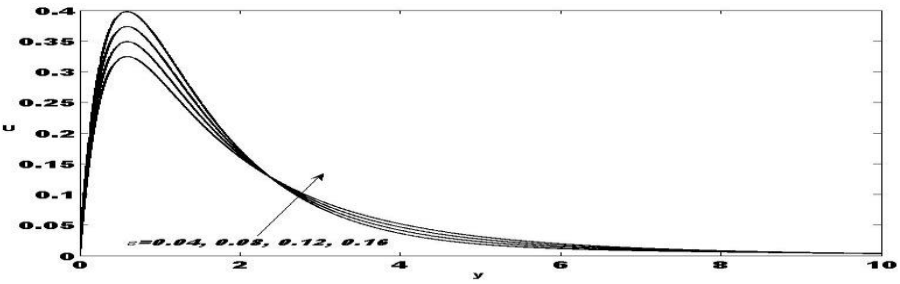

Fig10: Velocity profiles for different values of epsilon

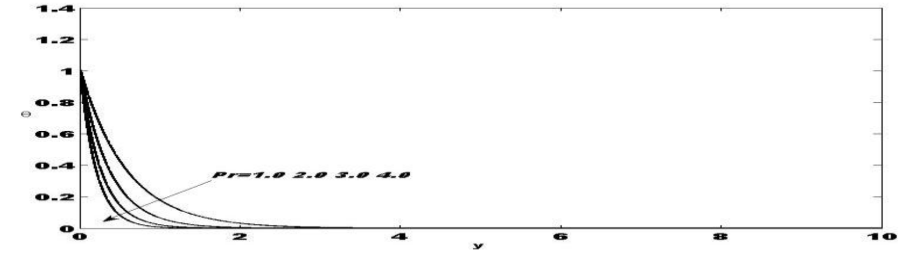

Fig11: Temperature profiles for different values of Prandtl number

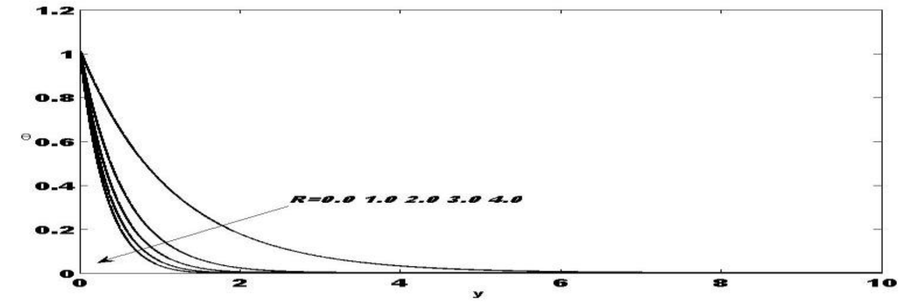

Fig12: Temperature profiles for different values of Radiation parameter

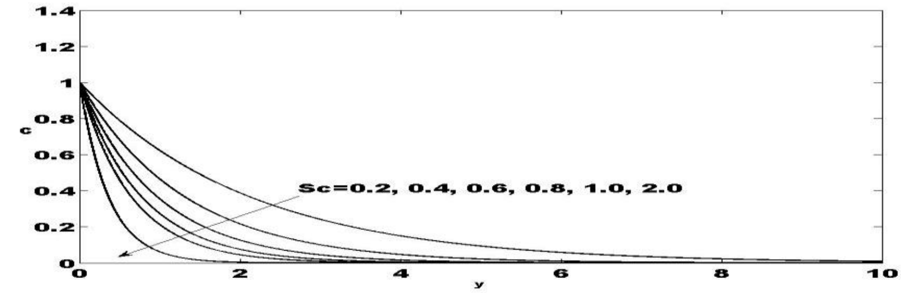

Fig13: Concentration profiles for different values of Schmidtl number

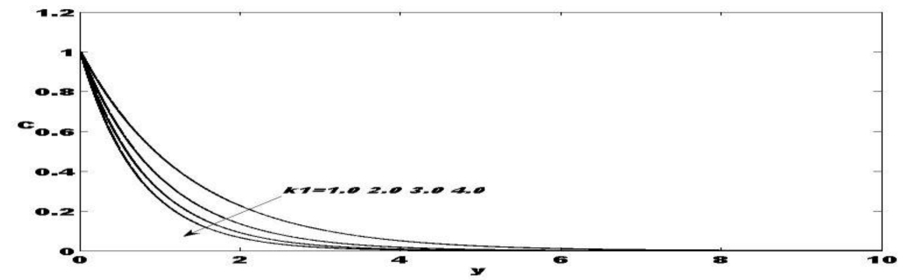

Fig14: Concentration profiles for different values of Chemical reaction parameter

Table 1: shows the effects of the solutal Grashof number Gc, thermal Grashof number Gr, Hartmann number M . Radiation parameter R, Prandtl number Pr, Schmidit number Sc ,viscoelastic parameter K, chemical reaction parameter k_1 and Reynold number on the skin-friction coefficient C_f , Sherwood number S_h and Nusselt number N_u .

M	*Sc*	*Pr*	*Gr*	Gc	K_1	*K*	*R*	*Rm*	C_f	*Nu*	*Sh*
5.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.05	0.7866	-3.537	-0.477
6.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.05	1.1926	-3.537	-0.477
7.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.05	2.1168	-3.537	-0.477
8.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.05	5.8322	-3.537	-0.477
5.0	0.3	0.71	1.0	2.0	0.3	0.1	5.0	0.05	0.7512	-3.537	-0.626
5.0	0.4	0.71	1.0	2.0	0.3	0.1	5.0	0.05	0.7212	-3.537	-0.764
5.0	0.5	0.71	1.0	2.0	0.3	0.1	5.0	0.05	0.6944	-3.537	-0.895
5.0	0.2	0.81	1.0	2.0	0.3	0.1	5.0	0.05	0.7144	-3.599	-0.477
5.0	0.2	0.91	1.0	2.0	0.3	0.1	5.0	0.05	0.6518	-3.663	-0.477
5.0	0.2	1.01	1.0	2.0	0.3	0.1	5.0	0.05	0.5971	-3.728	-0.477
5.0	0.2	0.71	2.0	2.0	0.3	0.1	5.0	0.05	1.6802	-3.537	-0.477
5.0	0.2	0.71	3.0	2.0	0.3	0.1	5.0	0.05	2.5737	-3.537	-0.477
5.0	0.2	0.71	4.0	2.0	0.3	0.1	5.0	0.05	3.4673	-3.537	-0.477
5.0	0.2	0.71	1.0	3.0	0.3	0.1	5.0	0.05	3.4138	-3.537	-0.477
5.0	0.2	0.71	1.0	4.0	0.3	0.1	5.0	0.05	3.3603	-3.537	-0.477
5.0	0.2	0.71	1.0	5.0	0.3	0.1	5.0	0.05	3.3068	-3.537	-0.477
5.0	0.2	0.71	1.0	2.0	0.4	0.1	5.0	0.05	3.4178	-3.537	-0.527
5.0	0.2	0.71	1.0	2.0	0.5	0.1	5.0	0.05	3.3735	-3.537	-0.571
5.0	0.2	0.71	1.0	2.0	0.6	0.1	5.0	0.05	3.3330	-3.537	-0.612
5.0	0.2	0.71	1.0	2.0	0.3	0.2	5.0	0.05	3.5889	-3.537	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.3	5.0	0.05	3.7172	-3.537	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.4	5.0	0.05	3.8530	-3.537	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.1	6.0	0.05	2.4045	-3.833	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.1	0.7	0.05	1.8677	-4.105	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.1	0.8	0.05	1.5401	-4.360	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.06	3.5367	-3.537	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.07	3.6060	-3.537	-0.477
5.0	0.2	0.71	1.0	2.0	0.3	0.1	5.0	0.08	3.6754	-3.537	-0.477

It is observed from this table that as M increases both the Skin-friction coefficients and the Nusselt number decreases whereas the Sherwood number remain unchanged. Increases in Schmidt number effects, both the Skin-friction coefficients and the Sherwood number decreases whereas the Nusselt number remain unchanged. Increases in the Prandtl number effects, both the Skin-friction coefficients and the Nusselt number decreases but the Sherwood number remain unchanged. Increasing in thermal Grashof number results increasing the Skin-friction coefficients whereas both the Nusselts and the Sherwood numbers remain unchanged.Also, it is observed from the table that, an increasing in the solutal Grashof number decreases the Skin-friction coefficients whereas both the Nusselts and the Sherwood numbers remain unchanged. Increase in the chemical reaction parameter effects, the Skin-friction coefficients and the Sherwood number decreases and the Nusselt number remain unchanged. Increasing the porosity effects, results in increasing the Skin-friction coefficients and decreasing in Sherwood number whereas the Nusselt number remain unchanged. Increasing the radiation

parameter effects leads to a decrease in both the Skin-friction coefficients and the Nusselt number while the Sherwood number remain unchanged. It can be noted from this table that an increasing in Rm lead to an increasing in the value of the skin-friction coefficient, whereas the Nusselt number and Shrewood number remains unchanged.

IV. Conclusion

We have examined the governing equations for unsteady hydromagnetic free convective Rivlin-Ericksen and mass transfer flow through a porous medium with time dependent suction bounded by an infinite vertical plate under the influence of a uniform tranverse magnetic field. The resulting partial differential equations were transformed into a set of ordinary differential equations and solved in closed-form. Numerical evaluation of the closed-form results performed and graphical results were obtained to illustrate the details of the flow and heat and mass transfer characteristics and their dependent on some physical parameters. It is found that when the solutal and thermal Grashof numbers were increased, the buoyancy effects were enhenced and therefore, the fluid velocity increased. Radiation effects caused reduction in the fluid temperature which resulted in decreased in fluid velocity.

References

[1.] Chandrasekhara, B. C., Namboodri, P. M. S. And Hanumanthappa, A. S., (1984), " Similarity solution or buoyancy induced flows in a saturated porous medium adjacent to impermeable surface", Warme-and-Stoffubertragung, 18, Pp. 17.

[2.] Chowdhury M.K and Islam M.N, (2000). MHD free convective flow of viscoelastic fluid past an infinite vertical porous plate. Heat and mass transfer, 36 pp. 393.

[3.] Gireesh Kumar J, Satya Narayana P.V and Ramakrishna S (2009). Effects of the chemical and mass transfer on MHD unsteady free convective flow past an infinite vertical plate with constant suction and heat sink. Ultra Science, 21(3), pp. 639-650.

[4.] Hossain M.N and Takhar H.S, (1996). Radiation effect on mixed convective along a vertical plate with uniform surface temperature. Heat mass transfer 31, pp. 243-248.

[5.] Ji Z, Rajagopal K.R and Szeri A.Z (1990).Multiplicity of solution in Von Karman flows of viscoelastic fluid,J Non-Newtonian Fluid Mech. 36 pp. 1-25.

[6.] Kafousias N.G and Ratis A.A (1981). Mass transfer and free convective effects on the flow past an accelerated vertical infinite plate with variable suction or injection, Rev. Roum. Sci. Techn-Mec.Apl. 26, pp11-12.

[7.] Muatafa S, Rafiuddin and Ramana Murthy M.V (2008). Unsteady MHD memory flow with oscillatory suction, variable free stream and heat source, ARPN Journal of Engineering and Applied Sciences, 3(3), pp. 17-24.

[8.] O.D. Makinde, Free-convective flow with thermal radiation and mass transfer past a moving vertical porous plate, Int. Comm Heat Mass Transfer, 32(2005) pp. 1411-1419.

[9.] Rao Rekha R and Finlayson Bruce A (1990). On the quality of viscoelastic flow solutions an adaptive refinement study of a Newtonian and a Maxwell fluid, Int. J. Numer. Methods Fluids, 11(5), pp. 571-585.

[10.] Raptis A.A and Tziyanidis G.J (1981). Viscoelastic flow past an infinite plate with suction and constant heat flux, Journal of Physics, 14(9), pp. 129.

[11.] Siddappa B and Khapate B.S (1975).Rivlin-Erickson fluid flow past stretching plate, Rev Roum. Sci, Tech. Mech. Appl, 21 pp. 497.

[12.] Rochelle S.G and Peddieson J (1980). Viscoelastic boundary-layer flow past a parabola and a paraboloid, Int. J Eng Sci. 18(6), pp. 869-874.

[13.] Sudheer Babu M and Satya Narayana P.V (2009). Effect of the chemical reaction and radiation absorption on free convective flow through porous medium with variable suction in the presence of uniform magnetic field, J. P. Journal of Heat and Mass transfer, 3 pp.219-234.

[14.] Vedhanayagam M., Jain, P. And Fairweather, G., (1987), Int. Comm. Heat mass Transfer 14, Pp. 495.