International Journal of
Energy & Technology
www.journal-enertech.eu
ISSN 2035-911X
International Journal of Energy & Technology 5 (7) (2013) 1–8

MHD DOUBLE DIFFUSIVE AND CHEMICALLY REACTIVE FLOW THROUGH POROUS MEDIUM BOUNDED BY TWO VERTICAL PLATES

V. RAVIKUMAR[1], M.C. RAJU[1], G.S.S. RAJU[2], A.J. CHAMKHA[3]

[1]Department of Mathematics, Annamacharya Institute of Technology and Sciences, (Autonomous), Rajampet- 516126, A.P, India. Email: vrkmaths1975@yahoo.in, mcrmaths@yahoo.co.in
[2]Department of Mathematics, JNTUA College of Engineering Pulivendula, Pulivendula, A.P, India. Email: rajugss@yahoo.com
[3]Manufacturing Engineering Department, Public Authority for Applied Education and Training, Shuweikh, 70654 Kuwait. Email: achamkha@yahoo.com

ABSTRACT

In this paper, a two dimensional steady free convective and mass transfer flow of an electrically conducting, viscous fluid through a porous medium bounded by two stationary infinite vertical porous plates in presence of thermo diffusion and chemical effect has been studied. A uniform magnetic field is assumed to be applied transversely to the direction of the flow. The plates are subjected to a constant normal suction/injection velocity. The governing equations are solved by regular perturbation technique. The expressions for the velocity field, temperature field, species concentration, skin friction and the coefficient of heat transfer (in terms of Nusselt number) at the walls are obtained and their numerical values are demonstrated in graphs. The effects of Hartmann number M, the Reynolds number Re, Schmidt number Sc and permeability parameter k on the flow and mass transfer are discussed.

Keywords: MHD, thermo diffusion, chemical reaction, skin friction, Nusselt number, suction and injection.

1. INTRODUCTION

Study of combined effect of heat and mass transfer through porous medium has been attracting the attention of many researchers due to its applications in engineering and science such as drying of porous solids, thermal insulation, cooling of nuclear reactors and underground energy transport [1]. Ling et al. [2] presented steady mixed convection boundary layer flow over a vertical flat plate in a porous medium filled with water at 4^oC: cases of variable wall temperature. The problem of free and forced convection and mass transfer flow past a porous plate has been studied by many authors [3-7]. There has been a renewed interest in studying the magneto hydrodynamic flow and heat and mass transfer effect on an electrically conducting fluid past a porous plate such as MHD pumps, MHD bearings and MHD generators. Kim [8] investigated the unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction. Chamkha and Khaled [9] have studied hydromagnetics combined heat and mass transfer by natural convection from a permeable surface embedded in fluid saturated porous medium. The ionized gas or plasma can be made to interact with the magnetic and alter heat transfer and friction characteristic. The growing need for chemical reactions in chemical and hydrometallurgical industries require the study of heat and mass transfer with chemical reaction. The presence of a foreign mass in water or air causes some kind of chemical reaction. This may be present either by itself or as mixtures with air or water. In many chemical engineering processes, a chemical reaction occurs between a foreign mass and the fluid in which the plate is moving. These processes take place in numerous industrial applications, for example, polymer production, manufacturing of ceramics or glassware and food processing. Chamkha [10] presented Hydro magnetic combined heat and mass transfer by natural convection from a permeable surface embedded in a fluid saturated porous medium. Anjali Devi and Kandasamy [11] considered the effects of chemical reaction, heat and mass transfer on non-linear MHD laminar boundary layer flow over a wedge with suction and injection. Kandasamy et al. [12-13] have studied the effects of chemical reaction, heat and mass transfer along a wedge with heat source and concentration in the presence of suction or injection. Chemically reacting MHD boundary layer flow of heat and mass transfer over a moving vertical plate with suction has been considered by Ibrahim and Makinde [14]. Srinivas & Muthuraj [15] have studied MHD flow with slip effects and temperature-dependent heat source in a vertical wavy porous space. Ahmed et al. [16] have studied MHD free convective poiseuille flow and mass transfer through a porous medium bounded by two infinite vertical porous plates.

The objective of this paper is to study MHD free convection flow through porous medium bounded by two vertical porous plates in presence of thermal diffusion, constant suction and chemical reaction. Most of previous works assumed that the region is bounded by semi infinite plate. In the present work it is assumed that the fluid region is bounded by an infinite vertical plate which is at rest. It is also assumed to consider that the viscous dissipation and also the rate of heat transfer and rate of mass transfer across the boundary layer.

2. FORMULATION OF THE PROBLEM

Consider a two dimensional steady flow of a laminar free convective, viscous incompressible electrically conducting fluid past an infinite vertical porous plate, embedded in a porous medium and subjected to a transverse uniform magnetic field B_0 and a homogeneous chemical reaction. Let h be the distance between the plates. It is assumed that there is applied voltage which results the absence of electric field. The transversely applied magnetic field and magnetic Reynolds number are assumed to be very small so that the induced magnetic field and Hall currents are negligible [1]. A Cartesian coordinate system (x', y', z') is introduced with x' is taken vertically upward direction along the plate and y' is perpendicular to it, directed into the fluid region. Let $q' = u'i + v'j$ be the fluid velocity at the point (x', y', z'). Since the plates are infinite in length therefore all the physical quantities except the pressure P are independent of x'. The governing equations are based on the balances of mass, linear momentum, energy and concentration species. Taking into consideration the assumptions made above, these equations can be written as follows:

Continuity Equation

$$\frac{dv'}{dy'} = 0 \tag{1}$$

Which is satisfied with $v' = -v_0 =$ constant suction / injection.

Momentum equation

$$-v_0 \frac{du'}{dy'} = v\frac{d^2u'}{dy'^2} + g\beta(T' - T'_s) + g\beta'(C' - C'_s) - \frac{\upsilon u'}{k} - \frac{\sigma B_0^2 u'}{\rho} \tag{2}$$

Energy equation

$$-v_0 \frac{dT'}{dy'} = \frac{\lambda}{\rho c_p}\frac{d^2T'}{dy'^2} + \frac{\upsilon}{c_p}\left(\frac{du'}{dy'}\right)^2 \tag{3}$$

The species concentration equation

$$-v_0 \frac{dc'}{dy'} = D\frac{d^2c'}{dy'^2} - K_1(C' - C'_s) + D_1\frac{d^2T'}{dy'^2} \tag{4}$$

where ρ is the density, ν is the kinematic viscosity, g is the acceleration due to gravity, v_0 is the constant suction/injection velocity, β is the coefficient of volume expansion for heat transfer, β' is the coefficient of volume expansion for mass transfer, D is the chemical molecular diffusivity, D_1 is the thermal diffusivity, k is the permeability of porous medium, σ is the electrical conductivity, c_p is the specific heat at constant pressure, B_0 is the strength of applied magnetic field, T' is the temperature, T_s' is the temperature at static condition, C' is the species concentration, C_s' is the concentration at static condition and the other symbols have their usual meanings.

The relevant boundary conditions are

$$y' = 0, \quad u' = 0, \quad T' = T'_0, \quad C' = C'_0$$
$$y' = h, \quad u' = 0, \quad T' = T'_1, \quad C' = C'_1 \tag{5}$$

We introduce the following non-dimensional quantities

$$y = \frac{y'}{h}, u = \frac{u'}{v_0}, \theta = \frac{T' - T'_s}{T'_0 - T'_s}, \phi = \frac{C' - C'_s}{C'_0 - C'_s}, p_r = \frac{\mu c_p}{\lambda},$$

$$\mathrm{Re} = \frac{v_0 h}{\upsilon}, G_r = \frac{hg\beta(T'_0 - T'_s)}{v_0^2}, G_m = \frac{hg\beta'(C'_0 - C'_s)}{v_0^2},$$

$$E = \frac{v_0^2}{c_p(T'_0 - T'_s)}, Sc = \frac{v}{D}, K_1 = \frac{Kc}{h^2}, M = \frac{\sigma B_0^2 h^2}{\rho v}, \alpha = \frac{k}{h^2}$$

$$m = \frac{T'_1 - T'_s}{T'_0 - T'_s}, n = \frac{C'_1 - C'_s}{C'_0 - C'_s}, S_0 = \frac{D_1(T'_0 - T'_s)}{\upsilon(C'_0 - C'_s)}, Kc = \frac{K_1\upsilon}{v_0^2}. \tag{6}$$

where p_r is the Prandtl number, Sc the Schmidt number, Re the Reynolds number, Gr the Grashof number for heat transfer, Gm the Grashof number for mass transfer, E the Eckert number, α the permeability parameter and M is the Hartmann number, θ the dimensionless temperature, ϕ the dimensionless concentration, So the Soret number, Kc the chemical reaction parameter, m and n are the constants.

The non-dimensional governing equations and boundary conditions are

$$-\frac{du}{dy} = \frac{1}{\mathrm{Re}}\frac{d^2u}{dy^2} + G_r\theta + G_m\phi - \frac{u}{\mathrm{Re}\,\alpha} - M\,\mathrm{Re}\,u \tag{7}$$

$$-\frac{d\theta}{dy} = \frac{1}{\mathrm{Re}\,p_r}\frac{d^2\theta}{dy^2} + \frac{E}{\mathrm{Re}}\left(\frac{du}{dy}\right)^2 \tag{8}$$

$$-\frac{d\phi}{dy} = \frac{1}{\mathrm{Re}\,Sc}\frac{d^2\phi}{dy^2} - K\,\mathrm{Re}\,\phi + \frac{S_0}{\mathrm{Re}}\frac{d^2\theta}{dy^2} \tag{9}$$

Subject to the boundary conditions

$$y = 0, \quad u = 0, \quad \theta = 1, \quad \phi = 1$$
$$y = 1, \quad u = 0, \quad \theta = m, \quad \phi = n \tag{10}$$

3. SOLUTION OF THE PROBLEM

In order to solve the set partial differential equations (7) to (9) in non-dimensional form subject to boundary conditions (10), we assumed the velocity, temperature and concentration in a series expansion in powers of E where E<<1 as given below.

$$u = u_0(y) + Eu_1(y) + O(E^2) \tag{11}$$

$$\theta = \theta_0(y) + E\theta_1(y) + O(E^2) \tag{12}$$

$$\phi = \phi_0(y) + E\phi_1(y) + O(E^2) \tag{13}$$

Substituting equations (11) to (13) into equations (7) to (9) and equating the coefficient of similar powers of E and neglecting the higher powers of E, we obtain the following ordinary differential equations for (u_0, θ_0, ϕ_0) and (u_1, θ_1, ϕ_1).

$$u_0'' + \mathrm{Re}\,u_0' - M_1 u_0 = -G_r\,\mathrm{Re}\,\theta_0 - G_m\,\mathrm{Re}\,\phi_0 \tag{14}$$

$$\theta_0'' + \mathrm{Re}\,P_r\theta_0' = 0 \tag{15}$$

$$\phi_0'' + \mathrm{Re}\,Sc\phi_0' - Kc\,\mathrm{Re}^2\,S\phi_0 = -S_0 Sc\theta_0'' \tag{16}$$

$$u_1^{//} + \operatorname{Re} u_1^{/} - M_1 u_1 = -G_r \operatorname{Re} \theta_1 - G_m \operatorname{Re} \phi_1 \quad (17)$$

$$\theta_1^{//} + \operatorname{Re} P_r \theta_1^{/} = -P_r u_0^{/^2} \quad (18)$$

$$\phi_1^{//} + \operatorname{Re} Sc \phi_1^{/} - Kc \operatorname{Re}^2 S \phi_1 = -S_0 Sc \theta_1^{//} \quad (19)$$

where $M_1 = \frac{1}{k} + MR^2$ and prime denotes the differentiation with respect to 'y'.

The boundary conditions (10) reduce to

$$\begin{aligned} &at\ y = 0 : u_0 = 0, \theta_0 = 1, u_1 = 0, \theta_1 = 0, \phi_0 = 1, \phi_1 = 0 \\ &at\ y = 1 : u_0 = 0, \theta_0 = m, u_1 = 0, \theta_1 = 0, \phi_0 = n, \phi_1 = 0 \end{aligned} \quad (20)$$

Solving equations (14) to (19) w. r. t the boundary conditions (20), we obtain the following solutions

$$\theta_0 = c_1 + c_2 e^{-k_1 y} \quad (21)$$

$$\phi_0 = c_3 e^{-m_1 y} + c_4 e^{-m_2 y} + k_3 e^{-k_1 y} \quad (22)$$

$$\begin{aligned} u_0 = c_5 e^{-m_3 y} + c_6 e^{-m_4 y} + k_8 + k_9 e^{-k_1 y} \\ + k_{10} e^{-m_1 y} + k_{11} e^{-m_2 y} + k_{12} e^{-k_1 y} \end{aligned} \quad (23)$$

$$\begin{aligned} \theta_1 = c_7 + c_8 e^{-k_1 y} + k_{15} e^{-2m_3 y} + k_{16} e^{-2m_4 y} \\ + k_{17} e^{-2k_1 y} + k_{18} e^{-2m_1 y} + k_{19} e^{-2m_2 y} \\ + k_{20} e^{-2k_1 y} + k_{21} e^{-(m_3+m_4)y} + k_{22} e^{-(m_4+k_1)y} \\ + k_{23} e^{-(m_3+k_1)y} + k_{24} e^{-(m_1+m_2)y} + k_{25} e^{-(m_2+k_1)y} \\ + k_{26} e^{-(m_1+k_1)y} + k_{27} e^{-(m_3+m_1)y} + k_{28} e^{-(m_3+m_2)y} \\ + k_{29} e^{-(m_3+k_1)y} + k_{30} e^{-(m_4+m_1)y} + k_{31} e^{-(m_4+m_2)y} \\ + k_{32} e^{-(m_4+k_1)y} + k_{33} e^{-(m_1+k_1)y} + k_{34} e^{-(m_2+k_1)y} + k_{35} e^{-2k_1 y} \end{aligned} \quad (24)$$

$$\begin{aligned} \phi_1 = c_9 e^{-m_1 y} + c_{10} e^{-m_2 y} + k_{39} e^{-k_1 y} + k_{40} e^{-2m_3 y} \\ + k_{41} e^{-2m_4 y} + k_{42} e^{-2k_1 y} + k_{43} e^{-2m_1 y} + k_{44} e^{-2m_2 y} \\ + k_{45} e^{-2k_1 y} + k_{46} e^{-(m_3+m_4)y} + k_{47} e^{-(m_4+k_1)y} \\ + k_{48} e^{-(m_3+k_1)y} + k_{49} e^{-(m_1+m_2)y} + k_{50} e^{-(m_2+k_1)y} \\ + k_{51} e^{-(m_1+k_1)y} + k_{52} e^{-(m_3+m_1)y} + k_{53} e^{-(m_3+m_2)y} \\ + k_{54} e^{-(m_3+k_1)y} + k_{55} e^{-(m_4+m_1)y} + k_{56} e^{-(m_4+m_2)y} \\ + k_{57} e^{-(m_4+k_1)y} + k_{58} e^{-(m_1+k_1)y} + k_{59} e^{-(m_2+k_1)y} + k_{60} e^{-2k_1 y} \end{aligned} \quad (25)$$

$$\begin{aligned} u_1 = c_{11} e^{-m_3 y} + c_{12} e^{-m_4 y} + k_{63} + k_{64} e^{-k_1 y} + k_{65} e^{-2m_3 y} \\ + k_{66} e^{-2m_4 y} + k_{67} e^{-2k_1 y} + k_{68} e^{-2m_1 y} + k_{69} e^{-2m_2 y} \\ + k_{70} e^{-2k_1 y} + k_{71} e^{-(m_3+m_4)y} + k_{72} e^{-(m_4+k_1)y} \\ + k_{73} e^{-(m_3+k_1)y} + k_{74} e^{-(m_1+m_2)y} + k_{75} e^{-(m_2+k_1)y} \\ + k_{76} e^{-(m_1+k_1)y} + k_{77} e^{-(m_3+m_1)y} + k_{78} e^{-(m_3+m_2)y} \\ + k_{79} e^{-(m_3+k_1)y} + k_{80} e^{-(m_4+m_1)y} + k_{81} e^{-(m_4+m_2)y} \\ + k_{82} e^{-(m_4+k_1)y} + k_{83} e^{-(m_1+k_1)y} + k_{84} e^{-(m_2+k_1)y} \\ + k_{85} e^{-2k_1 y} + k_{86} e^{-m_1 y} + k_{87} e^{-m_2 y} + k_{88} e^{-k_1 y} \\ + k_{89} e^{-2m_3 y} + k_{90} e^{-2m_4 y} + k_{91} e^{-2k_1 y} + k_{92} e^{-2m_1 y} \\ + k_{93} e^{-2m_2 y} + k_{94} e^{-2k_1 y} + k_{95} e^{-(m_3+m_4)y} \\ + k_{96} e^{-(m_4+k_1)y} + k_{97} e^{-(m_3+k_1)y} + k_{98} e^{-(m_1+m_2)y} \\ + k_{99} e^{-(m_2+k_1)y} + k_{100} e^{-(m_1+k_1)y} \\ + k_{101} e^{-(m_3+m_1)y} + k_{102} e^{-(m_3+m_2)y} + k_{103} e^{-(m_3+k_1)y} \\ + k_{104} e^{-(m_4+m_1)y} + k_{105} e^{-(m_4+m_2)y} + k_{106} e^{-(m_4+k_1)y} \\ + k_{107} e^{-(m_1+k_1)y} + k_{108} e^{-(m_2+k_1)y} + k_{109} e^{-2k_1 y} \end{aligned} \quad (26)$$

Coefficient of skin-friction, Nusselt number & Sherwood Number:

The skin-friction coefficient, the Nusselt number and the Sherwood number near the plate, are important physical parameters for this type of boundary-layer flow. These parameters can be defined and determined as follows:

$$\tau_0 = \frac{1}{R}\left[\frac{du}{dy}\right]_{y=0} = \frac{1}{R}\left[u_0^{/}(0) + E u_1^{/}(0)\right]$$

$$= \frac{1}{R}\left[k_{112} + E(k_{114})\right] \quad (27)$$

$$\tau_1 = \frac{1}{R}\left[\frac{du}{dy}\right]_{y=1} = \frac{1}{R}\left[u_0^{/}(1) + E u_1^{/}(1)\right]$$

$$= \frac{1}{R}\left[k_{113} + E(k_{115})\right] \quad (28)$$

$$Nu_0 = \left[\frac{d\theta}{dy}\right]_{y=0} = \theta_0^{/}(0) + E\theta_1^{/}(0)$$

$$= (-c_2 k_1) + E(k_{116}) \quad (29)$$

$$Nu_1 = \left[\frac{d\theta}{dy}\right]_{y=1} = \theta_0^{/}(1) + E\theta_1^{/}(1)$$

$$= (-c_2 k_1 e^{-k_1}) + E(k_{117}) \quad (30)$$

$$Sh_0 = \left[\frac{d\phi}{dy}\right]_{y=0} = \phi_0'(0) + E\phi_1'(0) = k_{118} + E(k_{119}) \quad (31)$$

$$Sh_1 = \left[\frac{d\phi}{dy}\right]_{y=1} = \phi_0'(1) + E\phi_1'(1) = k_{120} + E(k_{121}) \quad (32)$$

4. RESULTS AND DISCUSSION

In order to get the physical insight of the problem, numerical computations have been carried out for velocity, temperature, concentration, skin friction, Nusselt number and Sherwood number and the effects of various physical parameters on flow quantities are studied though graphs. The value of Pr is chosen as 0.71which corresponds to air respectively.

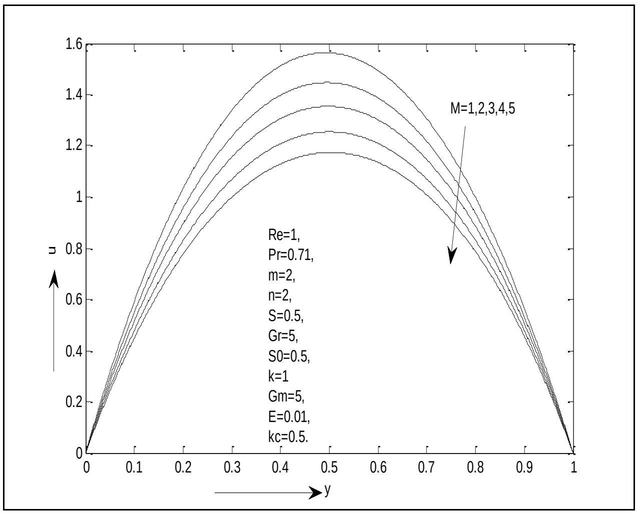

Figure 1. Velocity profiles for various values of M

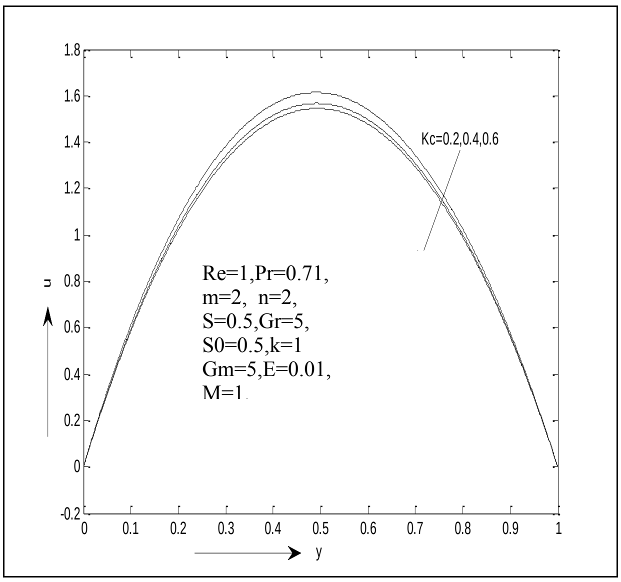

Figure 2. Velocity profiles for various values of Kc

The values of Schmidt number are chosen as 0.60, 0.78 and 0.96 which correspond to water vapour, NH_3 and CO_2 respectively. The values of Reynolds number Re, Grashof number Gr, Grashof number for mass transfer Gm, Hartmann number M, Permeability parameter k, Schmidt number Sc and Soret number So are chosen arbitrarily. The effects of other physical parameters which were previously studied by Ahmed [16], will not be repeated herein.

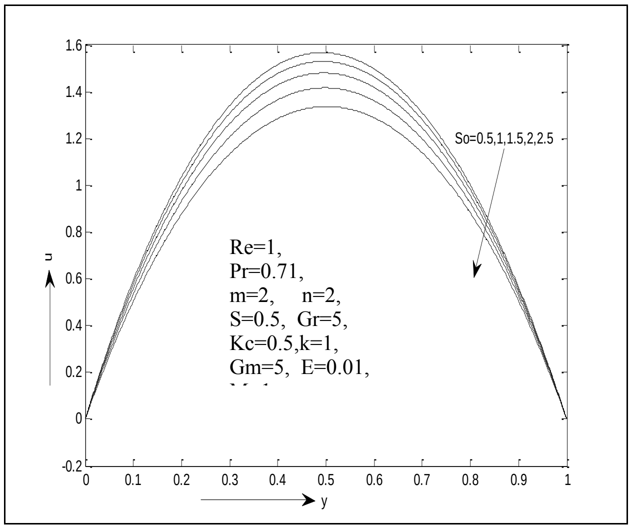

Figure 3. Velocity profiles for various values of So

Velocity profiles are displayed from Figures 1 to3. From these figures it is noticed that Velocity increase with decrease in M, Kc, So. It is due to the application of transverse magnetic field that acts as Lorentz's force which retards the flow.

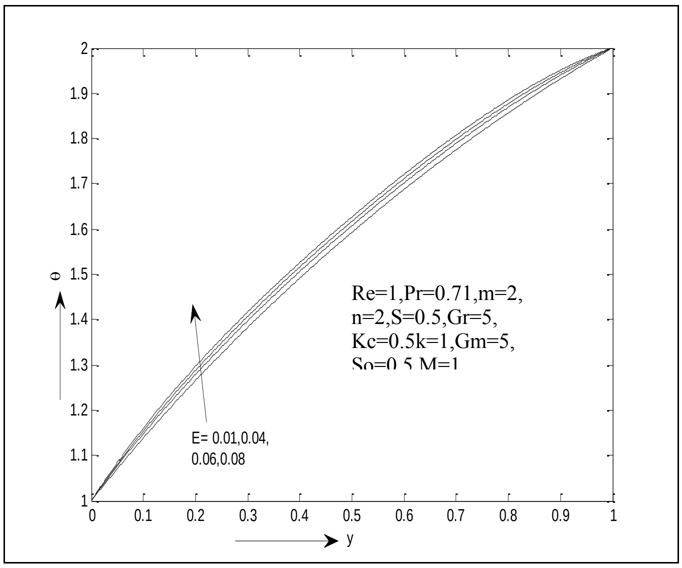

Figure 4. Temperature profiles for various values of E.

The variation of temperature under the influence of E is shown in Figures 4. From this figure it is observed that temperature decreases with an increase in E. The effects of E, Kc and So are displayed in Figures 5-7. From these figures it is observed that concentration decrease with increase in E, Kc, So.

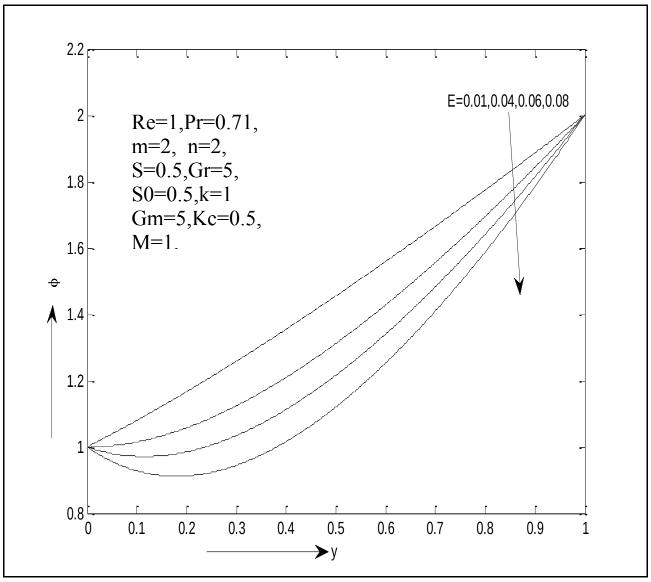

Figure 5. Concentration profiles for various values of E

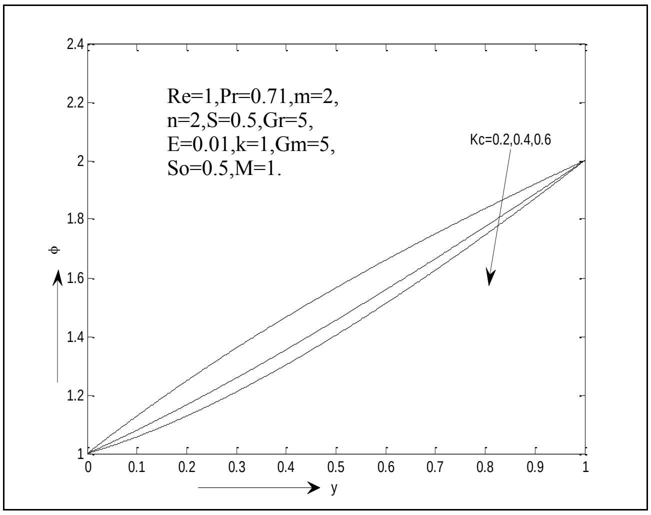

Figure 6. Concentration profiles for various values of Kc

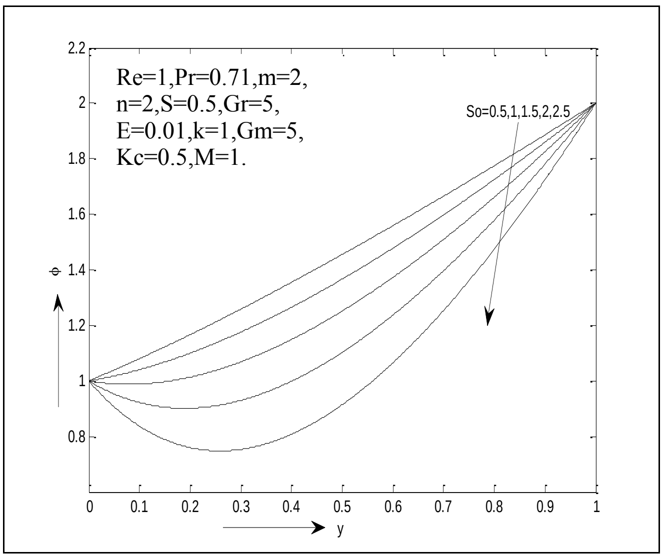

Figure 7. Concentration profiles for various values of So.

A variation in skin friction with chemical reaction parameter is displayed in figures 8-9. From these figures it is noticed that skin friction decreases with the increase in Kc. Effects of E on Nu are displayed in Figures 10-11, from these figures it is noticed that as an increase in E effects an increase in Nu near the plate y=0 and it shows the reverse effect near the plate y=1.

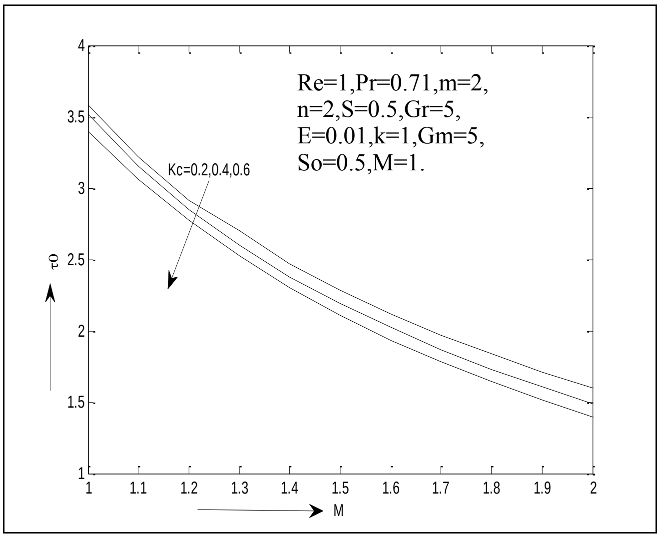

Figure 8. Coefficient of skin-friction profiles for various values of Kc

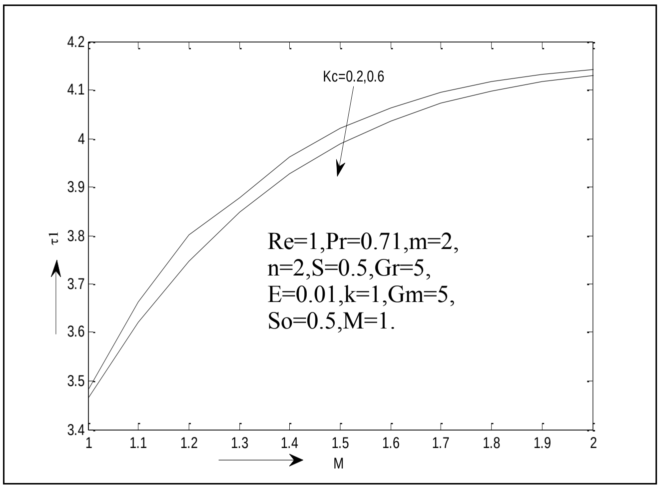

Figure 9. Coefficient of skin-friction profiles for various values of Kc

Figures 12-17 depict the effects of Kc, So and M on Sherwood number. From these figures it is observed that Sh decreases with the increase in Kc and So near the plate y=0, but it shows reverse effect at the plate y=1. Interestingly Sherwood number increases with an increase in magnetic parameter M at both ends of the plate.

5. CONCLUSION

The governing equations for MHD free convection flow through porous medium bounded by two vertical porous plates in presence of thermal diffusion, constant suction and chemical reaction is formulated. It is assumed that the fluid region is bounded by an infinite vertical plate which is at rest and the flow is subjected to a transverse magnetic field. The resulting partial differential equations were transformed into a set of ordinary differential equations using a two term series and solved in closed form. Numerical computations of the closed form results are performed and some graphical results were obtained to illustrate the details of the flow and heat and mass transfer characteristics and their dependence on some of the physical parameters.

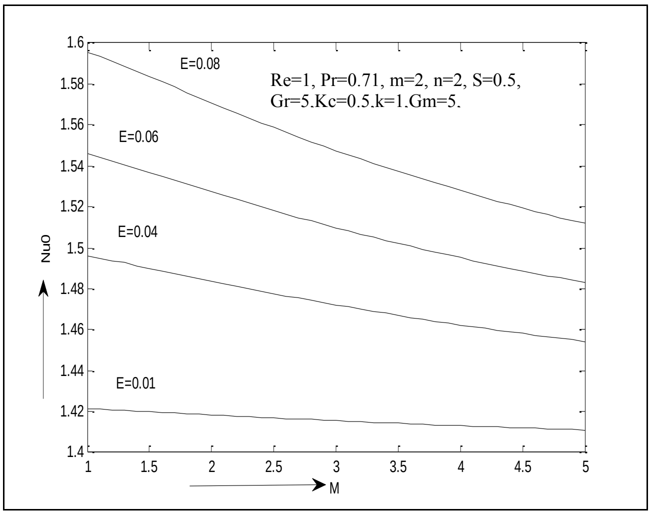

Figure 10. Rate of Heat-Transfer profiles for various values of E.

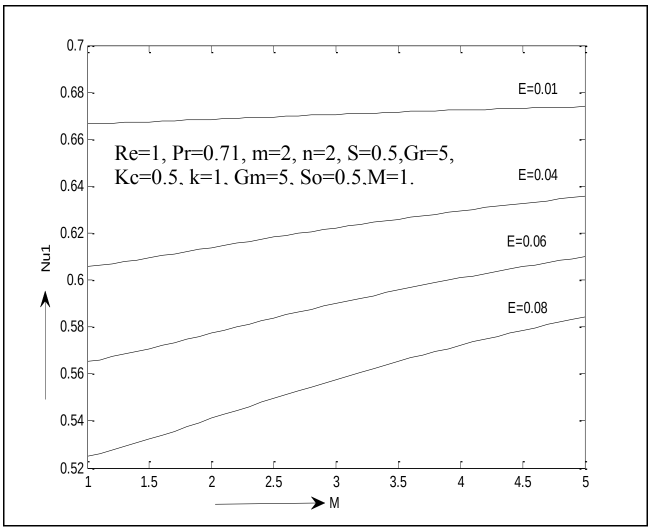

Figure 11. Rate of Heat-Transfer profiles for various values of E

It is found that velocity decreases with the increase in m, kc and so. Temperature increases with the increasing values of e. However concentration decreases with an increase in e, kc and so. In addition, it is found that skin friction coefficient decreases with an increase in kc. Nusselt number increases with an increase in e near one side of the plate and it shows reverse effect on the either side of the plate. Interestingly it is noticed that Sherwood number decreases with an increase in kc and so near the plate y=0 and it shows opposite reaction near the plate y=1. However Sherwood number increases with an increase in m near both sides of the plate**.**

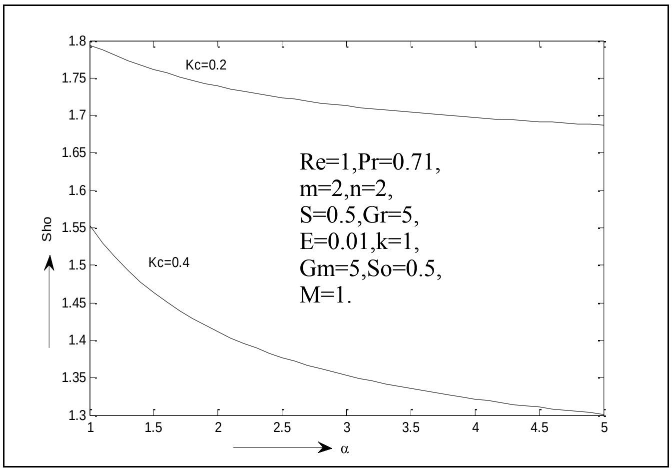

Figure 12. Sherwood number profiles for various values of Kc

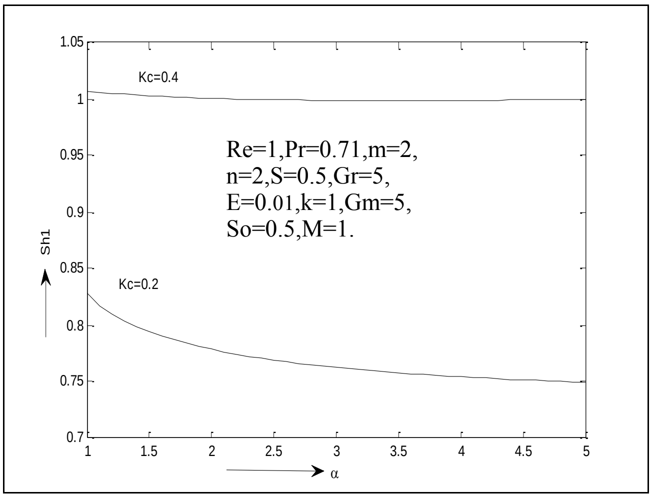

Figure 13. Sherwood number profiles for various values of Kc.

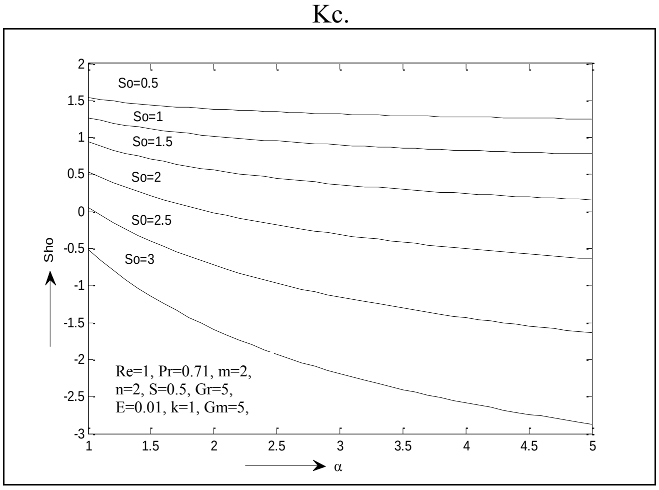

Figure14. Sherwood number profiles for various values of So.

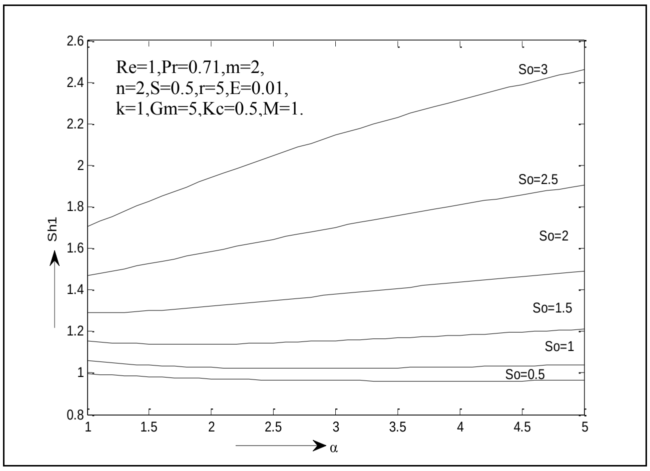

Figure15. Sherwood number profiles for various values of So.

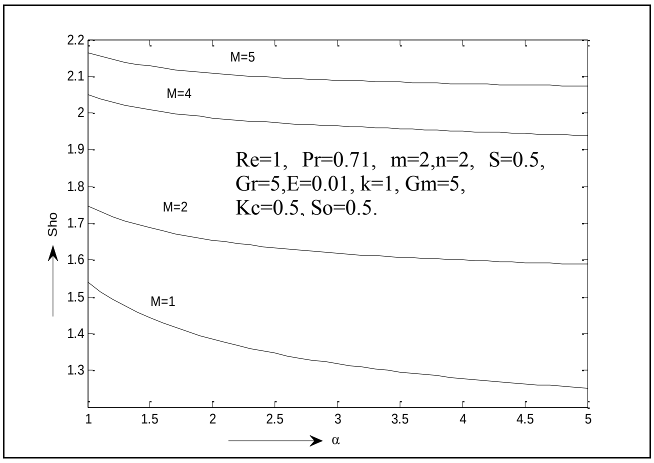

Figure 16. Sherwood number profiles for various values of M.

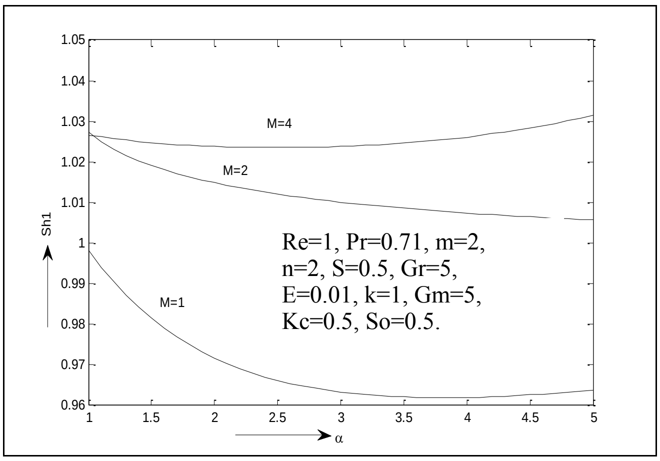

Figure 17. Sherwood number profiles for various values of M

6. REFERENCES

1. Chamkha, A.J, (2004), "Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption" *International Journal of Engineering Sciences*, 38, pp. 217-230.
2. Ling, S.C, Nazar, R, Pop, I, (2007), "Steady mixed convection boundary layer flow over a vertical flat plate in a porous medium filled with water at 4^0c: cases of variable wall temperature*", Transport in Porous Media,* 69 (3), pp. 359-372.
3. Alam, M.S, Rahman, M.M, and Samad, M.A, (2006), "Numerical study of the combined free forced convection and Mass transfer flow past a vertical porous plate in a porous medium with heat generation and thermal diffusion", *Nonlinear Analysis: Modeling and Control*, 11(4), pp. 331-343.
4. Bejan, A. and Khair, K.R, (1985), " Heat and mass transfer by natural convection in a porous medium", *Int. J. Heat Mass Transfer* 28(5), pp. 909-918.
5. Lai F,C and Kulaki, F.A, (1990), "The effect of variable viscosity on convective heat Transfer along a vertical surface in a saturated porous medium.," *Int. J. Heat Mass Transfer* 35(5), pp. 1028-1031.
6. Raju, M. C and Varma, S.V.K, Reddy, P.V and Suman, S, (2008) "Soret effects due to natural convection between heat inclined plates with Magnetic field", *J. of Mechanical Engineering* , 39, pp. 43-48.
7. Ananda Reddy, N , Raju, M.C & Varma, S.V.K ,(2010) "Unsteady free convective MHD non newtonian flow through a porous medium bounded by an infinite inclined porous plate", *Int. J. of Emerging Tech and applications in Engi Tech & Sciences*, 3(2), pp. 238-244.
8. Kim, J .Y, (2000), "Unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction" *International Journal of Engineering Sciences,* 38, pp. 833-845.
9. Chamkha, A.J, Khaled, A.R, (2000), " Hydromagnetic combined heat and mass transfer by natural convection from a permeable surface embedded in fluid saturated porous medium", *International Journal of Numerical methods for Heat and Fluid Flow*", 10(5), pp. 455-476.
10. Chamkha, A.J, (2000), " Hydromagnetic combined heat and mass transfer by natural convection from a permeable surface embedded in a fluid saturated porous medium".,*Int. J. Num. Methods for heat and fluid flow*, 10(5),pp. 455-476.
11. Anjali Devi, S. P and Kandasamy, R, (2002), "Effects of chemical reaction, heat and mass transfer on non-linear MHD laminar boundary layer flow over a wedge with suction and injection*", Int. Comm. Heat Mass Transfer,* 29, pp. 707.
12. Kandasamy, R, Periasamy, K, and Sivagnana Prabhu, K.K, (2005), "Effects of chemical reaction, heat and mass transfer along a wedge with heat source and concentration in the presence of suction or injection", *International Journal of Heat and Mass Transfer*, 48, pp. 1376-1388.
13. Kandasamy, R , Periasamy, K, Sivagnana Prabhu, K.K, (2005), "Chemical reaction, heat and mass transfer on MHD flow over a vertical stretching surface with heat

source and thermal stratification effects", *International Journal of Heat and Mass Transfer*, 48, pp. 4557–4561.
14. Ibrahim, S.Y, and Makinde, O.D, (2010), "Chemically reacting MHD boundary layer flow of heat and mass transfer over a moving vertical plate with suction", *Scientific Research and Essays*, 5(19), pp. 2875-2882.
15. Srinivas, S and Muthuraj, R, (2010), "MHD flow with slip effects and temperature-dependent heat source in a vertical wavy porous space", *Chem. Eng. Comm.*, 197, pp.1387–1403.
16. Ahmed, A, Kalita, D and Barman, D, (2010) "MHD free convective Poiseuille flow and mass transfer through a porous medium bounded by two infinite vertical porous plate", *International Journal of Applied Engineering Research*, 5(1), pp.25-35.

NOMENCLATURE

B_0 strengh of applied magnetic field
C' concentration
c_p specific heat at constant pressure
C_s' concentration at static condition
D chemical molecular diffusivety
D_1 thermal diffusivety
E Eckert number
g acceleration due to gravity
Gr Grashof number for heat transfer
Gm Grashof number for mass transfer
i, j unit vectors along x, y axes respectively
k permeability of the porous medium
K_1 dimensional chemical reaction parameter
Kc chemical reaction parameter
M magnetic parameter
m,n material parameters
Nu_0 Nusselt number at y=0
Nu_1 Nusselt number at y=1
Pr Prandtl number
q' Velocity vector
Re Reynolds number
Sh_0 Sherwood number at y=0
Sh_1 Sherwood number at y=1
S_0 Soret number
Sc Schmidt number
T' temperature
T_s' temperature at static condition
u,v velocity componets
V_0 constant suction/injection velocity
x', y', z' coordinate axes

Greek symbols

α dimensionless permeability parameter
β volumetric coefficient of thermal expansion for heat transfer
β' volumetric coefficient of thermal expansion for mass transfer
θ dimensionless temperature function
ϕ dimensionless concentration function
λ thermal conductivity
μ viscosity of the fluid
ν kinematic viscosity
ρ density of the fluid
σ electrical conductivity
τ_0 shearing stress at y=0
τ_1 shearing stress at y=1

Subscripts

w wall conditions
s surface conditions

Superscripts

/ differentiation with respect to y