American-Eurasian Journal of Scientific Research 8 (3): 135-143, 2013
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2013.8.3.1427

Effects of Chemical Reaction and Radiation on MHD Free Convection Flow of Kuvshinshiki Fluid Through a Vertical Porous Plate with Heat Source

[1]P. Mohan Krishna, [1]V. Sugunamma and [2]N. Sandeep

[1]Department of Mathematics, S.V. University, Tirupati, India
[2]Division of Fluid Dynamics, VIT University, Vellore, India

Abstract: The objective of this paper is to study the effect of Chemical reaction and Radiation on MHD free convection flow of Kuvshinshiki fluid through a vertical porous plate with heat source taking Visco-elastic and Darcy resistance terms into account and the constant permeability of the medium numerically and neglecting induced magnetic field in comparison to applied magnetic field. The velocity, temperature, concentration and skin friction distributions are derived, discussed numerically with the help of graphs.

Key words: Radiation · Kuvshinshiki fluid · Heat Source · MHD · Chemical Reaction

INTRODUCTION

Nowadays the physics of simultaneous heat and mass transfer has attracted various researchers because of its various ranges of applications in science and technology. It is used in food processing, wet-bulb thermometer and polymer solution and also in various fluids flows related engineering problems. In our daily life, the combined heat and mass transfer phenomenon is observed in the formation of fog. The convection flow associated with the combined heat and mass transfer has many applications in various branches of science and engineering. Nature of vertical convection flows from the buoyancy effects of thermal and mass diffusion has been done by Gebhart and Pera [1]. Singh and Singh [2] discussed the MHD free convection flow and mass transfer past a flat plate. Sandeep and Sugunamma [3] studied Effect of Inclined Magnetic Field on Unsteady Free Convective Flow of Dissipative Fluid past a Vertical Plate. Chamkha [4] investigated unsteady convective heat and mass transfer past a semi-infinite porous moving plate with heat absorption. Hady *et al* [5] studied the problem of free convection flow along a vertical wavy surface embedded in electrically fluid saturated porous media in the presence of internal heat generation or absorption effect. Chen [6] investigated the effects of heat and mass transfer in MHD free convection from a vertical surface. Muthucumaraswamy and Ganesan [7] have studied heat transfer effects on flow past an impulsively started semi-infinite vertical plate with uniform heat flux. On the other hand, Hydro magnetic free convective flows with heat and mass transfer through porous medium have many important applications such as oil and gas production, geothermal energy, cereal grain storage, in chemical engineering for filtration and purification process, in agriculture engineering to study the underground water resources and porous insulation.

The effects of radiation on free convection on the accelerated flow of a viscous incompressible fluid past an infinite vertical porous plate with suction has many important technological applications in the astrophysical, geophysical and engineering problem. Radiation and free convection flow past a moving plate was considered by Raptis and Perdikis [8].Ghosh *et al.* [9] has considered thermal radiation effects on unsteady hydromagnetic gas flow along an inclined plane with indirect natural convection. Radiation effects on MHD flow through a porous medium with variable temperature or variable mass diffusion was studied by Rajesh and Verma [10]. Rajesh [11] has studied radiation effects on MHD free convection flow near a vertical plate with ramped wall temperature. Chaudhary *et al* studied MHD heat and mass diffusion flow by natural convection past a surface embedded in a porous medium [12]. The study of magneto hydro-dynamics with mass and heat transfer in the presence of radiation and diffusion has attracted the attention of a large number of scholars due to diverse applications. In astrophysics and geophysics, it is applied

Corresponding Author: P. Mohan Krishna, Department of Mathematics, S.V. University, Tirupati, India.

to study the stellar and solar structures, radio propagation through the ionosphere, etc. In engineering we find its applications like in MHD pumps, MHD bearings, etc. Recently, Sandeep *et al*. [13] analyzed Effect of Radiation and Chemical Reaction on Transient MHD Free Convective Flow over a Vertical Plate Through Porous Media.

Thermal diffusion, also called thermo diffusion or Soret effect corresponds to species differentiation developing in an initial homogeneous mixture submitted to a thermal gradient. The Soret effect arises when the mass flux contains a term that depends on the temperature gradient. Both temperature and concentration gradients contribute to the initiation of convection and each may be stabilizing or destabilizing. Even when a concentration gradient is not externally imposed (the thermosolutal problem) it can be created by the applied thermal gradient via the Soret effect. Beg Anwar *et al*. [14] examined the combined effects of Soret and Dufour diffusion and porous impedance on laminar magneto-hydrodynamic mixed convection heat and mass transfer of an electrically-conducting, Newtonian, Boussinesq fluid from a vertical stretching surface in a Darcian porous medium under uniform transverse magnetic field. Olanrewaju [15] examined Dufour and Soret effects of a transient free convective flow with radiative heat transfer past a flat plate moving through a binary mixture and Dufour effects using both linear and non-linear stability analysis. Anghel *et al*. [16] investigated the Dufour and Soret effects on free convection boundary layer over a vertical surface embedded in a porous medium. Eldabe *et al*. [17] investigated the thermal-diffusion and diffusion-thermo effects on mixed free-forced convection and mass transfer boundary layer flow for non-Newtonian fluid with temperature dependent viscosity.

The present paper is to study the effect of Chemical reaction and Radiation on MHD free convection flow of Kuvshinshiki fluid through a vertical porous plate with heat source taking Visco-elastic and Darcy resistance terms into account and the constant permeability of the medium numerically and neglecting induced magnetic field in comparison to applied magnetic field.

Mathematical Analysis: We study the two-dimensional free convection and mass transfer flow of an incompressible Visco-elastic Kuvshinshiki type fluid past an infinite vertical porous plate under the following assumptions:

- The plate temperature is constant.
- Visco-elastic and Darcy's resistance terms are taken into account with constant permeability of the medium.
- Boussinesq's approximation is valid.
- Visco elastic Kuvshinshiki type fluid.
- The suction velocity normal to the plate is constant and can be written as,

$$v' = -U_o$$

A system of rectangular co-ordinates $O(x', y', z')$ is taken, such that $y' = 0$ on the plate and z' axis is along its leading edge. All the fluid properties considered constant except that the influence of the density variation with temperature is considered. The influence of the density variation in other terms of the momentum and the energy equation and the variation of the expansion coefficient with temperature is considered negligible. This is the well-known Boussinesq approximation. Under these conditions, the problem is governed by the following system of Equations:

Equation of Continuity:

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

Equation of Momentum:

$$\begin{aligned}\left(1+\lambda'\frac{\partial}{\partial t'}\right)\frac{\partial u'}{\partial t'} + v'\frac{\partial v'}{\partial y'} &= \upsilon\frac{\partial^2 v'}{\partial y'^2} + g\beta(T' - T_\infty') \\ &+ g\beta'(C' - C_\infty') - \left(1+\lambda'\frac{\partial}{\partial t'}\right)\left(\frac{\upsilon}{k'} + \frac{\sigma B_o{}^2}{\rho}\right)u'\end{aligned} \tag{2}$$

Equation of Energy:

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y'} + \frac{1}{\rho C_p}Q(T' - T_\infty') \tag{3}$$

Equation of Concentration:

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} + K_l'\left(C' - C_\infty'\right) + D_1\frac{\partial^2 T'}{\partial y'^2} \tag{4}$$

The corresponding boundary conditions are

$$\begin{aligned} &u' = 0, T' = T_w', C' = C_w' \quad at \quad y' = 0 \\ &u' = 0, T' = T_\infty, C' = C_\infty \quad as \quad y' \to \infty \end{aligned} \tag{5}$$

where u', v' are the velocity components. T', C' are the temperature and concentration components, υ is the kinematic viscosity. ρ is the density, σ is the electrical conductivity, β_o is the magnetic induction, β is the thermal expansion coefficient, β' is the concentration expansion coefficient, D is the concentration diffusivity and q_r is the radiative heat flux.

The local radiant for the case of an optically thin gray fluid is expressed by

$$\frac{\partial q_r}{\partial y'} = -4a^*\sigma\left(T_\infty'^3 - T'^4\right) \qquad (6)$$

Where a^* is the absorption constant. Considering the temperature differences within the flow sufficiently small, T'^4 can be expressed as the linear function of temperature. This is accomplished by expanding T'^4 in a Taylor series about T'_∞ and neglecting higher-order terms

$$T'^4 \cong 4T_\infty'^3 T' - 3T_\infty'^4 \qquad (7)$$

Using equations (6) and (7), equation (3) becomes

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y'^2} + \frac{16a^*\sigma\upsilon T'_\infty}{\rho c_p U_0^2}\left(T'_\infty - T'\right) + \frac{Q}{\rho c_p}\left(T' - T'_\infty\right) \qquad (8)$$

Introducing the following non-dimensional quantities

$$u = \frac{u'}{U_o}, t = \frac{t'U_o^2}{\upsilon}, y = \frac{y'U_o}{\upsilon}, \theta = \frac{T' - T_\infty'}{T_w' - T_\infty'}, \phi = \frac{C' - C_\infty'}{C_w' - C_\infty'}$$
$$K = \frac{k'U_o^2}{\upsilon^2}, \Pr = \frac{\mu c_p}{k}, Sc = \frac{\upsilon}{D}, M = \frac{\sigma B_o^2 v}{\rho U_o^2}, R = \frac{16a^*\sigma\upsilon T_\infty'^3}{\rho c_p U_0^2}$$
$$Gr = \frac{g\beta\upsilon(T_w' - T_\infty')}{U_o^3}, N = \frac{\beta'(C_w' - C_\infty')}{\beta(T_w' - T_\infty')}, \lambda = \frac{\lambda' U_o^2}{\upsilon} \qquad (9)$$
$$H = \frac{Q\upsilon}{\rho c_p U_o^2}, Sr = \frac{D_1\left(T_w' - T_\infty'\right)}{\upsilon\left(C_w' - C_\infty'\right)}, K_l = \frac{K_l'\upsilon}{U_o^2}$$

where Pr is the Prandtl number, Gr is the Grashof number, N is the buoyancy ratio, Sc is the Schmidt number, M is the magnetic parameter, K is the Darcy permeability parameter, R is the Radiation parameter, Sr is the Soret effect, K_i is dimensionless chemical reaction parameter, K_l' is the chemical reaction parameter, H is the heat source parameter and λ is the Visco-elastic parameter.

Using (9), equations (1), (2), (4) and (8) reduces to

$$\left(1 + \lambda\frac{\partial}{\partial t}\right)\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr(\theta + N\phi) - \left(1 + \lambda\frac{\partial}{\partial t}\right)\left(\frac{1}{K} + M\right)u \qquad (10)$$

$$\frac{\partial\theta}{\partial t} - \frac{\partial\theta}{\partial y} = \frac{1}{\Pr}\frac{\partial^2\theta}{\partial y^2} - R\theta + H\theta \qquad (11)$$

$$\frac{\partial\phi}{\partial t} - \frac{\partial\phi}{\partial y} = \frac{1}{Sc}\frac{\partial^2\phi}{\partial y^2} + K_l\phi + Sr\frac{\partial^2\theta}{\partial y^2} \qquad (12)$$

The corresponding boundary conditions are

$$\begin{aligned} &u = 0, \theta = 1, \phi = 1 \quad at \quad y = 0 \\ &u = 0, \theta = 0, \phi = 0 \quad as \quad y \to \infty \end{aligned} \qquad (13)$$

Method of Solution: We assume the solution of equations (10), (11) and (12) as

$$u(y,t) = u_o(y)e^{-nt} \qquad (14)$$

$$\theta(y,t) = \theta_o(y)e^{-nt} \qquad (15)$$

$$\phi(y,t) = \phi_o(y)e^{-nt} \qquad (16)$$

Substituting the equations (14) - (16) in equations (10) - (12), we obtain

$$u_o'' + u_o' - \left[\left(M + \frac{1}{K} - n\right)(1 - n\lambda)\right]u_o = -Gr\theta_o - GrN\phi_o \qquad (17)$$

$$\theta_o'' + \Pr\theta_o' + \Pr(n - R + H)\theta_o = 0 \qquad (18)$$

$$\phi_o'' + Sc\phi_o' + Sc(n + K_l)\phi_o = -ScSr\theta_o'' \qquad (19)$$

Under the boundary conditions are

$$\begin{aligned} &u_o = 0, \theta_o = 1, \phi_o = 1 \quad at \quad y = 0 \\ &u_o = 0, \theta_o = 0, \phi_o = 0 \quad as \quad y \to \infty \end{aligned} \qquad (20)$$

Solving equations (17) - (19) with the boundary conditions (20), we get

$$u_o(y) = (1 + A_3 N) A_1 (e^{-m_3 y} - e^{-m_1 y}) + A_2 (e^{-m_3 y} - e^{-m_2 y}) \quad (21)$$

$$\theta_o(y) = e^{-m_1 y} \quad (22)$$

$$\phi_o(y) = A_4 e^{-m_2 y} - A_3 e^{-m_1 y} \quad (23)$$

Where

$$m_1 = \frac{\Pr + \sqrt{\Pr^2 - 4\Pr(n - R + H)}}{2}$$

$$m_2 = \frac{Sc + \sqrt{Sc^2 - 4Sc(n + K_l)}}{2}$$

$$m_3 = \frac{1 + \sqrt{1 + 4\left(M + \frac{1}{K} - n\right)(1 - n\lambda)}}{2}$$

$$A_1 = \frac{Gr}{m_1^2 - m_1 - \left\{\left(M + \frac{1}{K} - n\right)(1 - n\lambda)\right\}}$$

$$A_2 = \frac{Gr\, N}{m_2^2 - m_2 - \left\{\left(M + \frac{1}{K} - n\right)(1 - n\lambda)\right\}}$$

$$A_3 = \frac{ScSrm_1^2}{m_1^2 - Scm_1 + Sc\left(n + K_l\right)}$$

$$A_4 = 1 + A_3$$

Substituting the equations (21) - (23) in equations (14) - (16), we obtain the velocity, temperature and concentration distribution in the boundary layer as

$$u(y,t) = \begin{bmatrix} (1 + A_3 N) A_1 (e^{-m_3 y} - e^{-m_1 y}) \\ + A_2 (e^{-m_3 y} - e^{-m_2 y}) \end{bmatrix} e^{-nt} \quad (24)$$

$$\theta(y,t) = e^{-m_1 y} e^{-nt} \quad (25)$$

$$\phi(y,t) = \left(A_4 e^{-m_2 y} - A_3 e^{-m_1 y}\right) e^{-nt} \quad (26)$$

Skin Friction:

$$\tau = -\left(\frac{\partial u}{\partial y}\right)_{y=0} = [(1 + A_3 N) A_1 (m_3 - m_1) + A_2 (m_3 - m_2)] e^{-nt} \quad (27)$$

RESULTS AND DISCUSSION

The influence of Magnetic field on the velocity has been studied in Fig.1. It is seen that the Magnetic field increases, velocity decreases in general. Fig.2 shows the velocity profiles for different values of Gr. It is clear that the velocity increases with an increase of Grashof number. The contribution of Prandtl number on the velocity is noticed in Fig. 3. An increase of Prandtl number contributes to the decrease in the velocity field. The velocity profiles for different values of Heat source parameter are represented in Fig. 4. While all other participating parameters are held constant and Heat source is increased, it is seen that the velocity increases in general. Fig. 5 illustrates the velocity for different values of Radiation parameter. The trend shows that the velocity decreases with an increase of Heat source parameter. Fig. 6 represents the velocity profiles for different values of Schmidt number. It is noticed that the velocity of flow field is increasing as the values of Schmidt number increasing. Fig. 7 shows that the effect of Visco elastic parameterλ on velocity field. It is evident that the velocity increases by an increase in λ . Influence of Soret effect on the velocity profiles is illustrated in Fig. 8. It is observed that an increase of Soret effect contributes the increase of velocity of the fluid. Fig. 9 shows that the effect of buoyancy ratio on velocity field. We observe that the velocity increases with an increase of buoyancy ratio. Fig. 10 illustrates the velocity for different values of the Chemical reaction parameter. It is clear that the velocity decreases with an increase of Chemical reaction parameter. The effect of Prandtl number on temperature profiles is illustrated in Fig. 11. It is observed that, while all other participating parameters are held constant and Pr is increased, it is seen that the temperature decreases in general. From Fig. 12 we noticed that the velocity of flow field is decreasing as the value of Radiation parameter is increasing. Fig. 13 shows the variation of temperature for different values of Heat source parameter, it is clear that the temperature increases with an increase of Heat source parameter. From Fig. 14 it is noticed that, while all other participating parameters are held constant and chemical reaction parameter is increased, it is seen that the temperature increases in general. Fig. 15 represents the variation of concentration for different values of Schmidt number, it is seen that the concentration decreases with an increase of Schmidt number. From Fig. 16 it is observed that the concentration decreases with an increase of Heat source parameter. Fig. 17 illustrates the variation of concentration for different values of Soret effect, it is clear that the

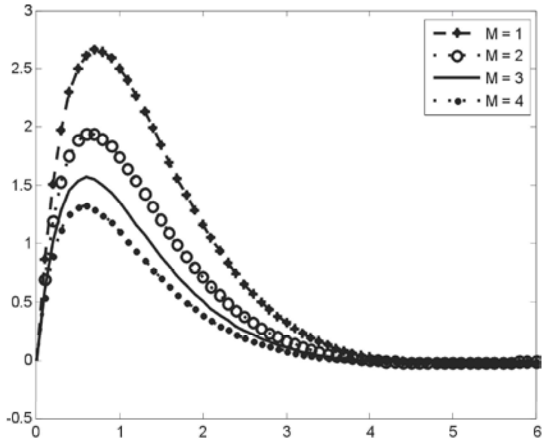

Fig. 1: Velocity profiles for different values of M when Gr=2, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

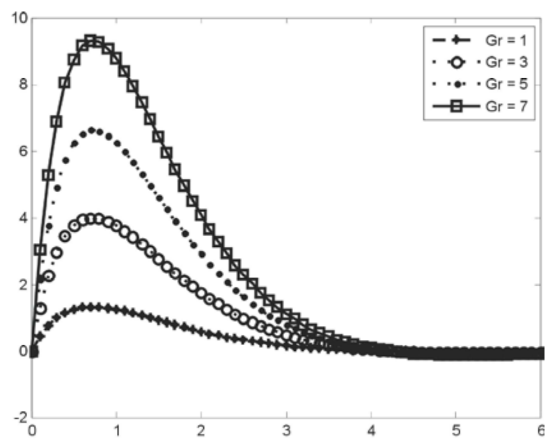

Fig. 2: Velocity profiles for different values of Gr when M=1, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

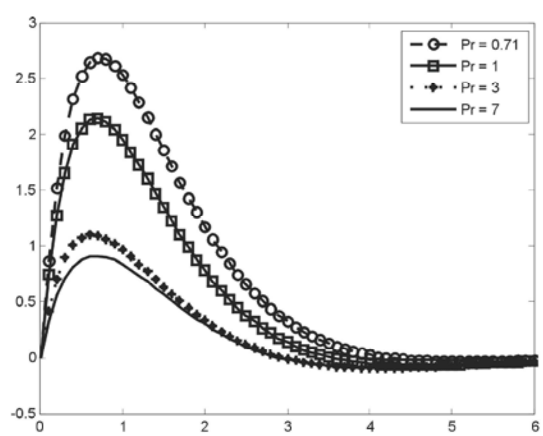

Fig. 3: Velocity profiles for different values of Pr when Gr=2, λ=0.1, M=1, H=0.1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

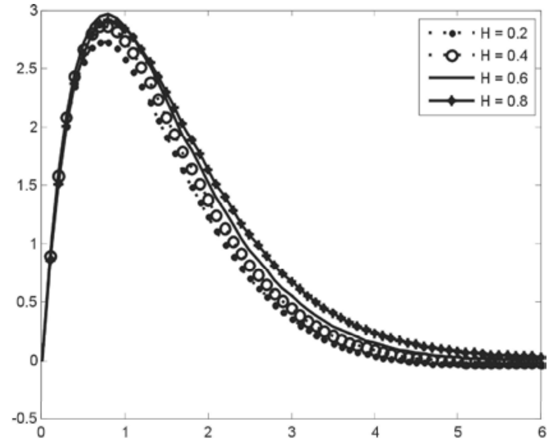

Fig. 4: Velocity profiles for different values of H when Gr=2, λ=0.1, Pr=0.71, M=1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

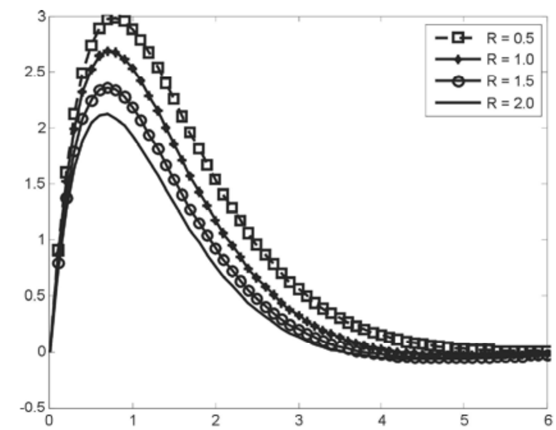

Fig. 5: Velocity profiles for different values of R when Gr=2, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, M=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

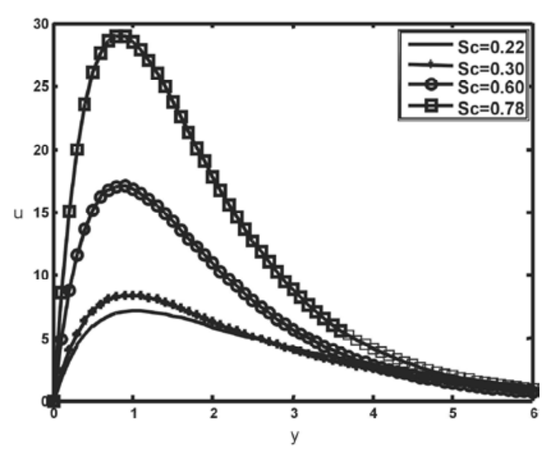

Fig. 6: Velocity profiles for different values of Sc when Gr=2, λ=0.1, Pr=0.71, H=0.1, M=1, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

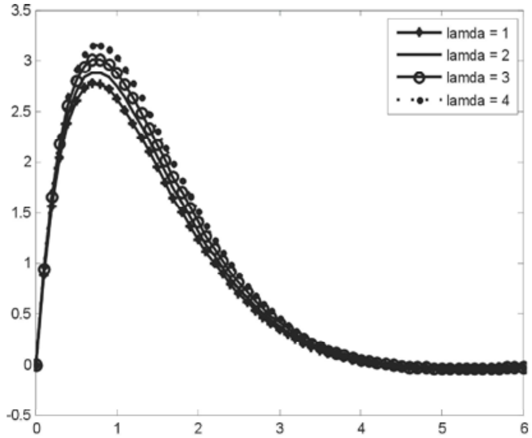

Fig. 7: Velocity profiles for different values of λ when Gr=2, M=1, Pr=0.71, H=0.1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

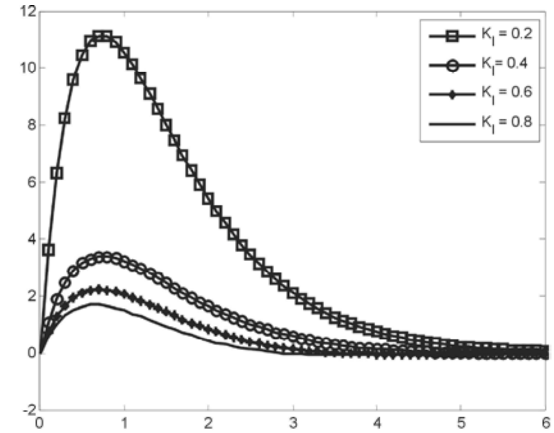

Fig. 10: Velocity profiles for different values of λ when Gr=2, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, R=1, M=1, Sr=0.5, N=2.5, k=100.

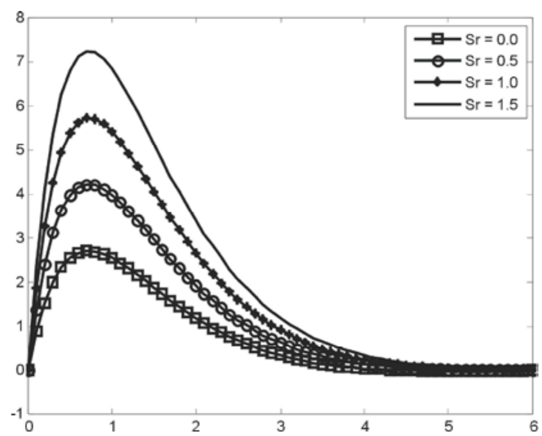

Fig. 8: Velocity profiles for different values of Sr when Gr=2, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, R=1, K_l=0.5, M=1, N=2.5, k=100.

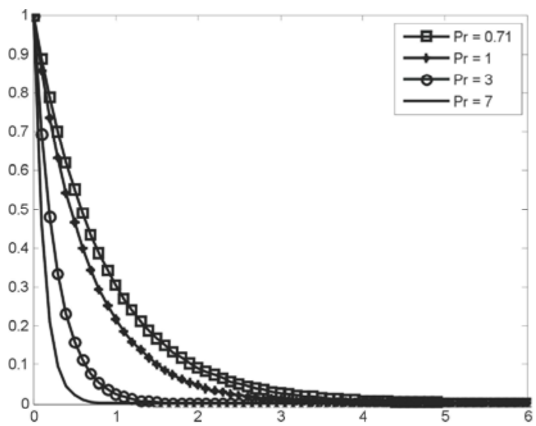

Fig. 11: Temperature profiles for different values of Pr when Gr=2, λ=0.1, M=1, H=0.1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

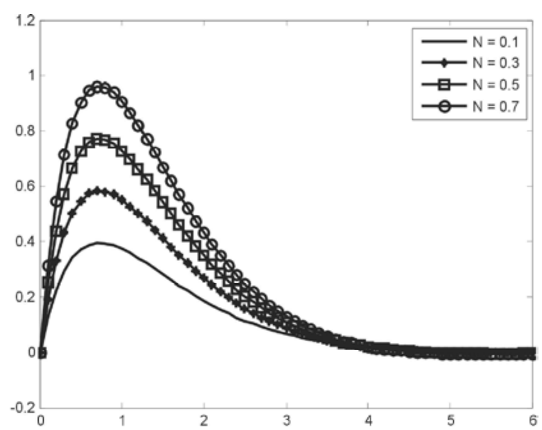

Fig. 9: Velocity profiles for different values of N when Gr=2, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, R=1, K_l=0.5, Sr=0.5, M=1, k=100.

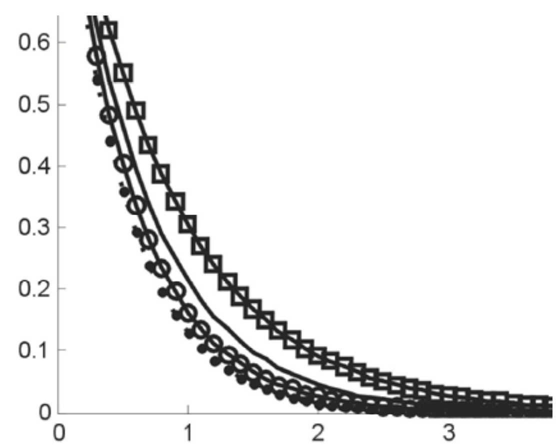

Fig. 12: Temperature profiles for different values of R when Gr=2, λ=0.1, Pr=0.71, H=0.1, Sc=1.5, M=1, K_l=0.5, Sr=0.5, N=2.5, k=100.

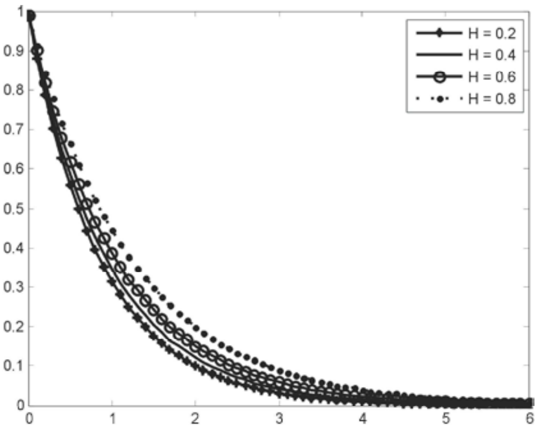

Fig. 13: Temperature profiles for different values of H when Gr=2, λ =0.1, Pr=0.71, M=1, Sc=1.5, R=1, K_l =0.5, Sr=0.5, N=2.5, k=100.

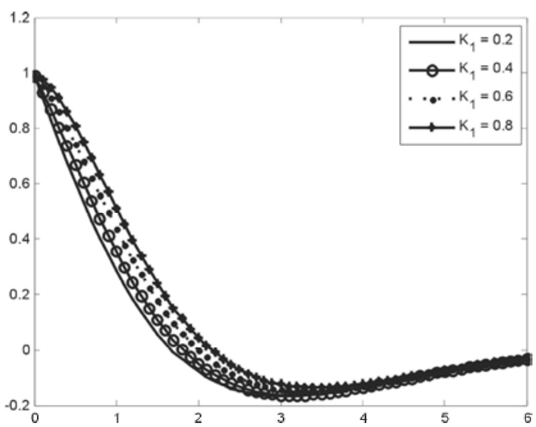

Fig. 14: Concentration profiles for different values of λ when Pr=0.71, H=0.1, Sc=1.5, R=1, Sr=0.5.

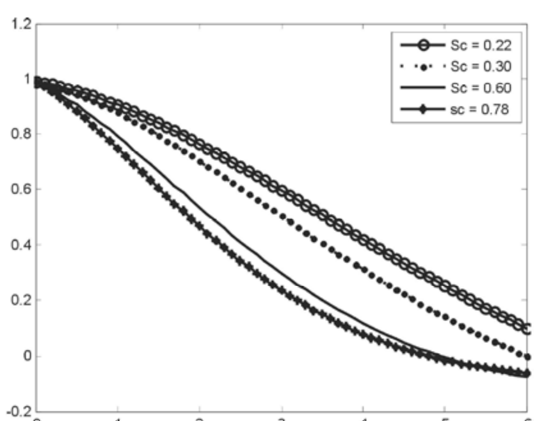

Fig. 15: Concentration profiles for different values of Sc When Pr=0.71, H=0.1, R=1, K_l =0.5, Sr=0.5.

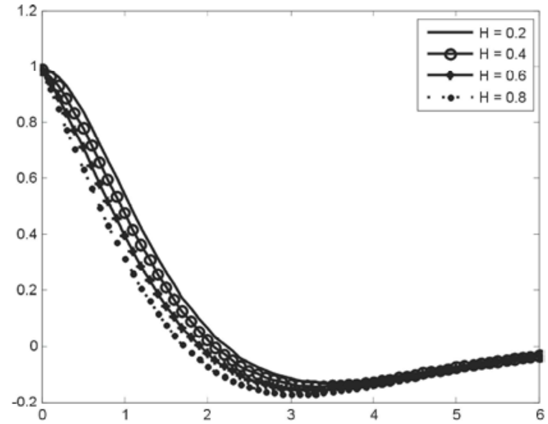

Fig. 16: Concentration profiles for different values of H when Pr=0.71, R=1, K_l =0.5, Sr=0.5, Sc=1.5.

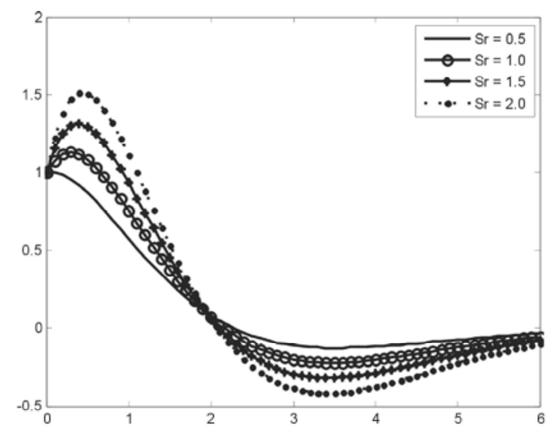

Fig. 17: Concentration profiles for different values of Sr when Pr=0.71, H=0.1, Sc=1.5, R=1, K_l =0.5.

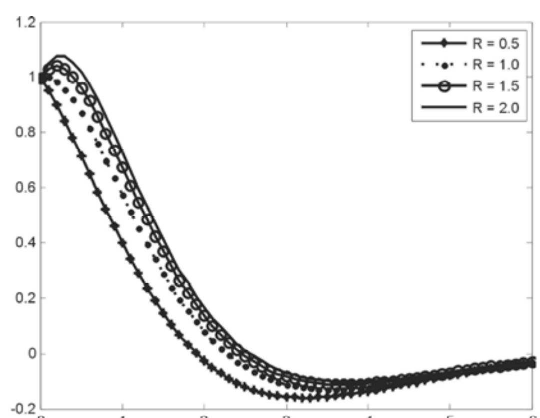

Fig. 18: Concentration profiles for different values of R when Pr=0.71, H=0.1, Sc=1.5, K_l =0.5, Sr=0.5.

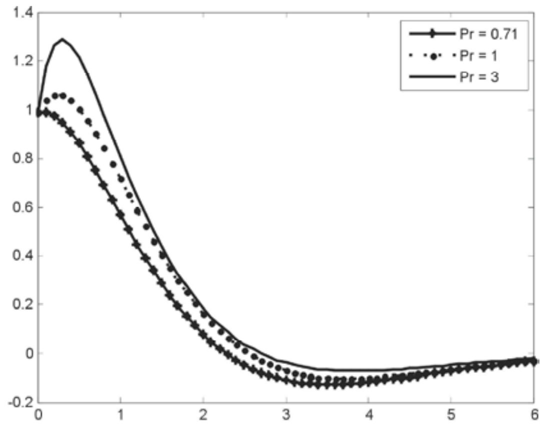

Fig. 19: Concentration profiles for different values of Pr when H=0.1, Sc=1.5, R=1, K_l =0.5, Sr=0.5,

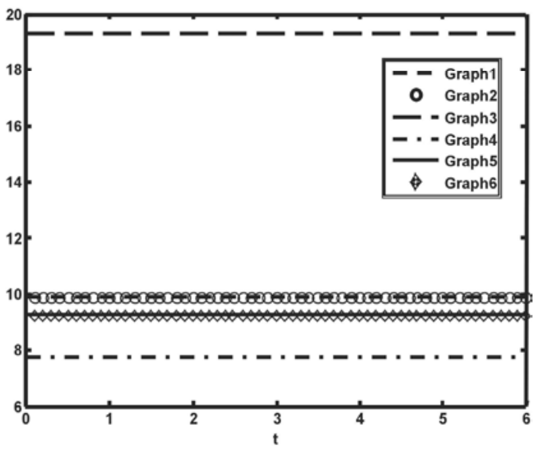

Fig. 20: Variation of Skin friction coefficient

concentration increases with an increase of Soret effect but after y=2 the effect reverses. Fig. 18 represents the profiles of concentration for different values of Radiation parameter, it is observed that the concentration increases with an increase of Radiation parameter. Fig. 19 shows the variation of concentration for different values of Prandtl number, it is seen that the concentration increases with an increase of Prandtl number.

Skin-friction distribution is tabulated in Table 1 and plotted in Fig 20 having six graphs at Pr=0.71, Sc=1.5, H=0.1, N=2.5, R=1, n=0.1, Sr=0.5 and K_l =0.

	Gr	M	K	λ
For Graph-1	2	1	100	0
For Graph-2	2	1	100	0.5
For Graph-3	4	1	100	0.5
For Graph-4	2	2	100	0.5
For Graph-5	2	1	200	0.5
For Graph-6	2	1	100	1

Table 1: Value of skin-friction for different values of Gr, M, K and λ .

t	Graph 1	Graph 2	Graph 3	Graph 4	Graph 5	Graph 6
0	9.83204	10.04723	20.09445	8.20487	10.02092	10.17779
0.2	9.63735	9.84828	19.69655	8.04240	9.82249	9.97626
0.4	9.44652	9.65327	19.30653	7.88315	9.62799	9.77871
0.6	9.25947	9.46212	18.92424	7.72706	9.43735	9.58508
0.8	9.07612	9.27476	18.54951	7.57405	9.25048	9.39528
1	8.89639	9.09111	18.18221	7.42407	9.06730	9.20924

It is noticed that skin friction decreases gradually with increasing time t. It is also from figure-20 that the skin friction increases with an increase of Gr, M and λ , but it decreases with the increase in M.

CONCLUSIONS

- Velocity increases with the increase in Grashof number, Schmidt number, Soret effect, Heat source, Buoyancy ratio and Visco elastic parameter.
- Velocity decreases with the decreases of Prandtl number and Chemical reaction parameter.
- Skin friction increases with the increase in Grashof number, magnetic field parameter and Visco elastic parameter.
- It is observed that velocity, temperature profiles are more influenced by effects physical parameters.

REFERENCES

1. Gebhart, B. and L. Pera, 1971. The nature of vertical convection flows resulting from the combined buoyancy effects of thermal and mass diffusion, Int. J. Heat Mass Transfer, 14, 2025.
2. Singh, N.P. and A.K. Singh, 2007. MHD free convection and mass transfer flow past a flat plate, The Arabian J. Sci. and Engg., 32, 1A, 93.
3. Sandeep, N. and V. Sugunamma, 2013. Effect of Inclined Magnetic Field on Unsteady Free Convective Flow of Dissipative Fluid past a Vertical Plate. World Applied Sciences Journal 22(7): 975-984.
4. Chamkha, A.J., 2004.Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption, Int. J. Eng. Sci., 24: 217-230.
5. Hady, F.M., R.A. Mohamed and A. Mahdy, 2006. MHD free convection flow along a vertical wavy surface with heat generation or absorption effec, Int. Comm. Heat mass Transfer, 33: 1253-1263.
6. Chien-Hsin-Chen, 2004. Combined heat and mass transfer in MHD free convection from a vertical surface with Ohmic heating and viscous dissipation, Int. J. Engg. Science, 42: 699-713.

7. Muthucumaraswamy, R. and P. Ganesan, 2002. Heat transfer effects on flow past an impulsively started semi-infinite vertical plate with uniform heat flux. Nuclear Engineering and Design, 215: 243-250.
8. Raptis, A. and C. Perdikis, 1999. Radiation and free convection flow past a moving plate. Int. J. of App. Mech. And Engg., 4: 817-821.
9. Ghosh, S.K., S. Rawat, O.A. Beg and T.A. Beg, 2010. Thermal radiation effects on unsteady hydromagnetic gas flow along an inclined plane with indirect natural convection. Int. J. Appl. Math and Mech., 6(13): 41-57.
10. Rajesh, V. and S. Vijay Kumar Verma, 2010. Radiation effects on MHD flow through a porous medium with variable temperature or variable mass diffusion. Int. J. Appl. Math and Mech., 6(1): 39-57.
11. Rajesh, V., 2010. Radiation effects on MHD free convection flow near a vertical plate with ramped temperature. Int. J. Appl. Math and Mech., 6(21): 60-77.
12. Chaudhary, R.C. and A. Jain, 2009. MHD heat and mass diffusion flow by natural convection past a surface embedded in a porous medium, Theoret. Appl. Mech., 36(1): 1.
13. Sandeep, N., A. Vijaya Bhaskar Reddy and V. Sugunamma, 2012. Effect of Radiation and Chemical Reaction on Transient MHD Free Convective Flow over a Vertical Plate Through Porous Media, Chemical and Process Engineering Research, 2: 1-9.
14. Beg Anwa, O., A.Y. Bakier and V.R. Prasad, 2002. Numerical study of free convection magnetohydrodynamic heat and mass transfer from a stretching surface to a saturated porous medium with Soret and Dufour effects, Computational Material Science, 46: 57-65.
15. Olanrewaju Philip Oladapo, 2009. Dufour and Soret effects of a transient free convective flow with Radiative Heat Transfer Past a Flat Plate Moving through a Binary Mixtur, Pasific Journal of Science and Technology, 11(1).
16. Anghel, M., H.S. Takhar and I. Pop, 2000. Dufour and Soret effects on free-convection boundary layer over a vertical surface embedded in a porous medium,Studia Universitatis Babes-Bolyai, Mathematica, Vol. XLV, pp: 11-21.
17. Eldabe, N.T., A.G. El-Saka and A. Fouad, 2004. Thermal-diffusion and diffusion-thermo effects on mixed free-forced convection and mass transfer boundary layer flow for non-Newtonian fluid with temperature dependent viscosity,Appl. Math. and Compt., 152: 867-883.