Radiation Effect on MHD Unsteady Free Convective Viscoelastic Fluid with Constant Suction and Heat Sink

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Abstract - The present study is unsteady hydromagnetic free convective memory flow of incompressible and electrically conducting fluid past an infinite vertical porous plate in the presence of radiations with constant suction and heat absorbing sink have been discussed. Approximate solutions have been derived for the mean velocity, mean temperature, mean skin-friction and mean rate of heat transfer using multi-parameter perturbation technique. The obtained results are discussed with the help of graphs to observe that the effect of various parameter like Prandtl number, Magnetic parameter and Radiation parameter.

Keywords: *Radiation, Free convection, MHD, and Viscoelastic fluid*

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I. INTRODUCTION

Free convection flow involving coupled heat and mass transfer occurs frequently in nature. It occurs not only due to temperature difference but also due to concentration difference or a combination of these two. For example in atmospheric flows there exist differences in the H_2O concentration. A few representative fields of interest in which combined heat and mass transfer plays an important role are designing of chemical processing equipment, formation and dispersion of fog, distribution of temperature and moisture over agricultural fields and groves of fruit trees, crop damage due to freezing, and environmental pollution of the environment.

An extensive study has been performed in the last few decades to get an enhanced analysis of viscoelastic fluid flow due to many practical applications which can be approximated as transport phenomena in porous media. The mechanisms of viscoelastic boundary layer flow are capitalized in various manufacturing processes such as fabrication of adhesive tapes, extrusion of plastic sheets, coating layer in rigid surfaces ect. Various blood flow problems are also explained using the viscoelastic boundary layer theory. In view of the above recently some of the authors studied by Chenna Kesavaiah and Sudhakaraiah [6] studied A note on heat transfer to magnetic field oscillatory Flow of a viscoelastic fluid. Rita chodhury and Bamdeb Dey [7] studied by flow features of a conducting Visco-elastic fluid past a vertical permeable plate.

In many rheological models the mechanical behavior has been proposed through viscoelastic fluid flow. The analysis of chemical reaction, heat and mass transfer in MHD viscoelastic fluid flows have attracted numerous scientists and engineers for the last several decades because of its fascination and importance in various technological devices and understanding the diverse cosmic phenomena and power generation of energy. This study helps to solve many biological problems. Considering the model of viscoelastic fluid, many scientists have solved problems of engineering interests viz., Nayak et.al [8] heat and mass transfer effects on MHD of viscoelastic fluid over a stretching sheet through porous medium in presence of chemical reaction, Ramana Murthy et.al [4] studied MHD unsteady free convective Walter's memory flow with constant suction and heat sink. Shanker and Kishan [2] presented the effect of mass transfer on the MHD flow past an impulsively started infinite vertical plate. The effect of magnetic field on free convective flow of electrically conducting fluids past a semi- infinite flat plate has been analyzed by Soundalgekar, [3], Mass transfer effects on MHD unsteady free convective Walter's memory flow with constant suction and heat sink studies by Gireesh Kumar and Satyanarayana [5], Saxena and Dubey [9] Unsteady MHD heat and mass transfer free convection flow of polar fluids past a vertical moving porous plate in a porous medium with heat generation, Choudhury and Dey [10] Free convective viscoelastic flow with heat and mass transfer through a porous medium with periodic permeability, Choudhury and Das [11] Viscoelastic MHD free convective flow through porous media in presence of radiation and chemical reaction with heat and mass transfer, Choudhury and Dhar [12] Effects of MHD viscoelastic fluid flow past a moving plate with double diffusive convection in presence of heat generation.

However, the interaction of radiation in an electrically conducting fluid past a moving vertical plate has received a little attention. Hence, the object of this paper is to study the thermal radiation effects on unsteady two dimensional hydro magnetic free convection flows of a viscous, incompressible fluid, constant suction and heat sink. The behavior of the mean velocity, mean temperature, mean skin-friction and mean rate of heat transfer has been discussed.

II. FORMULATION OF THE PROBLEM

Let the x-axis be taken in the vertically upward direction along the infinite vertical plate in the presence of radiation and y-axis normal to it. Neglecting the induced magnetic field and applying Boussineq's approximation, the equations of the flow is governed as:

 ISSN: 2454-4248
308 – 313

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

i.e, $v=-v_0$ (constant) (2)

$$\frac{\partial u}{\partial t}+v\,\frac{\partial u}{\partial y}=\nu\,\frac{\partial^2 u}{\partial y^2}+g\,\beta(T-T_\infty)$$
$$-B_1\left(\frac{\partial^3 u}{\partial t\,\partial y^2}+v\,\frac{\partial^3 u}{\partial y^3}\right)-\frac{\sigma B_0^2 u}{\rho} \tag{3}$$

$$\frac{\partial T}{\partial t}+v\,\frac{\partial T}{\partial y}=k\,\frac{\partial^2 T}{\partial y^2}+\frac{\nu}{C_p}\left(\frac{\partial u}{\partial y}\right)^2$$
$$-\frac{1}{\rho C_p}\frac{\partial q_r}{\partial y}+S\left(T-T_\infty\right) \tag{4}$$

On disregarding the Joulean heat dissipation, the boundary conditions for the velocity and temperature fields are

$$u=0, v=-v_0, T=T_w+\varepsilon(T_w-T_\infty)e^{i\omega t}\ at\ y=0$$
$$u=0,\ T\to T_\infty\quad as\ y\to\infty \tag{5}$$

The radiative heat flux q_r given by Equation (4), in the spirit of Cogley et al. [1], becomes

$$\frac{\partial q_r}{\partial y}=4(T-T_\infty)I \tag{6}$$

where $I=\int_0^\infty K_{\lambda w}\frac{\partial e_{b\lambda}}{\partial T^*}d\lambda,\ K_{\lambda w}-$ is the absorption coefficient at the wall and $e_{b\lambda}-$ is Planck's function, I is absorption coefficient

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

$$y^*=\frac{v_0\,y}{\nu}, t^*=\frac{t\,v_0^2}{4\nu}, \omega^*=\frac{4\nu\,\omega}{v_0^2}, u^*=\frac{u}{v_0}$$
$$\nu=\frac{\eta_0}{\rho},\qquad T^*=\frac{T-T_\infty}{T_w-T_\infty},\qquad K=\frac{K_0}{\rho C_p}$$
$$Gr=\frac{\nu\,\beta\,g(T_w-T_\infty)}{v_0^3},\quad M=\frac{\left(\sigma B_0^2/\rho\right)\nu}{V_0^3} \tag{7}$$
$$S^*=\frac{4S\nu}{v_0^2}, R_m=\frac{B_1 v_0^2}{\nu^2}\ Ec=\frac{v_0^2}{C_p(T_w-T_\infty)}$$
$$R=\frac{4\nu I}{v_0^2}, \Pr=\frac{\nu}{K}$$

where

$g,\beta,\nu,B_0,\sigma,B_1,\rho,k,\Pr,Gr,S,Ec,M,R,\ and\ R_m$

are acceleration due to gravity, kinematic visco-elasticity, kinematic viscosity, magnetic field of uniform strength, electrical conductivity, coefficient of volumetric expansion, density, thermal conductivity, specific heat at constant pressure, Prandtl number, Grashof number, Sink strength, Eckert number, Hartmann number, radiation parameter and Magnetic Reynolds number, respectively. Using equations (6) and (7), equations (3) and (4) become:

$$\frac{1}{4}\left(\frac{\partial u}{\partial t}\right)-\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+Gr\ T$$
$$-R_m\left[\frac{1}{4}\left(\frac{\partial^2 u}{\partial t\,\partial u^2}-\frac{\partial^3 u}{\partial y^3}\right)\right]-M\,u \tag{8}$$

$$\frac{\Pr}{4}\left(\frac{\partial T}{\partial t}\right)-\Pr\left(\frac{\partial T}{\partial y}\right)=\frac{\partial^2 T}{\partial y^2}+\Pr\ Ec\left(\frac{\partial u}{\partial y}\right)^2$$
$$-\Pr\left(RT\right)+\Pr\left(\frac{S\,T}{4}\right) \tag{9}$$

(After the dropping the asterisks)

The corresponding dimensionless boundary conditions are

$$u=0,\quad T=1+\varepsilon e^{i\omega t}\quad at\ y=0$$
$$u\to 0,\quad T\to 0\qquad as\ y\to\infty \tag{10}$$

To solve equations (8) and (9), we assume ω to be very small and the velocity and temperature in the neighborhood of the plate as

$$u(y,t)=u_0(y)+\varepsilon\ e^{i\omega t}\,u_1(y)$$
$$T(y,t)=T_0(y)+\varepsilon\,e^{i\omega t}\,T_1(y) \tag{11}$$

where u_0 and T_0 are mean velocity and mean temperature.

III. SOLUTION OF THE PROBLEM

Substituting (11) in equations (8) and (9), equating harmonic and non-harmonic terms for mean velocity and mean temperature, after neglecting higher order terms of coefficient of $o\left(\varepsilon^2\right)$, we get

$$R_m u_0'''+u_0''+u_0'-Mu_0=-Gr\,T_0 \tag{12}$$
$$T_0''+\Pr T_0'+\Pr T_0 N_1=-\Pr Ec\left(u_0'\right)^2 \tag{13}$$
$$R_m u_1'''+u_1''N_3+u_1'-u_1\,N_4=-Gr\,T_1 \tag{14}$$
$$T_1''+\Pr T_1'+\Pr T_1 N_2=-2\Pr Ec\ u_0'\ u_1' \tag{15}$$

where $N_1=\left(\frac{S}{4}-R\right), N_2=\left(\frac{S}{4}-R-\frac{i\omega}{4}\right),$

$N_3=\left(\frac{R_m i\omega}{4}-1\right)$ and $N_4=\left(M+\frac{i\omega}{4}\right)$

The equation (12) is third order differential equation due to presence of elasticity. Therefore u_0 is expanded using Beard and Walters rule [1].

$$u_{00}=u_{00}+R_m u_{01} \tag{16}$$

 ISSN: 2454-4248
308 – 313

Zero-order of R_m

$$u''_{00}+u'_{00}-Mu_{00}=-Gr\,T_0 \tag{17}$$

First-order of R_m

$$u''_{01}+u'_{01}-Mu_{01}=-u'''_0 \tag{18}$$

Using multi parameter perturbation technique and assuming $Ec<<1$, we write

$$\begin{aligned} u_{00}(y)&=u_{000}(y)+Ec\,u_{001}(y)\\ u_{01}(y)&=u_{011}(y)+Ec\;u_{012}(y)\\ T_{00}(y)&=T_{000}(y)+Ec\,T_{001}(y)\end{aligned} \tag{19}$$

Substituting (19) in Equations (13) -(17) and (18) equating the coefficients of Ec^0 and Ec^1 and neglecting the terms in Ec^2 and higher order, we get the following equations.

The zero order of Ec

$$u''_{000}+u'_{000}-Mu_{000}=-Gr\,T_{00} \tag{20}$$

$$u''_{011}+u'_{011}-Mu_{011}=-u'''_{000} \tag{21}$$

$$T''_{000}+\Pr T'_{000}+N_1T_{000}=0 \tag{22}$$

First zero order of Ec

$$u''_{001}+u'_{001}-Mu_{001}=-GrT_{01} \tag{23}$$

$$u''_{012}+u'_{012}-Mu_{012}=-u'''_{001} \tag{24}$$

$$T''_{001}+\Pr T'_{001}+N_1T_{001}=-\Pr\left(u'_{011}\right)^2 \tag{25}$$

where prime denotes ordinary differentiation with respect to y.

The corresponding dimensionless boundary conditions are

$$\left.\begin{aligned} &u_{000}=u_{001}=u_{011}=u_{012}=0\\ &T_{000}=1,\qquad T_{001}=0\end{aligned}\right\}\ at\ \ y=0$$
$$\left.\begin{aligned} &u_{000}=u_{001}=u_{011}=u_{012}=0\\ &T_{000}=1,\qquad T_{001}=0\end{aligned}\right\}\ at\ \ y\to\infty \tag{26}$$

Solving these differential equations from (20) - (25), using boundary conditions (26), and then making use of equations (19).

Finally with the help of equation (16), we obtain the mean velocity u_0 and mean temperature T_0 as follows

$$\begin{aligned} u_0 &= A_1\left(e^{m_2y}-e^{m_1y}\right)+Ec\left\{A_{19}e^{m_2y}+A_{12}e^{m_1y}\right.\\ &+A_{13}e^{2m_2y}+A_{14}e^{2m_2y}+A_{15}e^{2m_1y}+A_{16}e^{2m_2y}\\ &\left.+A_{17}e^{(m_1+m_2)y}+A_{18}e^{(m_1+m_2)y}\right\}\\ &+R_m\left[\left(A_4e^{m_2y}+A_2e^{m_2y}+A_3e^{m_1y}\right)\right.\\ &+Ec\left\{A_{28}e^{m_2y}+A_{20}e^{m_2y}\right.\\ &+A_{21}e^{m_1y}+A_{22}e^{2m_2y}+A_{23}e^{2m_2y}+A_{24}e^{2m_1y}\\ &\left.\left.+A_{25}e^{2m_2y}+A_{26}e^{(m_1+m_2)y}+A_{27}e^{(m_1+m_2)y}\right\}\right]\end{aligned}$$

$$\begin{aligned} T_0 &= e^{m_1y}+Ec\left\{A_{11}e^{m_1y}+A_5e^{2m_2y}+A_6e^{2m_2y}+A_7e^{2m_1y}\right.\\ &\left.+A_8e^{2m_2y}+A_9e^{(m_1+m_2)y}+A_{10}e^{(m_1+m_2)y}\right\}\end{aligned}$$

Mean Skin-Friction:

The mean skin friction at the plate in dimensionless form is given by

$$\tau_\omega{}^m=\left(\frac{\partial u_0}{\partial y}\right)_{y=0}=u'_o(0)$$

$$\begin{aligned} &=A_1\left(m_2e^{m_2y}-m_1e^{m_1y}\right)+Ec\left\{A_{19}m_2e^{m_2y}+A_{12}m_1e^{m_1y}\right.\\ &+2A_{13}m_2e^{2m_2y}+2A_{14}m_2e^{2m_2y}+2A_{15}m_1e^{2m_1y}+2m_2A_{16}e^{2m_2y}\\ &\left.+A_{17}(m_1+m_2)e^{(m_1+m_2)y}+A_{18}(m_1+m_2)e^{(m_1+m_2)y}\right\}\\ &+R_m\left[\left(A_4m_2e^{m_2y}+A_2m_2e^{m_2y}+A_3m_1e^{m_1y}\right)\right.\\ &+Ec\left\{A_{28}m_2e^{m_2y}+A_{20}m_2e^{m_2y}+A_{21}m_1e^{m_1y}\right.\\ &+2A_{22}m_2e^{2m_2y}+2A_{23}m_2e^{2m_2y}+2A_{24}m_1e^{2m_1y}\\ &+2A_{25}m_2e^{2m_2y}+A_{26}(m_1+m_2)e^{(m_1+m_2)y}\\ &\left.\left.+A_{27}(m_1+m_2)e^{(m_1+m_2)y}\right\}\right]\end{aligned}$$

Mean Rate of Heat Transfer

Similarly, the mean rate of heat transfer at the plate is given by

$$q_\omega{}^m=\left(\frac{\partial T_0}{\partial y}\right)_{y=0}=T'_o(0)$$

$$\begin{aligned} &=m_1e^{m_1y}+Ec\left\{A_{11}m_1e^{m_1y}+2A_5m_2e^{2m_2y}+2A_6m_2e^{2m_2y}\right.\\ &+2A_7m_1e^{2m_1y}+2m_2A_8e^{2m_2y}+A_9(m_1+m_2)e^{(m_1+m_2)y}\\ &\left.+A_{10}(m_1+m_2)e^{(m_1+m_2)y}\right\}\end{aligned}$$

IV. RESULTS AND DISCUSSION:

In order to discuss the effect of various physical parameters on the mean velocity field, thermal boundary layer, mean skin friction and mean rate of heat transfer on the wall, the numerical computation of the solutions, have been carried out and they are represented in figures (1) – (6). The values of Prandtl number (Pr) are taken as 0.025, 1.0 and 7.0, which physically corresponds to mercury, electrolyte solution and water respectively. The numerical values of the mean rate of heat transfer and mean skin-friction are computed for different parameters such as the magnetic parameter and heat sink parameter. The purpose of the calculations given here is to assess the effects of the parameters Gr, R, M and Pr upon the nature of the flow and transport. The solutions are in terms of exponential.

Mean Velocity:

The mean velocity profiles for different values of the radiation parameter (R) are shown in figure (1). It is observed that the mean velocity increases with increasing the radiation parameter. The effect of magnetic field (M) on velocity profiles in the boundary layer is depicted in figure (2). From this figure it is seen that the velocity starts from minimum value of zero at the surface and increases till it attains the peak value and then starts decreasing until it reaches to the minimum value at the end of the boundary layer for all the values of magnetic field parameter. It was also clear from figure (2) that the mean velocity was greater for mercury (Pr=0.025) than that of electrolyte (Pr=1.0).

Mean temperature:

Figure (3) is obtained from the flow solution for flow parameter free convection parameter affect the fluid flow. Evidently, the mean temperature increases steadily with increase in the material Grashof parameter (Gr), reaches a maximum and then decreases to zero at the edge of the boundary layer. Also, the mean temperature profiles exhibit large overshoots for increasing values of the parameters. In general, the mean temperature distribution in the layer tends asymptotically to a similarity form. Figure (4) displays the evolution of mean temperature due to variations in radiation parameter (R). It is observed that increase in radiation parameter decreases the mean temperature exponentially. This is because large values of radiation parameter correspond to an increase in dominance of conduction over radiation, thereby decreasing the buoyancy force and the thickness of the thermal boundary layer. Consequently, these parameters produce an inward flow of heating that accelerates the flux of heat to the plate. The effect of Prandtl number on mean temperature may be analyzed from the figure (5). It is inferred that the thickness of thermal boundary layer is greater for mercury (Pr = 0.025) and there is more uniform temperature distribution across the thermal boundary layer as compared to water (Pr = 7.0) and electrolyte solution (Pr = 1.0). It is observed that the increase of Prandtl number results in the decrease of mean temperature distribution. The reason is that smaller values of Prandtl number are equivalent to increasing thermal conductivity and therefore heat is able to diffuse away from the heated surface more rapidly than for higher values of Prandtl number. Thus mean temperature falls more rapidly for water, mercury and electrolyte solution. The maximum of the temperature occur in the vicinity of the plate and asymptotically approaches to zero in the free convection region.

Table-1 showed the mean skin-friction for mercury and electrolytic solution. It was noticed that the increase in magnetic field strength decreases the mean skin-friction, for both mercury and electrolytic solution. Similar effect noted in sink strength. Table-2 showed the mean rate of heat transfer for mercury and electrolytic solution. It was observed that the mean rate of heat transfer decreases with the increase in magnetic field strength or sink strength for both mercury and electrolytic solution.

Table -1: Values of mean skin-friction $\tau_{\omega}{}^{m}$ for fixed values of Gr = 5.0, Ec = 0.001 and ω = 5.0

Pr	M	S	$\tau_{\omega}{}^{m}$
Mercury $(\mathrm{Pr}=0.025)$	1.0	-0.05	2.82549
	5.0	-0.05	1.44254
	5.0	-0.10	1.65141
Electrolytic solution $(\mathrm{Pr}=1.0)$	1.0	-0.05	7.42351
	5.0	-0.05	2.72543
	5.0	-0.10	2.61941

Table – 2: Values of mean rate of heat transfer $q_{\omega}{}^{m}$ for fixed values of Gr = 5.0, Ec = 0.001 and ω = 5.0

Pr	M	S	$q_{\omega}{}^{m}$
Mercury $(\mathrm{Pr}=0.025)$	1.0	-0.05	-0.0458
	5.0	-0.05	-0.0558
	5.0	-0.10	-0.0652
Electrolytic solution $(\mathrm{Pr}=1.0)$	1.0	-0.05	-0.8956
	5.0	-0.05	-1.0269
	5.0	-0.10	-1.0456

V. CONCLUSIONS

The following conclusions are made in this paper:

- It is observed that, the velocity increases with increasing values of the radiation parameter.
- However, the mean temperature decreases with an increasing radiation parameter.
- Mean velocity and mean temperature are shown graphically for various parameters like Grashof number, Prandtl number, Magnetic parameter and radiation parameter

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APPENDIX

$$m_1=-\left(\frac{\mathrm{Pr}+\sqrt{\mathrm{Pr}^2-4N_1}}{2}\right),\qquad m_2=-\left(\frac{1+\sqrt{1+4M}}{2}\right)$$

$$N_1=\left(\frac{S}{4}-R\right), N_2=\left(\frac{S}{4}-R-\frac{i\omega}{4}\right), N_3=\left(\frac{Rm}{4}i\omega-1\right)$$

$$N_4=\left(M+\frac{i\omega}{4}\right),\quad A_1=-\frac{Gr}{m_1^2+m_1-M}$$

$$A_2=-\frac{A_1 m_2^3}{m_2^2+m_2-M},\quad A_3=-\frac{A_1 m_1^3}{m_2^2+m_2-M}$$

$$A_4=-\left(A_2+A_3\right),\ A_5=-\frac{A_4^2}{4m_2^2+2\Pr m_2+N_1}$$

$$A_6=-\frac{A_2^2}{4m_2^2+2\Pr m_2+N_1}, A_7=-\frac{A_3^2}{4m_1^2+2\Pr m_1+N_1}$$

$$A_8=-\frac{2A_2A_4}{\left(m_1+m_2\right)^2+\Pr\left(m_1+m_2\right)+N_1}$$

$$A_9=-\frac{2A_2A_3}{\left(m_1+m_2\right)^2+\Pr\left(m_1+m_2\right)+N_1}$$

$$A_{10}=-\frac{2A_3A_4}{\left(m_1+m_2\right)^2+\Pr\left(m_1+m_2\right)+N_1}$$

$$A_{11}=-\left(A_5+A_6+A_7+A_8+A_9+A_{10}\right)$$

$$A_{12}=-\frac{GrA_{11}}{m_1^2+m_1-M}, A_{13}=-\frac{GrA_5}{4m_2^2+2m_2-M}$$

$$A_{14}=-\frac{GrA_6}{4m_2^2+2m_2-M}, A_{15}=-\frac{GrA_7}{4m_1^2+2m_1-M}$$

$$A_{16}=-\frac{GrA_8}{\left(m_1+m_2\right)^2+\left(m_1+m_2\right)-M}$$

$$A_{17}=-\frac{GrA_9}{\left(m_1+m_2\right)^2+\left(m_1+m_2\right)-M}$$

$$A_{18}=-\frac{GrA_{10}}{\left(m_1+m_2\right)^2+\left(m_1+m_2\right)-M}$$

$$A_{19}=-\left(A_{12}+A_{13}+A_{14}+A_{15}+A_{16}+A_{17}+A_{18}\right)$$

$$A_{20}=-\frac{m_2^3A_{19}}{m_2^2+m_2-M}, A_{21}=-\frac{m_1^3A_{12}}{m_1^2+2m_1-M}$$

$$A_{22}=-\frac{8m_2^3A_{13}}{4m_2^2+2m_2-M}, A_{23}=-\frac{8m_1^3A_{14}}{4m_1^2+2m_1-M}$$

$$A_{24}=-\frac{8m_1^3A_{15}}{4m_1^2+2m_1-M}, A_{25}=-\frac{2m_2^3A_{16}}{2m_2^2+2m_2-M}$$

$$A_{26}=-\frac{\left(m_1+m_2\right)^3A_{17}}{\left(m_1+m_2\right)^2+\left(m_1+m_2\right)-M}$$

$$A_{27}=-\frac{\left(m_1+m_2\right)^3A_{18}}{\left(m_1+m_2\right)^2+\left(m_1+m_2\right)-M}$$

$$A_{28}=-\left(A_{20}+A_{21}+A_{22}+A_{23}+A_{24}+A_{25}+A_{26}+A_{26}+A_{27}\right)$$

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REFERENCES

[1] A C Cogley W G Vincenti S E and Gill: "Differential approximation for radiative transfer in a non-gray-gas near equilibrium", AIAA, J., Vol. 6, pp.551-555, 1968

[2] B Shanker and N Kishan: "The effects of mass transfer on the MHD flow past an impulsively started infinite vertical plate with variable temperature or constant heat flux", J. Engg. Heat Mass Transfer, Vol. 19, pp.273-278, 1997

[3] V M Soundalgekar and M R Patil: "Stokes problem for a vertical plate with constant heat flux", Astrophys. Space Sci. Vol.70, pp.179-182, 1980

[4] M V Ramana Murthy, G Noushima Humera, M Rafiuddin and M Chenna Krishan Reddy: "MHD unsteady free convective Walter's memory flow with constant suction and heat sink", ARPN Journal of Engineering and Applied Sciences, Vol. 2 (5), pp.12-16, 2007

[5] J Gireesh Kumar and P V Satyanarayana: "Mass transfer effects on MHD unsteady free convective Walter's memory flow with constant suction and heat sink", Int. J. of Appl. Math and Mech. **7** (19): pp. 97-109, 2011

[6] D Chenna Kesavaiah and A Sudhakaraiah: "A note on heat transfer to magnetic field oscillatory flow of a viscoelastic fluid", International Journal of Science, Engineering and Technology Research, Volume 2, (5), pp. 1007-1012, 2013

[7] Rita Chodhury and Bamdeb Dey: "Flow features of a conducting viscoelastic fluid past a vertical permeable plate", Global Journal of Pure and Applied Mathematics, Vol. 13 (9), pp. 5687-5702, 2017

[8] M K Naya, G C Dash and L P Singh: "Heat and mass transfer effects on MHD of viscoelastic fluid over a stretching sheet through porous medium in presence of chemical reaction", Propulsion and Power Research, Vol 5 (1), pp. 70-80, 2017

[9] S S Saxena and G K Dubey: "Unsteady MHD heat and mass transfer free convection flow of polar fluids past a vertical moving porous plate in a porous medium with heat generation", Advances in Applied Science Research, Vol. 2 (4), pp. 259-278, 2011

[10] R Choudhury and D Dey: "Free convective viscoelastic flow with heat and mass transfer through a porous medium with periodic permeability" International journal of heat and mass transfer, Vol 53, pp. 1666-1672, 2010

[11] R Choudhury and S Das: "Viscoelastic MHD free convective flow through porous media in presence of radiation and chemical reaction with heat and mass transfer", Journal of Applied Fluid Mechanics, Vol. 7 (4), pp. 603-609, 2014

[12] R Choudhury and P Dhar: "Effects of MHD viscoelastic fluid flow past a moving plate with double diffusive convection in presence of heat generation" WSEAS Transaction on Fluid Mechanics, Vol. 9, pp. 196-205, 2014

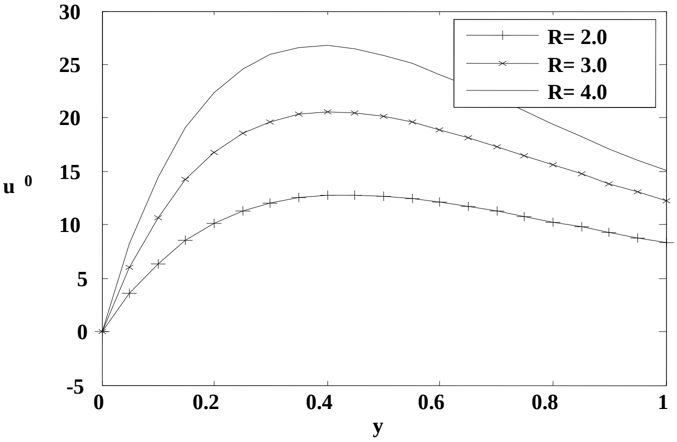

Figure 1. Effect of R on Mean velocity profiles

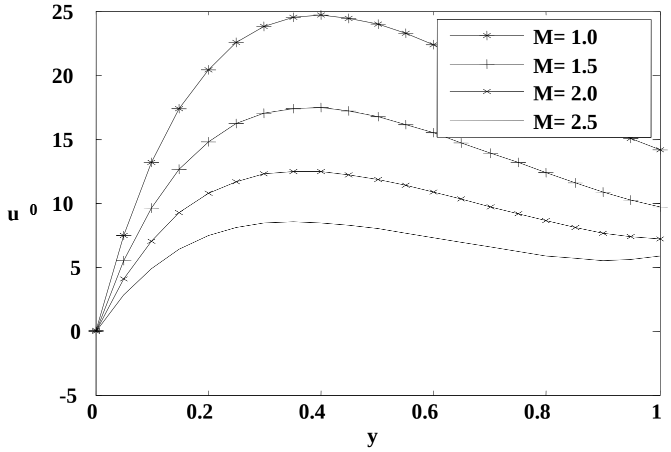

Figure 2. Effect of M on Mean velocity profiles

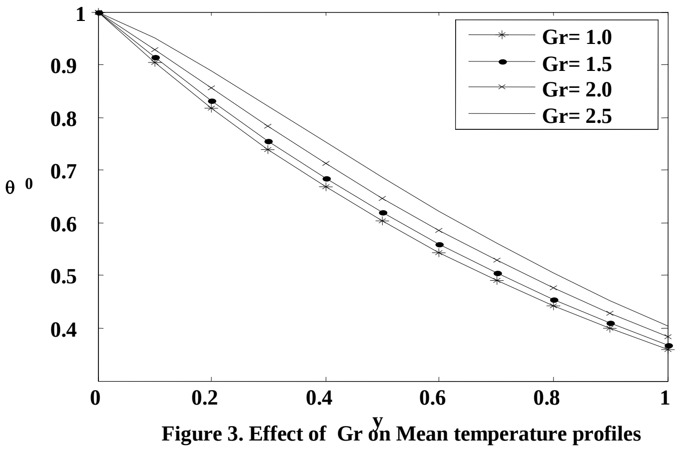

Figure 3. Effect of Gr on Mean temperature profiles

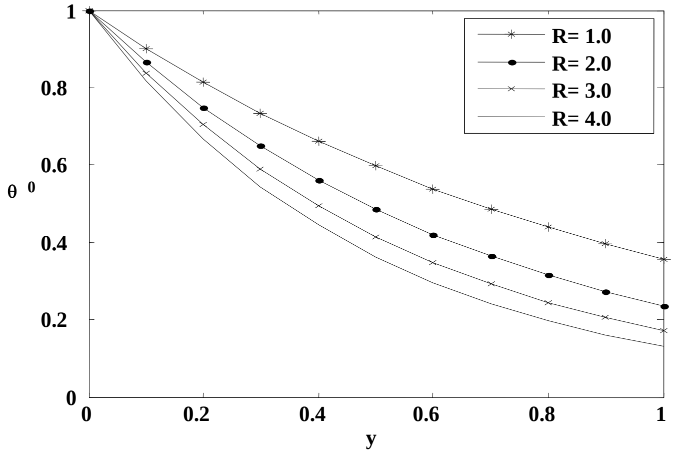

Figure 4. Effect of R on Mean temperature profiles

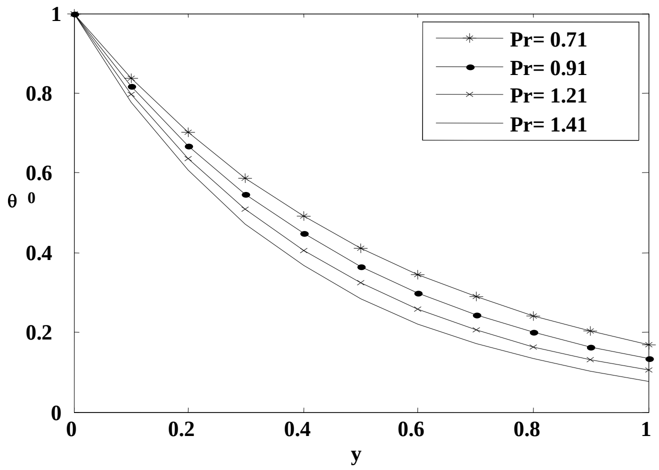

Figure 5. Effect of Pr on Mean temperature profiles