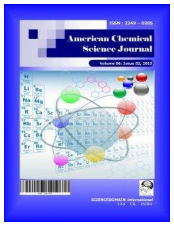

American Chemical Science Journal
7(3): 150-159, 2015, Article no.ACSj.2015.069
ISSN: 2249-0205

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MHD Mixed Convection Flow Past a Vertical Porous Plate in a Porous Medium with Heat Source/Sink and Soret Effects

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Authors' contributions

This work was carried out in collaboration between all authors. Author CK designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors CK and NK managed the analyses of the study. Author MCKR managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ACSj/2015/16257
Editor(s):
(1) Yunjin Yao, School of Chemical Engineering, Hefei University of Technology, Tunxi, Hefei, Anhui, China.
Reviewers:
(1) Anonymous, Malaysia.
(2) Anonymous, Nigeria.
(3) Anonymous, Pakistan.
(4) Sudarsan Reddy, Department of Mathematics, Rajeev Gandhi Memorial Engineering College, Nandyal, India.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=1047&id=16&aid=8986

Original Research Article

Received 19th January 2015
Accepted 30th March 2015
Published 27th April 2015

ABSTRACT

The present analysis is to study the boundary layer flow of an incompressible, steady combined free-forced convection and mass transfer flow over a vertical porous plate embedded in a porous medium with the effects of heat source/sink, suction/injection and thermal diffusion under the influence of magnetohydrodynamics. The uniform magnetic field is applied along the plate. With the help of similarity transformations the partial differential equations are transformed into a coupled non-linear ordinary differential equations, which are solved numerically by applying the implicit finite difference scheme known as Keller Box method. The effects of physical parameters on velocity, temperature and concentration profiles are illustrated graphically showing the effects of the different parameter values of the magnetic field, suction, local heat source/sink, permeability parameters, Soret number and Schmidt number. Finally, the numerical data for the local skin friction coefficient, the coefficient of local Nusselt number and coefficient of local Sherwood numbers also have been tabulated.

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Keywords: MHD; mixed convection; porous plate; heat source/sink; suction/injection; finite difference scheme.

1. INTRODUCTION

Several studies have been found to analyze the influence of the combined heat and mass transfer process by convection in a porous medium, owing to its wide applications, such as development of advanced technologies for nuclear waste management, hot dike complexes in volcanic regions for heating of ground water, separation process in chemical engineering etc,. This can be attributed to the great interest of many researchers to estimate the heat and fluid flow rates and behavior through enclosed in various geometries. More applications and good understanding of the subject are given in the work of Nield and Bejan [1]. When heat and mass transfer occur simultaneously in a moving fluid, the relation between the fluxes and the driving potentials are of more intricate nature. It has been found that an energy flux can be generated not only by temperature gradients but by composition gradients as well. The energy flux caused by a composition gradient is called the Dufour or diffusion-thermo effect. On the other hand, mass fluxes can also be created by temperature gradient and this is the Soret or thermal–diffusion effect. These effects are considered as second-order phenomena, on the basis that they are of smaller order of magnitude than the effects described by Fourier's and Fick's laws. In view of the importance of these above mentioned effects, Dursukanya Z. and Worek [2] studied Diffusion thermo- thermal diffusion effects in transient and steady natural convection from vertical surface whereas Kafoussias N.G. and William [3] studied the same effects on mixed convective and mass transfer boundary layer flow with temperature dependent viscosity. Partha et al. [4] studied the effects of magnetic and mass transport considering the Soret Dufour effects in non-Darcy porous medium.

In many metallurgical processes involving cooling of continuous strips, the rate of cooling can be controlled by the use of electrically effects is followed in some physical problems such fluids undergoing exothermic or endothermic chemical reactions. The study of convective flow with heat and mass transfer under the influence of magnetic field heat source/sink has practical applications in many areas of science and engineering. This phenomenon plays an important role in chemical industry, petroleum industry, cooling of nuclear reactors and packed-bed catalytic reactors. In this direction, Vajrvelu and Nayfeh [5] studied the hydromagnetic convection at a cone and at a wedge in presence of temperature-dependent heat generation and absorption effect. Chamkha [6] later examined the effect of heat generation or absorption on hydromagnetic three dimensional free convection flow over a vertical stretching surface. The MHD free convection and mass transfer flow with Hall current, viscous dissipation, joule heating and thermal diffusion is studied by Singh. A. K. [7]. B. Shanker and N. Kishan [8] studied the effect of mass transfer on the MHD flow past an impulsively started infinite plate with temperature. In recent years it has been proposed to alter flow kinematics that it leads to a slower rate of solidification as compared with water. To control flow parameters one of the technique is the idea of applying the magnetic field on the most attractive one to both because of (i) its easy of its implementation (ii) its intrusive nature. In fluid mechanics the properties desired for an outcome of such a process would mainly depend on two aspects one is the rate of cooling of liquid used and other is rate of stretch. The rate of cooling and the desired properties of the end product can be controlled by the use of electrically conducting fluid and applications of magnetic fields. The magnetic field applications can be used in the process of purification of molten metals from non-metallic inclusions Rahman and Sattar [9] have investigated the effect of heat generation or absorption on convective flow of micropolar fluid past a continuously moving vertical porous plate in presence of magnetic field. Ibrahim et al. [10] studied the effect of chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction. Hunegnaw and Kishan [11,12] studied the influence of the MHD on a steady and unsteady convective heat transfer, past a stretching sheet embedded in a porous medium by taking into the effects variable viscosity, heat source/sink, viscous dissipation, chemical reaction. The influence of magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media with Soret and Dufour effects has been carried out by Postelnicu [13]. R Ellahi, S Aziz, A Zeeshan [14] studied Non-Newtonian nano fluids through porous medium with heat transfer and variable viscosity. Ahammad and Mollah [15] performed the MHD free convection flow and mass transfer problem over a stretching sheet considering Dufour and Soret effects with magnetic field.

Alam et al. [16] investigated the numerical study of mixed convection and mass transfer flow past a vertical porous plate in a porous medium in the presence of heat generation and thermal diffusion. Raptis and Perdikis [17] investigated viscous flow for a non-linearly stretching sheet with chemical reaction and magnetic field. Samad et al. [18] studied natural convection flow through a porous medium considering the effect of magnetic field with thermal radiation, viscous dissipation and variable suction. Alam and Rahman [19] studied the mixed convection flow past a vertical porous plate with variable suction an the effects of Dufour and Soret. Study of stream wise transverse magnetic fluid flow with heat transfer around a porous obstacle is analysed by S. Rashidi et al. [20]. BS Malga, N Kishan [21] studied the finite element analysis for unsteady MHD heat and mass transfer free convection flow of polar fluids past a vertical moving plate in a porous medium with heat generation and thermal diffusion. Recently Alam et al. [22] studied the mixed convection and mass transfer flow apart a semi-infinite vertical porous flat plat embedded in a porous medium. Sheikholeslami. M, Ellahi. R. et al. [23] studied the effects of heat transfer in flow of nanofluids over a permeable stretching. R. Ellahi [24] studied the MHD and temperature dependent viscosity of non-Newtonian nanofluid in a pipe.

In the present study is to investigate the influence of magneto hydrodynamics on combined free-forced convection and mass transfer flow past a semi-infinite vertical porous flat plate embedded in a porous medium with the effects of heat source/sink and thermal diffusion. The non-linear partial differential equations are reduced to a system of coupled linear equations by using the suitable transformation and then solved by the implicit finite difference method called Keller Box.

2. MATHEMATICAL ANALYSIS

A two-dimensional steady combined free-forced convective and mass transfer flow of a viscous, incompressible fluid over an isothermal semi-infinite vertical porous flat plate embedded in a porous medium is considered. The flow is assumed to be in the x-direction, which is taken along the vertical plate in the upward direction and the y-axis is taken to be normal to the plate. The surface of the plate is maintained at a uniform constant temperature T_w and a uniform constant concentration C_w of a foreign fluid, which are higher than the corresponding values T_∞ and C_∞ respectively, sufficiently far away from the flat surface. It is also assumed that the free stream velocity U_∞, parallel to the vertical plate is constant. Then under the boundary layer and Boussinesq's approximations, the governing equations are given by:-

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \, , \tag{1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} = \nu\frac{\partial^2 u,}{\partial y^2} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\nu}{K'}u - \frac{\sigma B_0{}^2}{\rho}u \, , \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2} + \frac{Q_o}{\rho c_p}(T - T_\infty), \tag{3}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_M\frac{\partial^2 C}{\partial y^2} + D_T\frac{\partial^2 T}{\partial y^2} \, , \tag{4}$$

Where u, v are the velocity components in the x – and y - directions respectively, $\boldsymbol{\nu}$ is the kinematic viscosity, g is the acceleration due to gravity, ρ is the density of the fluid, β is the coefficient of volume expansion, β^* is the volumetric coefficient of expansion with concentration, T, T_w, T_∞ are the temperature of the fluid inside the thermal boundary layer, the plate temperature and the fluid temperature in the free stream, respectively, while C , C_w and C_∞ are the corresponding concentrations. Also, K' is the permeability of the porous medium, k is the thermal conductivity, C_p is the specific heat at constant pressure, Q_o is the heat generation constant, D_M is the coefficient of mass diffusivity and D_T is the coefficient of thermal diffusivity.

For the flow there is no-slip at the plate. For uniform plate temperature and concentration the appropriate boundary conditions for the above problem are as follows

$$u = 0\, , \; v = v_w(x), \; T = T_w, \; C = C_w \; at \;\; y = 0, \tag{5(a)}$$

$$u = U_\infty, \; T = T_\infty, \; C = C_\infty \; as \;\; y \to \infty, \tag{5(b)}$$

In order to obtain similarity solution of the problem we introduce the following non-dimensional variables

$$\eta = y\sqrt{\frac{U_\infty}{\nu x}} \, , \; \psi = \sqrt{\nu x \, U_\infty} \; f(\eta) \, , \tag{6(a)}$$

$$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty} \, , \qquad \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty} \, ,$$

where ψ is the stream function.

Since $u = \frac{\partial \psi}{\partial y}$, and $v = -\frac{\partial \psi}{\partial x}$ we have from equation

$u = U_\infty f\,'$ and $v = -\sqrt{\frac{\nu\, U_\infty}{x}}\left(f - \eta f'\right)$, 6(b)

Here prime denotes differentiation with respect to η.

Now substituting equation (6) in equations (2) – (4) we obtain

$$f\,''' + \frac{1}{2}\, f\, f\,'' - Kf\,' + g_s\theta + g_c\emptyset - Mf\,' = 0 \quad (7)$$

$$\theta\,'' + \frac{1}{2} Prf\,\theta' + PrQ\theta = 0, \quad (8)$$

$$\emptyset\,'' + \frac{1}{2} Scf\,\emptyset' + SoSc\,\theta'' = 0, \quad (9)$$

The boundary conditions (5) then turn into

$$f = f_w,\ f' = 0,\ \theta = 1,\ \emptyset = 1,\ \text{at } \eta = 0, \quad (10a)$$

$$f' = 1,\quad \theta = 0,\ \emptyset = 0,\quad \text{as } \eta \to \infty, \quad (10b)$$

where $f_w = -2v_w(x)\sqrt{\frac{x}{\nu\, U_\infty}}$ is the suction parameter. The dimensionless parameters introduced in the above equations are defined as follows:

$K = \frac{\nu x}{K' U_\infty}$ is the local permeability parameter,

$G_r = \frac{g\beta(T_w - T_\infty)x^3}{\nu^2}$ is the local temperature Grashof number,

$G_m = \frac{g\beta^*(C_w - C_\infty)x^3}{\nu^2}$ is the local mass Grash of number,

$R_e = \frac{U_\infty x}{\nu}$ is the local Reynolds number,

$g_s = \frac{G_r}{Re^2}$ is the temperature buoyancy parameter,

$g_c = \frac{G_m}{Re^2}$ is the buoyancy number,

$P_r = \frac{\nu\rho c_p}{k}$ is the Prandtl number,

$Q = \frac{Q_0}{\rho c_p U_\infty}$ is the local heat generation parameter,

$S_c = \frac{\nu}{D_M}$ is the Schmidt number,

$S_o = \frac{D_T(T_w - T_\infty)}{\nu(C_w - C_\infty)}$ is the Soret number.

and $M = \frac{\sigma {B_0}^2}{\rho} U_\infty x$. is the magnetic parameter.

3. Skin-friction Coefficient, Nusselt Number and Sherwood Number

The parameters of engineering interest for the present problem are the local skin-friction coefficient, local Nusselt number and the local Sherwood number which indicate physically wall shear stress, rate of heat transfer and rate of mass transfer respectively.

The equation defining the wall skin-friction is

$$\tau_w = \mu\left(\frac{\partial u}{\partial x}\right)_{y=0} = \mu U_\infty \sqrt{\frac{U_\infty}{\nu x}}\, f''(0),$$

Hence the skin-friction coefficient is given by

$C_f = \frac{2\tau_w}{\rho {U_\infty}^2}$ or $\frac{1}{2} C_f (Re)^{\frac{1}{2}} = f''(0)$,

Now the heat flux (q_w) and the mass flux (M_w) at the wall are given by

$q_w = -k\left(\frac{\partial u}{\partial x}\right)_{y=0} = -k\,\Delta T\sqrt{\frac{U_\infty}{\nu x}}\,\theta'(0)$ and

$M_w = -D_M\left(\frac{\partial C}{\partial x}\right)_{y=0} = -D_M\,\Delta C\sqrt{\frac{U_\infty}{\nu x}}\,\emptyset'(0),$

Where $\Delta T = T_w - T_\infty$ and $\Delta C = C_w - C_\infty$,

Hence the Nusselt number (Nu) and Sherwood number (Sh) are obtained as

$Nu = \frac{xq_w}{k\Delta T} = -(Re)^{\frac{1}{2}}\theta'(0)\ i.e., Nu(Re)^{-\frac{1}{2}} = -\theta'(0),$

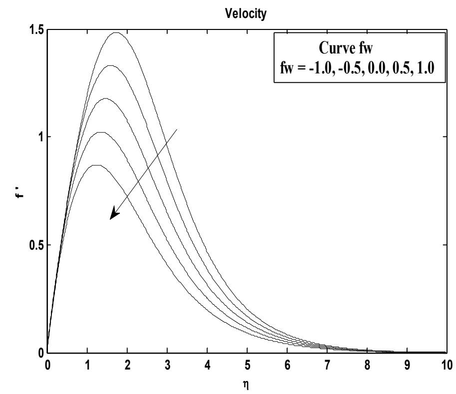
and $Sh = \frac{xM_w}{D_M \Delta C} = -(Re)^{\frac{1}{2}}\emptyset'(0), Sh(Re)^{-\frac{1}{2}} = \emptyset'(0).$

These above coefficients are then obtained numerically and are sorted in Table 1.

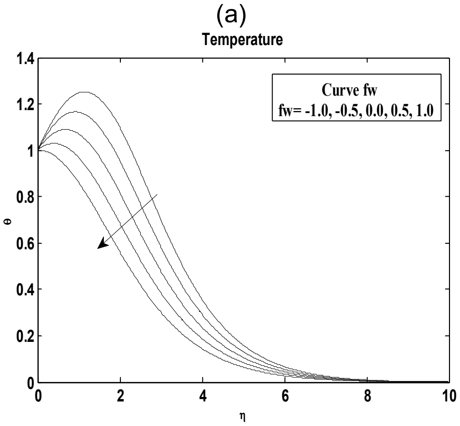
4. RESULTS AND DISCUSSION

The partial differential equations governed by the problems are transformed into a ordinary differential equations by using the similarity transformation. The numerical solutions of boundary value problems for the system of non-linear coupled ordinary differential equation equations (7) to (9) together with boundary conditions equation (10) have been performed by applying the implicit finite difference scheme known as Keller box method. Since the physical phenomenon of the underlying problem and bounded, the computational domain is chosen sufficiently large in order to meet the infinite boundary condition. In the present case the transverse distance is fixed to 10 (i.e. η→∞). In a computational process first the missing initial condition at the initial point of the interval is assumed, the differential equation is then integrated numerically as on initial value problem to the terminal point. The accuracy of the assumed the missed initial condition is then verified by comparing the calculated value of dependent variable at the terminal point with its given value there. If a different exits, the another value of missing condition must be assumed as the process is repeated. The computations are carried out for the velocity, temperature and concentration profiles, to analyze the effects of governing flow parameters such as magnetic field parameter M, suction parameter f_w , temperature buoyancy parameter g_s, mass buoyancy parameter g_c, local heat generation parameter Q, Schmidt number Sc, Soret number So, Prandtl number Pr, permeability parameter K. The local skin coefficient f ''(0), rate heat transfer $-\theta'(0)$ and rate of mass transfer$-\emptyset'(0)$, for a different flow parameters are presented in Table (1). Fig. (1) shows the effects of the suction parameter f_w for (a) Velocity (b) Temperature and (c) Concentration profiles respectively. The effect of f_w is to decrease the velocity profile with the increase of suction parameter (f_w>0), and it increases in case of injection (f_w<0). It is due to the increase of suction parameter indicating the usual fact that suction stabilizes the boundary layer growth where as it is disstabilizes in injection. It can be seen from the Figs. 1(b) and 1(c) the effect of f_w on temperature and concentration fields with the increase of f_w in suction (f_w>0) is to reduces both temperature and concentration profiles. Sucking is to decelerated fluid particle through the porous wall reduce the growth of the fluid boundary layer as well as thermal and concentration boundary layers. The temperature and concentration profiles increases in injection (f_w<0). Injecting as a accelerate fluid particle through the porous wall increase the growth of the boundary layer as well as thermalite concentration boundaries. Figs. 2(a)-(c) illustrates the effects of its heat source (Q<0) and heat sink (Q>0) for dimensionless profiles of (a) Velocity (b) Temperature and (c) Concentration. From the figure it can be seen that increase in the strength of heat source (Q<0), the fluid velocity and temperature profiles decreases as the momentum and thermal boundary layer thickness reduces. On the other hand, for the increase of heat sink strength (Q>0), the velocity and temperature profiles increases as the momentum and thermal boundary layer thickness enlarges. It is also notices from the Fig. 2(c) that the concentration increases with the increase of strength of heat sources (Q<0), whereas it decreases concentration profiles with the increase of heat sink strength (Q>0). The influence of the magnetic parameter M on the velocity, temperature and concentration profiles are shown in Figs. 3 (a) – (c) respectively. From these figures it can be seen that the velocity profile f' decreases with the increase of magnetic field parameter M. Consequently, the momentum boundary thickness decreases. Thus, the Lorentz forces arising because of interaction of magnetic and electric fields for the motion of an electrically conducting fluid makes the momentum boundary layer thin by reduces fluid motion in boundary layer. From Figs. 3(b) and (c) it is observed that the temperature profiles as well as concentration profiles increases with the increase of magnetic field parameter. So, the thermal boundary layer thickness increases with increases in M. The effect of permeability parameter K on velocity, temperature and concentration profiles plotted in Figs. 4(a) – (c) respectively. From 4(a) and (b) is observed that the velocity and temperature profiles decrease with increases of permeability parameter. From Fig. 4 (c) it can be seen that the concentration profiles increases with increases of permeability parameter. Fig. 5(a) shows the variation of dimensionless velocity profile f ' and Fig. 5(b) dimensionless concentration profiles for different values of So. It is seen that the velocity profile increase with the increase of So. It shows that the fluid velocity rises due to greater thermal diffusion. It can be observed from Fig. 5(b) the concentration profiles increases significantly with an increase of Soret number.

Figs. 6(a) and (b) depicts the effect of Schmidt number Sc on dimensionless velocity and concentration profiles. It can be seen from the figure that effect of Schmidt number Sc is to decreases both the velocity and concentration profiles. The concentration profiles decreases significantly with the increase of Sc. It means the high Schmidt number shows that the low mass diffusion rate is in action. For the physical point of view the different values of flow parameters such as M, f_w, Sc, So, g_c, g_s, K, Q and Pr, on the local skin co-efficient f ''(0) , Nusselt number



(a)



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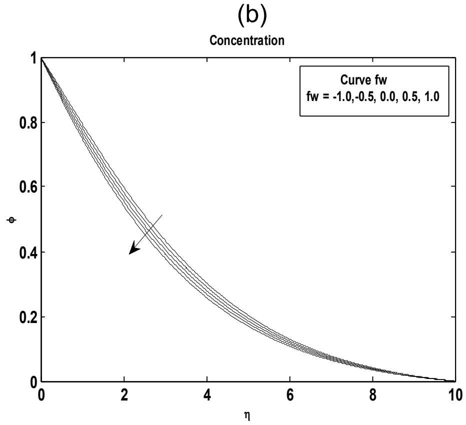
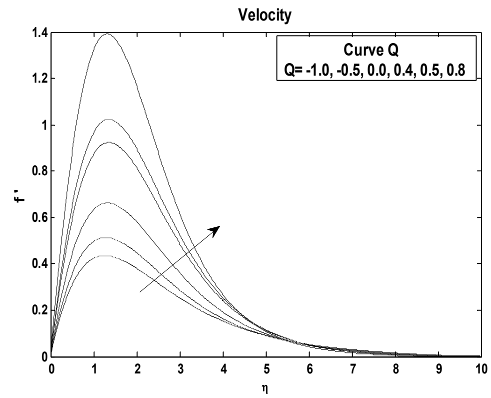
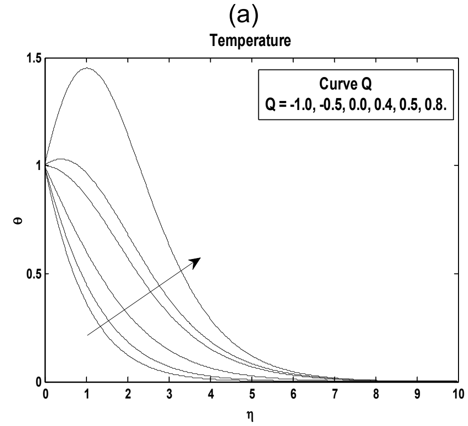


(c)

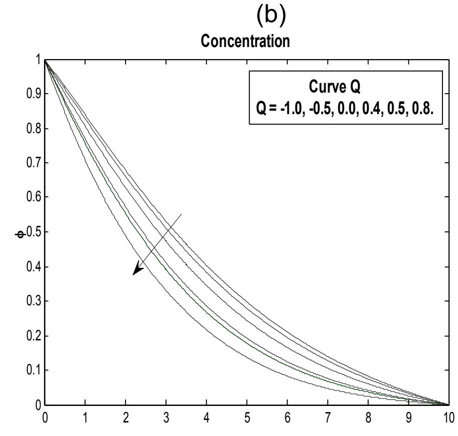
Fig. 1. The effects of suction/injection parameter f_w on (a) velocity (b) temperature (c) concentration profiles



(a)



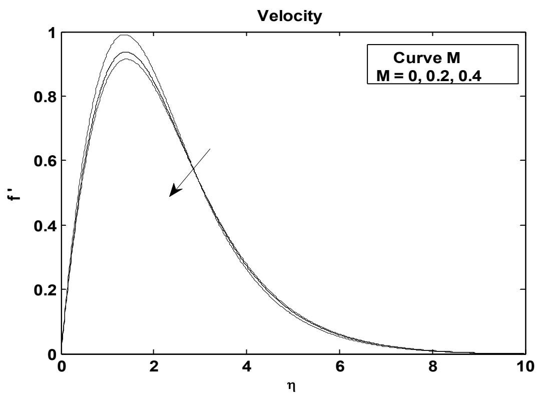
(b)



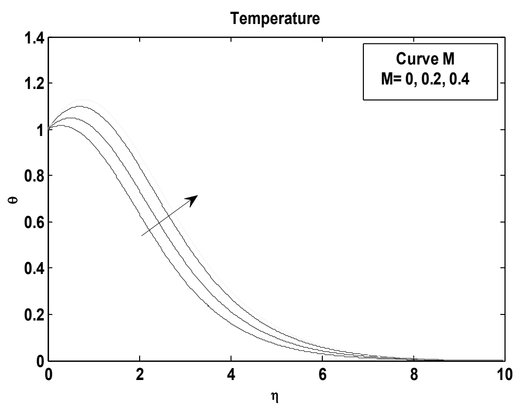
(c)

Fig. 2. The effects heat generation parameter Q on (a) velocity (b) temperature (c) concentration profiles

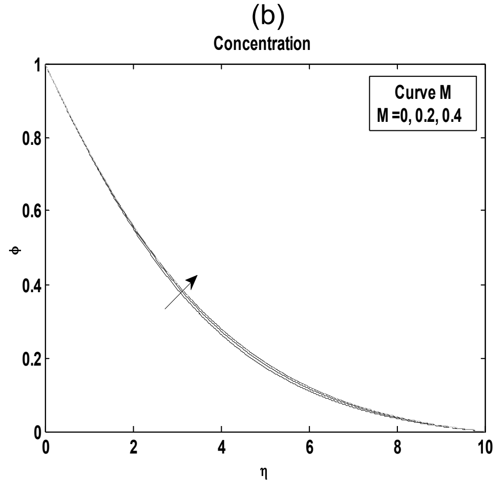
co-efficient $-\theta\,'(0)$, Sherwood number $-\emptyset^{'}(0)$ are presented in Table (1). From the table it can be seen that the skin friction coefficient $f''(0)$ is to decreases with the increase of magnetic field parameter M, Soret number S_o, Prandtl number Pr and permeability parameter K, whereas it increases with the increase of S_c, g_s, G_c, and f_w (f_w<0). And the $f\,''(0)$ value decreases for heat source (Q<0) and increases for heat sink (Q>0). The Nusselt number coefficient $-\theta'(0)$ is to decreases with the increase of M, Pr, S_o, S_c, g_c, K where as it increases with the increase of f_w. The Sherwood number $-\emptyset^{'}(0)$ increases with the increase of M, S_o, S_c, g_s decreases with the increase of K, Pr, g_c. The Nusselt number value increases with heat source (Q<0) and decreases with heat sink (Q>0). The heat source (Q<0) will decreases the Sherwood number value $-\theta'(0)$ while it increases for the heat sink (Q<0).



(a)

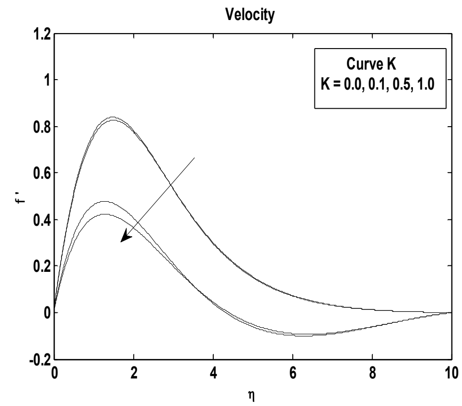


(b)

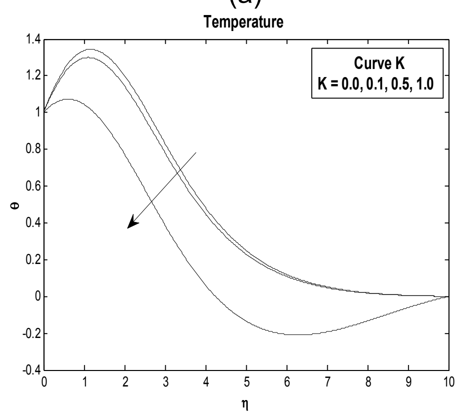


(c)

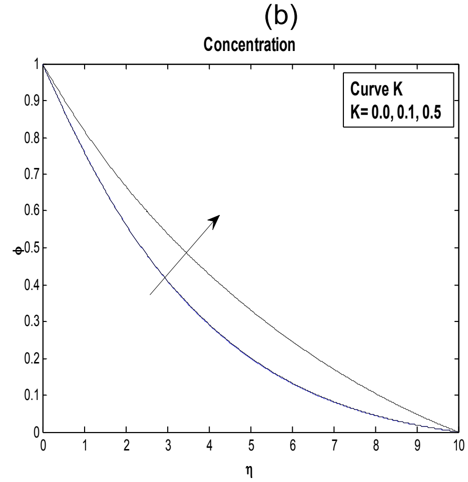
Fig. 3 The effects of magnetic field parameter M on (a) velocity (b) temperature (c) concentration profiles



(a)



(b)



(c)

Fig. 4. The effects permeability parameter K on (a) velocity (b) temperature (c) concentration profiles

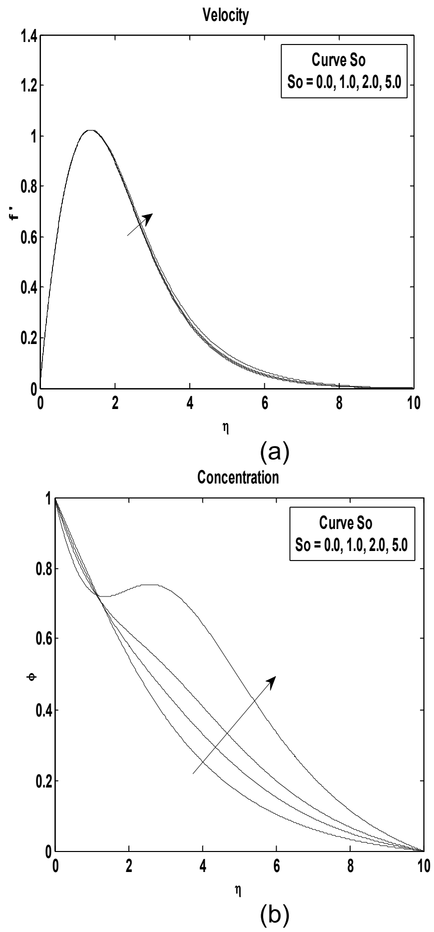


Fig. 5. Effects So on (a) velocity (b) concentration Profiles.

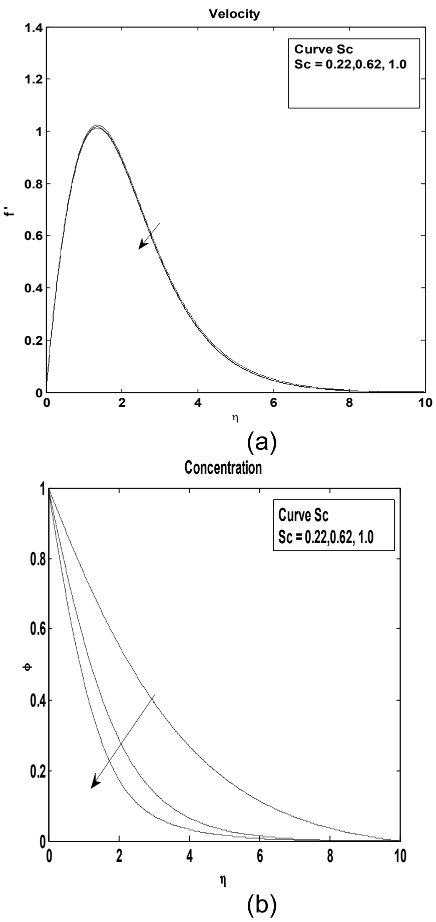


Fig. 6 Effects Sc on (a) velocity (b) concentration profiles.

Table 1. Numerical Coefficient values of $f''(0)$, $-\theta'(0), -\emptyset'(0)$

M	Q	f_w	So	Sc	gs	gc	Pr	K	$f''(0)$	$-\theta'(0)$	$-\emptyset'(0)$
0	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.05	1.7216	-0.1077	0.2589
0.2	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.05	1.6080	-0.1943	0.2567
0.4	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.05	1.5180	-0.2833	0.2559
0.5	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.05	1.4797	-0.3286	0.2558
1.0	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.05	1.3347	-0.5605	0.2582
1.0	0.5	0.5	0.2	0.22	1.0	0.1	1.0	0.05	1.3194	-0.7048	0.2555
1.0	0.5	0.5	0.2	0.22	1.0	0.1	7.0	0.05	0.7829	-1.1618	0.2103
1.0	0.5	-0.5	0.2	0.22	1.0	0.1	0.71	0.05	1.2615	-0.7528	0.2197
1.0	0.5	0.0	0.2	0.22	1.0	0.1	0.71	0.05	1.3165	-0.6822	0.2399
1.0	0.5	1.0	0.2	0.22	1.0	0.1	0.71	0.05	1.3112	-0.3859	0.2746
1.0	0.5	0.5	0.2	0.22	2	0.1	0.71	0.05	1.9964	-0.1542	0.2587
1.0	0.5	0.5	0.2	0.22	5	0.1	0.71	0.05	3.7419	-0.1755	0.2822
1.0	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.0	1.6906	-0.1291	0.2582
1.0	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.1	1.6339	-0.1724	0.2572
1.0	0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.5	1.4620	-0.3514	0.2559
1.0	0.5	0.5	1.0	0.22	1.0	0.1	0.71	0.05	1.3305	-0.5589	0.3622
1.0	0.5	0.5	0.2	0.62	1.0	0.1	0.71	0.05	1.3336	-0.5820	0.5045
1.0	0.5	0.5	0.2	0.62	1.0	1.0	0.71	0.05	1.8265	-0.2567	0.2567
1.0	-0.5	0.5	0.2	0.22	1.0	0.1	0.71	0.05	0.6937	0.7225	0.1366
1.0	0.0	0.5	0.2	0.22	1.0	0.1	0.71	0.05	0.8373	0.3700	0.1681

5. CONCLUSION

The present problem deals with the study of magneto hydrodynamics combined free-forced convection and mass transfer flow over a semi-infinite vertical porous plate embedded in a porous medium in presence of heat generation and thermal- diffusion. From the present numerical investigation the following conclusions may be drown:

1. The effect of magnetic field parameter is to reduces the velocity profiles, while increase the temperature and concentration profiles.
2. Wall suction stabilizes the velocity, thermal as well as concentration boundary layer growth. The wall injection is disstabilizes the fluid motion.
3. Both the velocity and temperature profiles increase whereas the concentration profile decreases with the increase of heat source parameter. Whereas the strength of heat sink is to reduces the both velocity, temperature profiles and increases the concentration profiles.
4. Both the velocity and concentration profiles increase with the increase of Soret number.
5. The increase in magnetic field parameter is to reduces the $f''(0), -\theta'(0), and -\emptyset'(0)$ values. In mixed convection regime, both the Skin-friction coefficient and Sherwood number increases whereas the Nusselt number decreases with the increase of both heat generation parameter and Soret number.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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