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Effect of Chemical Reaction and Radiation on MHD Flow along a moving Vertical Porous Plate with Heat Source and Suction

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Abstract:

In this article, we consider effects of force buoyancy and magnetohydrodynamic on convective mass and heat transfer flow past a touching vertical porous plate in the incidence of thermal radiation and chemical reaction. The governing partial differential equations are concentrated to a system of self-similar equations using the similarity transformations. The resulting equations are solved numerically using the 4th order Runge-Kutta method along with the shooting technique. The outcomes are found for the velocity, temperature, concentration, Nusselt number, Sherwood number and skin-friction. The effects of various parameters on flow variables are illustrated graphically, and the physical aspects of the problem are discussed.

Key words: MHD, porous medium, heat and mass transfer, thermal radiation, chemical reaction.

INTRODUCTION

In recent years, the problems of free convective heat and mass transfer flows through a porous medium under the effect of a magnetic field have attracted the attention of many researchers because of their possible applications in many branches of technology and science, such as its applications in transportation cooling of re-entry vehicles and rocket boosters, cross-hatching on ablative surfaces and film vaporization in combustion chambers.

R.Wooding[2] has studied steady State Free Thermal Convection of Liquid in a Saturated Permeable Medium. Rapitset.al.,[3] have analyzed magneto Hydrodynamics Free Convective Flow and Mass Transfer through a porous Medium Bounded by an Infinite Vertical Porous Plate with constant Heat Flux. Abdus et.al.,[4]have been presented unsteady free-convection interaction with thermal Radiation in a boundary layer flow past a vertical porous plate. Bakier[5] was investigated thermal radiation effects on horizontal surfaces in saturated porous medium. England [6] studied thermal radiation effects on the laminar free convection boundary layer of an absorbing gas, J. of Heat Transfer. Acharya et.al.,[7] analyzed the magnetic Field Effects on the Free Convection and Mass Transfer Flow through Porous Medium with constant Suction and constant Heat Flux. Das et.al.,[8] have discussed three-Dimensional Free Convective MHD Flow and Heat Transfer through Porous Medium. Muthucumaraswamy et.al.,[9]analyzed effect of a Chemical Reaction on a Moving Isothermal Vertical Surface with Suction. Kim et.al.,[10] have studied heat and mass transfer in MHD micropolar flow over a vertical moving porous plate in a porous medium. Makinde [11] presented free Convection Flow with Thermal Radiation and Mass Transfer Past a Moving Vertical Porous Plate. Ibrahim et.al.,[12] gave an exact solution for effect of the 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. Mostafa et.al.,[13] studied thermal radiation effect on unsteady MHD free convection flow past a vertical plate vertical plate with temperature-dependent viscosity. Later some authors studied on MHD, chemical reaction and radiation effects, see[1,14-26].

Henceforward, the impartial of this research paper is to analyses the effect of radiation on MHD free convection flow past along a moving vertical porous plate in presence of thermal radiation and chemical reaction. The governing equations are changed by the resultant dimensionless equations are resolved numerically by using shooting technique and using unsteady similarity transformation. The effects of different governing parameters on the concentration, temperature, velocity, are obtained.

MATHEMATICAL ANALYSIS

Consider an unsteady two-dimensional free convection flow of a viscous incompressible electrical conducting, thermal radiating and chemical reacting fluid flow along a moving vertical porous plate immersed in a porous medium. The x-axis is taken along the plate in the upward direction and y-axis is taken normal to the plate. The fluid is considered to be a gray, absorbing emitting radiation but non-scattering medium and the Rosseland approximation is used to describe the radiation heat flux in the energy equation. A uniform magnetic field is applied in the direction perpendicular to the plate. The fluid is assumed to be slightly conducting, and hence the magnetic Reynolds number is much less than unity and the induced magnetic field is negligible in comparison with the applied magnetic field. It is assumed that the external electrical field is zero and the electric field due to the polarization of charges is negligible. Initially, the plate and the fluid are at the same temperature T_∞ and the concentration C_∞. At time t > 0, the plate temperature and concentration are raised to T_w and C_w respectively and are maintained constantly thereafter. It is also assumed that all fluid properties are constant except that the influence of the density variation with temperature and concentration in the body force term (Boussinesq's approximation). Also, there is chemical reaction between the diffusing species and the fluid. The foreign mass present in the flow is assumed to be at low level and hence Soret and Dufour effects are negligible. Under these assumptions, the governing boundary layer equations of the flow field are:

Conservation of mass:

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

Conservation of momentum:

$$\begin{aligned} \frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y} &= \nu\left(1+\frac{1}{\beta_0}\right)\frac{\partial^2 u}{\partial y^2} + g\beta\left(T-T_\infty\right) \\ &\quad + g\beta^*\left(C-C_\infty\right) - \left(\frac{\sigma B_0^2}{\rho} + \frac{\nu}{K^*}\right)u \end{aligned} \tag{2}$$

Conservation of energy (Heat):

$$\rho c_p\left(\frac{\partial T}{\partial t} + v\frac{\partial T}{\partial y}\right) = k\frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y} + \frac{Q}{\rho cp}\left(T-T_\infty\right) \tag{3}$$

Conservation of species (Concentration):

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

where *u* and *v* are the velocity components in *x* and *y* directions respectively, σ -the electrical conductivity of the fluid, B_0 -the magnetic induction, *k*-the thermal conductivity, Kr^* -the chemical reaction parameter. q_r -the local radiative heat flux ,*C*-the species concentration in the boundary layer, C_∞ -the species concentration in fluid far away from the plate, *D*-the mass diffusivity T_∞ -the temperature of the fluid far away from the plate, *T*-the temperature of the fluid in the boundary layer, ν -the kinematic viscosity, τ -Thermo porosity parameter,Q- heat source parameter, β_0 - Casson parameter, *g*-the acceleration due to gravity, ρ -the fluid density, β, β^* -the thermal and concentration expansion coefficients respectively, and α -the thermal diffusivity.

The second and third terms on the right hand side of the momentum equation (2) denote the thermal and concentration buoyancy effects respectively.

The boundary conditions for the velocity, temperature and concentration fields are:

$$\begin{aligned} &t \le 0: u = 0, v = 0, T = T_\infty, C = C_\infty \quad \text{for all} \quad y \\ &t > 0: \begin{cases} u = U, v = v(t), T = T_w, C = C_w \ \text{ at } \ y = 0 \\ u \to 0, v \to 0, T = T_\infty, C = C_\infty \ \text{ as } \ y \to \infty \end{cases} \end{aligned} \tag{5}$$

where U is said to be the plate characteristic velocity. Thermal radiation is expected in a unidirectional flux in y - direction i.e., q_r by using Rosseland approximation value the radiative heat flux q_r is given by

$$q_r = -\frac{4\sigma_s}{3k_e}\frac{\partial T^4}{\partial y} \tag{6}$$

It should be noted that by using the Rosseland approximation, the present analysis is limited to optically thick fluids. If temperature differences within the flow are sufficiently small, then equation (6) can be linear zed by expanding T^4 in Taylor series about T_∞ which after neglecting higher order terms takes the form:

$$T^4 \approx 4T_\infty^3 T - 3T_\infty^4 \tag{7}$$

In view of equations (6) and (7), equation (3) reduces to:

$$\rho c_p\left(\frac{\partial T}{\partial t} + v\frac{\partial T}{\partial y}\right) = k\frac{\partial^2 T}{\partial y^2} + \frac{16\sigma_s}{3k_e}T_\infty^3\frac{\partial^2 T}{\partial y^2} + Q_0\left(T-T_\infty\right) \tag{8}$$

We introduce similarity variables and the dimensionless quantities i.e.,

$$\begin{aligned} &\eta = \frac{y}{2\sqrt{\nu t}}, u = Uf(\eta), \theta = \frac{T-T_\infty}{T_w-T_\infty}, \phi = \frac{C-C_\infty}{C_w-C_\infty}, \\ &Gc = \frac{4g\beta^*\left(C_w-C_\infty\right)t}{U}, Gr = \frac{4g\beta\left(T_w-T_\infty\right)t}{U}, \\ &M = \frac{4\sigma B_0^2 t}{\rho}, K^* = \frac{K\nu}{tc}, R = \frac{16\sigma_s\left(T_w-T_\infty\right)^3}{3k_e k}, \\ &N = \frac{T_\infty}{T_w-T_\infty}, \Pr = \frac{\mu c_p}{k}, Sc = \frac{\nu}{D}, Kr^* = \frac{Kr}{4t} \end{aligned} \tag{9}$$

From equation (1), v is either a constant or a function of time. Following (Singh and Soundalgekar [21], we choose

$$v = -c\left(\frac{\nu}{t}\right)^{\frac{1}{2}} \tag{10}$$

where $c > 0$ is the suction parameter.

In view of equations(10)and (9), the equations (8), (2) and (4) reduce to

$$f''\left(1+\frac{1}{\beta}\right) + 2\left(\eta+c\right)f' + Gr\theta + Gc\phi - \left(M+\frac{1}{K}\right)f = 0 \tag{11}$$

$$\theta'' + 2\left(\eta+c\right)\Pr\theta' + R\left(3(N+\theta)^2\theta'^2 + (N+\theta)^3\theta''\right) + \frac{Q\theta}{\Pr} = 0 \tag{12}$$

$$\phi'' + Sc\left[2\left(\eta+c\right)\phi' - Kr\phi + \tau\left(\phi\theta'' + \phi'\theta'\right)\right] = 0 \tag{13}$$

where the primes denote the differentiation with respect to η, $\Pr$ is the Prandtl number, M is the magnetic field parameter, Gr is the thermal Grashof number, Sc is the Schmidt number, R is radiation parameter, Gc is the modified Grashof number, Kr is the chemical reaction parameter ,N is the temperature difference parameter. τ -Thermo porosity parameter, Q-heat source parameter and β_0 -Casson parameter.

The corresponding dimensionless boundary conditions are

$$\begin{cases} f = 1, \theta = 1, \phi = 1, & \text{at} \quad \eta = 0 \\ f \to 0, \ \ \theta \to 0, \ \ \phi \to 0 & \text{as} \ \ \eta \to \infty \end{cases} \tag{14}$$

SOLUTION OF THE PROBLEM

The set of coupled non-linear governing boundary layer equations (11)-(13) together with the boundary conditions (14) are solved numerically by using Runge-Kutta fourth order technique along with shooting method. First of all, higher order non-linear differential Equations (11)-(13) are converted into simultaneous linear differential equations of first order and they are further transformed into initial value problem by applying the shooting technique. The resultant initial value problem is solved by employing Runge-Kutta fourth order technique. The step size $\Delta\eta = 0.005$ = 0.05 is used to obtain the numerical solution with decimal place accuracy as the criterion of convergence.

RESULTS AND DISCUSSION

The problem considering for unsteady MHD free convection fluid flow past a moving vertical porous plate embedded in porous medium with thermal radiation and chemical reaction in presence of suction. The numerical values of velocity (f), temperature (θ) and concentration (ϕ) with the boundary layer have been computed for different parameters as the thermal Grashof number Gr, solutal Grashof number Gc, magnetic field parameter M, Permeability parameter K, Prandtl number Pr, thermal radiation parameter R, Schmidt number Sc, τ -Thermo porosity parameter,Q- heat source parameter, β_0 - Casson parameter and suction parameter c. In the present study, we adopted the following default parametric values: Gr = 5, Gc = 10, M = 1.0, K = 0.5, Pr = 0.71, R = 0.5, N = 0.1, Sc = 0.6, Kr = 0.5, c = 0.5, τ =0.01,B=10,c=0.5 and Q=0.05. All the graphs therefore correspond to these values unless specifically indicated on the appropriate graph.

The effect of Mass Grashof number on the velocity field has been illustrated in figure.1. It is observed that as the mass Grashof number (Gm) increases the velocity field decreases. The effect of suction parameter (c) on the cross velocity of the flow field is shown in Fig. (2) for four different values of the suction parameter. The cross flow velocity is found to decrease with the increase of suction parameter. Fig. (3) depicts the effect of suction parameter on the temperature of the flow field. In presence of growing suction, the temperature of the flow field is found to decrease. Further, in absence of suction the temperature profile becomes very much linear. The influence of the suction parameter on the concentration profile is seen in Fig. 8. The concentration profile is a decreasing function of suction parameter c. This is in accordance with the fact that the fluid experiences a resistance upon increasing the friction between its layers. As a consequence, there is a decrease in concentration.

In figure 5,7,10 and 18 fluid velocity profile 'V' increases on increment in Gc, K, Pr and τ while decreases in figure 1,2,6,8,11,13,16 and 20 on increment in Gr, c, M, N, Q Sc, Kr and R. The Temperature profile Theta in figure 15, 12 and 21 increases on increment in N, Q and R. Temperature for short time increases and then decreases. Temperature increases sharply with increase in N, Q and R.. And temperature in figure 3, 9, decreases on increment of c and Pr. In figure 4,14 and 17 the concentration profile decreases on increment in c, Sc and Kr. Since the concentration is taken inversely to the time. In figure 19 the concentration profile increases on increment in τ .

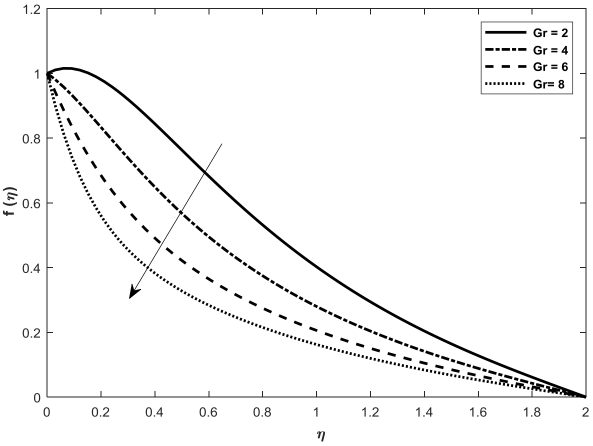

Fig. 1: Velocity profiles for dissimilar values of Grashoff Number (Gr).

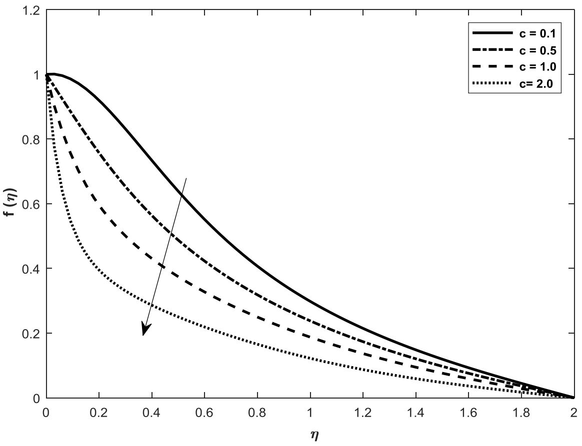

Fig. 2: Velocity profiles for dissimilar values of suction parameter (*c)*

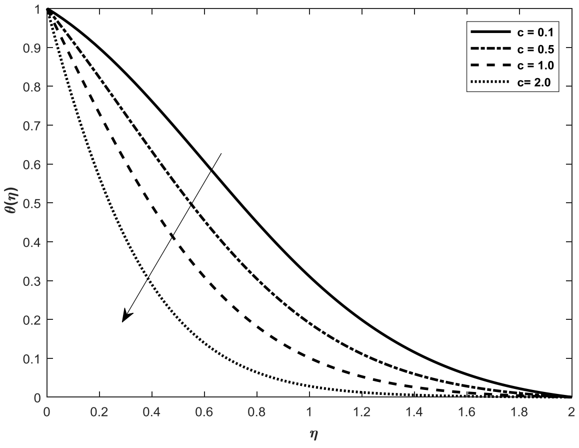

Fig. 3: Temperature profiles for dissimilar values of suction parameter (*c)*

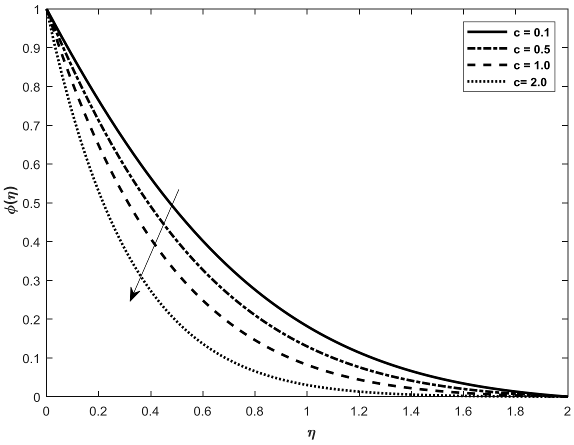

Fig. 4: Concentration profiles for dissimilar values of suction parameter (*c)*

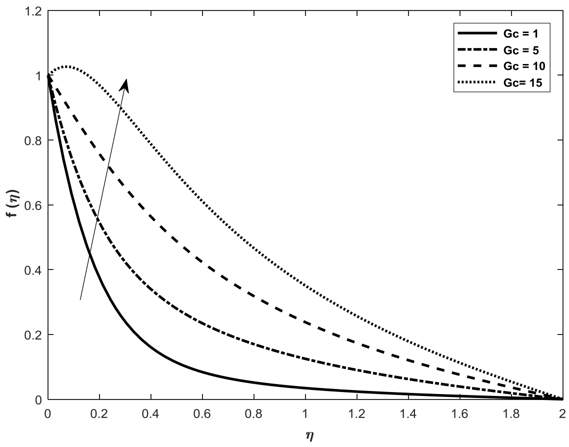

Fig. 5: Velocity profiles for dissimilar values of solutal Grashof number (*Gc)*

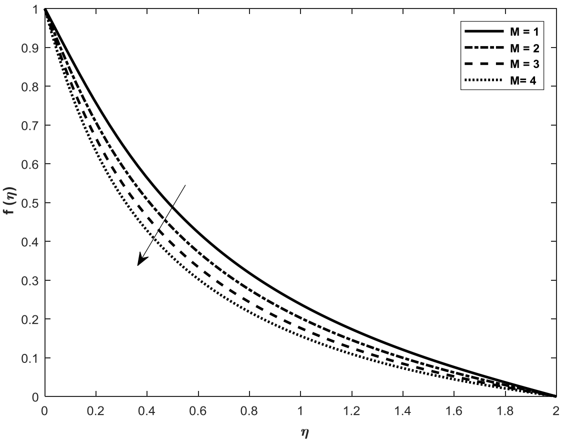

Fig. 6: Velocity profiles for dissimilar values of magnetic field parameter (M*)*

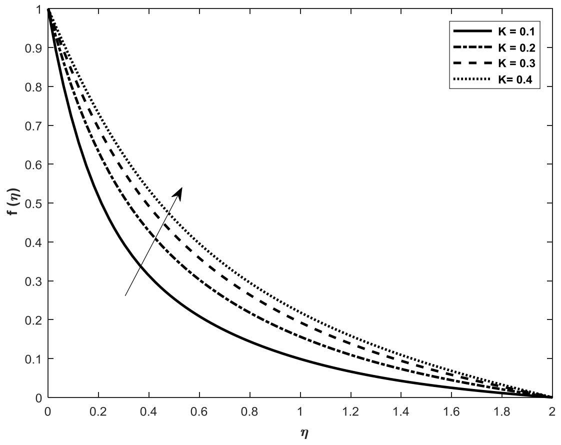

Fig. 7: Velocity profiles for dissimilar values of Permeability parameter (K*)*

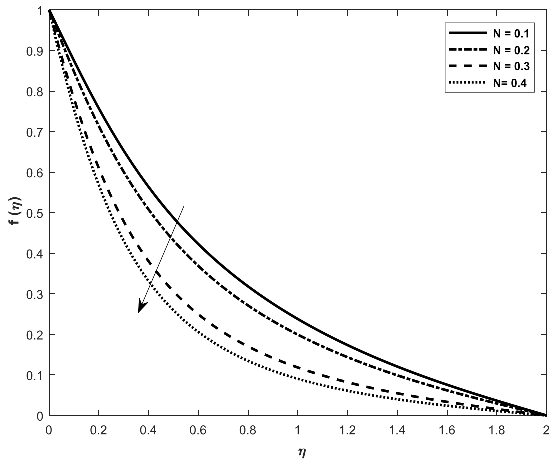

Fig. 8: Velocity profiles for dissimilar values of temperature difference parameter N

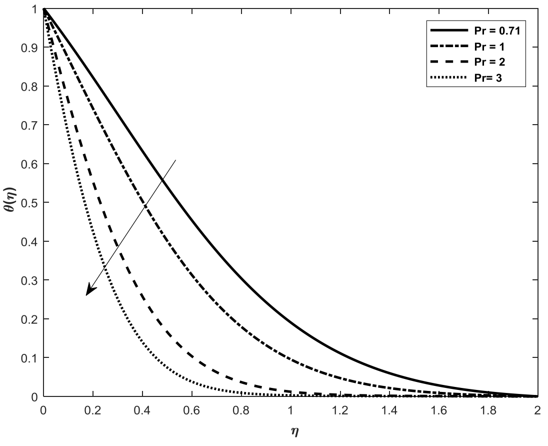

Fig. 9: Temperature profiles for dissimilar values of Prandtl Number(Pr)

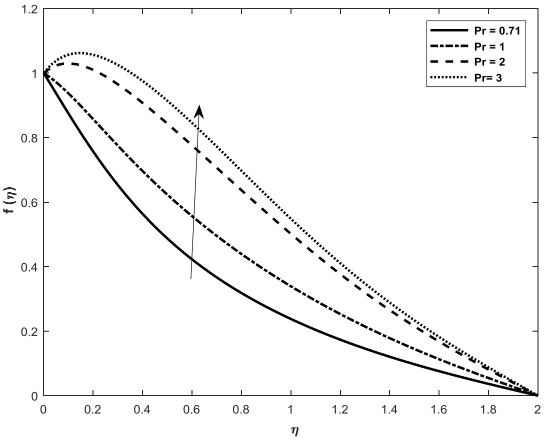

Fig. 10: Velocity profiles for dissimilar values of Prandtl Number(Pr)

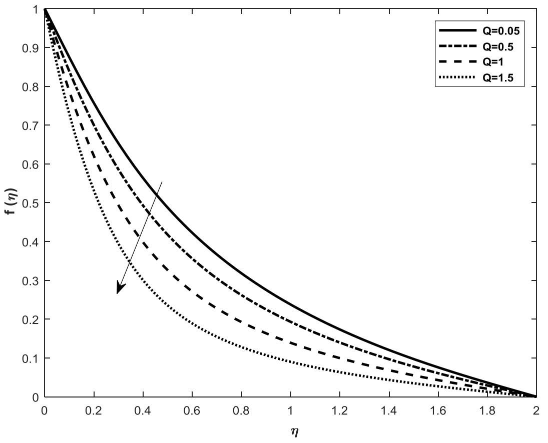

Fig. 11: Velocity profiles for dissimilar values of Q

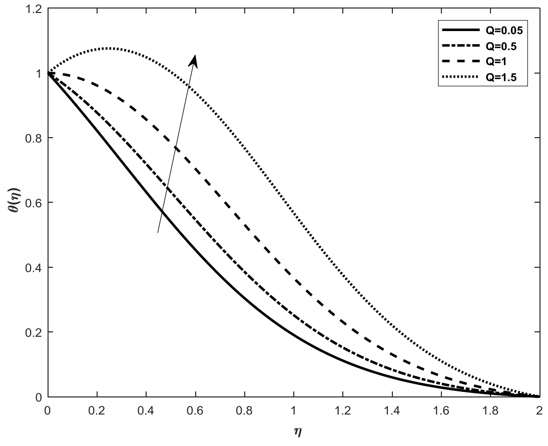

Fig. 12: Temperature profiles for dissimilar values of Q

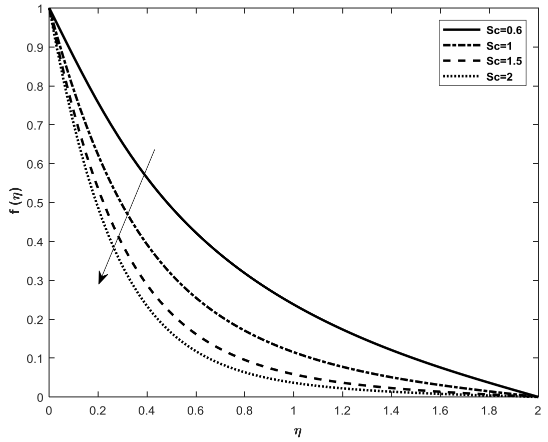

Fig. 13: Velocity profiles for dissimilar values of Schmidt Number(Sc)

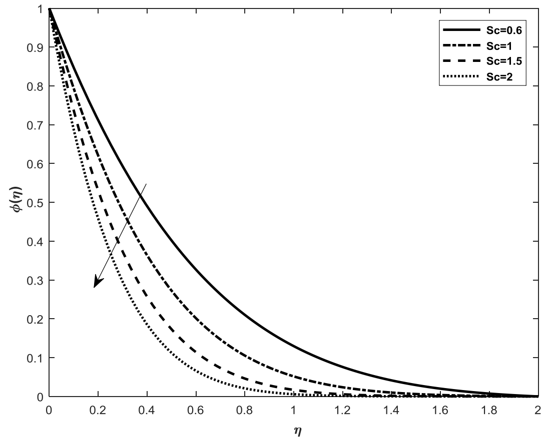

Fig. 14: Concentration profiles for dissimilar values of Schmidt Number(Sc)

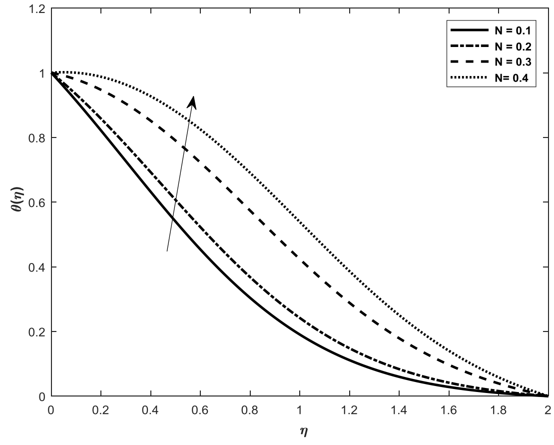

Fig. 15: Temperature profiles for dissimilar values of temperature difference parameter N

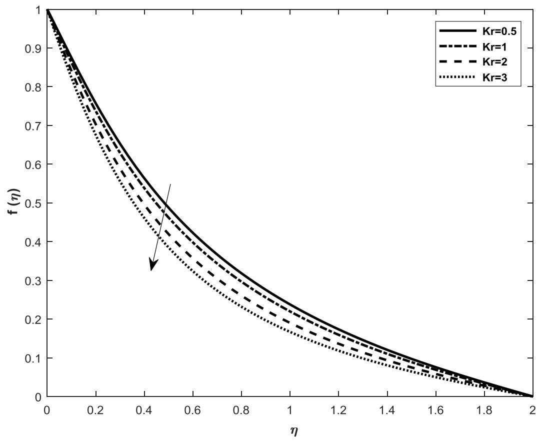

Fig. 16: Velocity profiles for dissimilar values of Chemical reaction parameter (Kr)

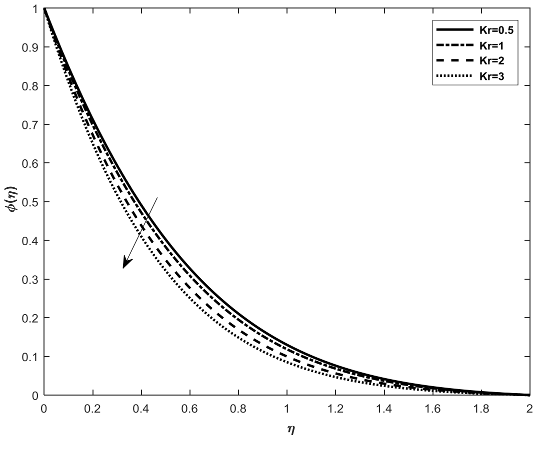

Fig. 17: Concentration profiles for dissimilar values of Chemical reaction parameter(Kr)

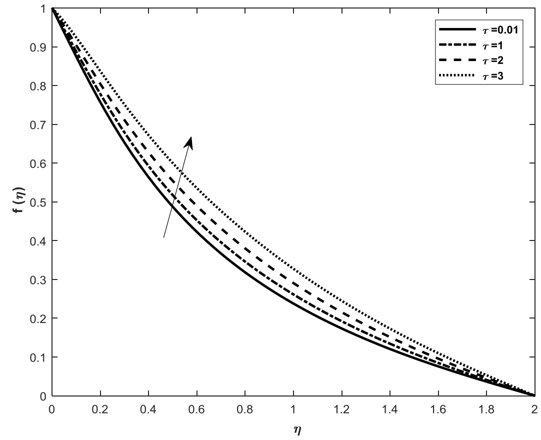

Fig. 18: Velocity profiles for dissimilar values of τ

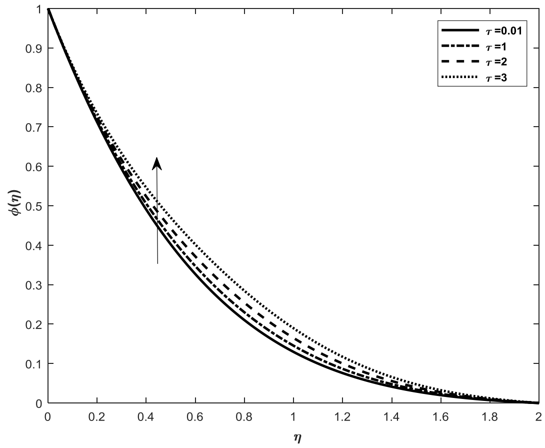

Fig. 19: Concentration profiles for dissimilar values of τ

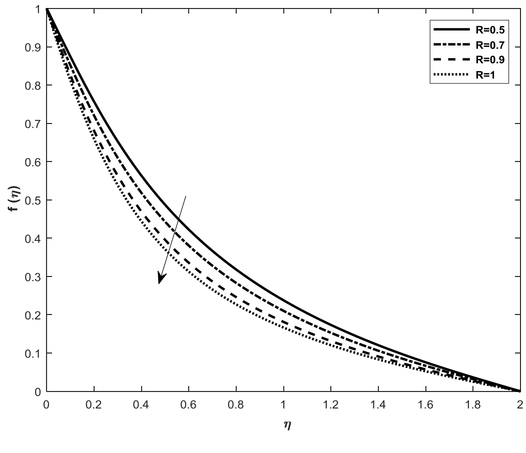

Fig. 20: Velocity profiles for dissimilar values of thermal radiation parameter(R)

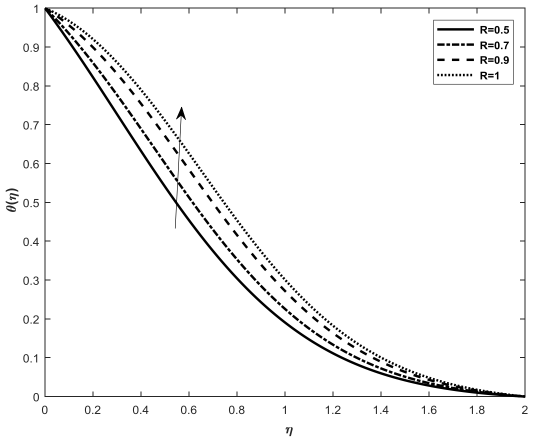

Fig. 21: Temperature profiles for dissimilar values of thermal radiation parameter(R)

CONCLUSIONS

In this research paper, thermal radiation properties on MHD free convection flow through a moving vertical porous plate embedded in a porous medium is analyzed. The expressions for the concentration, temperature, and velocity deliveries which are the equations governing the flow are numerically solved by the 4th-order Runge-Kutta method along with shooting technique.

The following conclusions:

1. Velocity profile increases on increment in Gc, K, Pr and τ while decreases in Gr, c, M, N, Q Sc, Kr and R increases.
2. The Temperature profiles are increases on increment in N, Q and R. Temperature for short time increases and then decreases. Temperature increases sharply with increase in N, Q and R. And temperature profiles are decreases on increment of c and Pr.
3. The concentration profile are decreases on increment in c, Sc and Kr. Since the concentration is taken inversely to the time. The concentration profile increases on increment in τ .

REFERENCES

[1]. G. Darcy, “Lee Fort Airs Publication La villededijan Victor Dalonat,” Paris, Vol. 1, 1857, p. 41.

[2]. R. Wooding, “Steady State Free Thermal Convection of Liquid in a Saturated Permeable Medium,” Journal of Fluid Mechanics, Vol. 2, No. 3, 1957, pp. 273-285. doi:10.1017/S0022112057000129

[3]. Rapits and N. Kafousias, “Magneto Hydrodynamics Free Convective Flow and Mass Transfer through a Porous Medium Bounded by an Infinite Vertical Porous Plate with constant Heat Flux,” Canadian Journal of Physics, Vol. 60, No. 12, 1982, pp. 1724-1729.

[4]. AbdusSattar, M.D., Hamid Kalim, M.D., “Unsteady free-convection interaction with thermal Radiation in a boundary layer flow past a vertical porous plate”, J. Mathematics and Physical Sciences, Vol. 30, pp.25-37, 1996.

[5]. Bakier, A.Y., Gorla, R.S.R., “Thermal radiation effects on horizontal surfaces in saturated porous medium”, Transport Porous Media, Vol. 23, pp. 357-61,1996.

[6]. England, W. G. and Emery, A. F. (1969): Thermal radiation effects on the laminar free convection boundary layer of an absorbing gas, J. of Heat Transfer, Vol. 91, pp. 37-44.

[7]. M. Acharya, G. C. Das and L. P. Singh, “Magnetic Field Effects on the Free Convection and Mass Transfer Flow through Porous Medium with Constant Suction and Con- stant Heat Flux,” Indian Journal Pure Applied Mathematics, Vol. 31, No. 1, 2000, pp. 1-18.

[8]. U. N. Das, N. Ahmed and D. Sharma, “Three-Dimensional Free Convective MHD Flow and Heat Transfer through Porous Medium,” FJAM, Vol. 4, No. 3, 2000, pp. 357- 369.

[9]. Muthucumaraswamy, R., “Effect of a Chemical Reaction on a Moving Isothermal Vertical Surface with Suction”, ActaMechanica, Vol. 155, pp. 65-70, 2002.

[10]. Kim, J.Y., “Heat and mass transfer in MHD micropolar flow over a vertical moving porous plate in a porous medium”, Transport in Porous Media, Vol. 56, pp. 17–37, 2004.

[11]. Makinde, O.D., “Free Convection Flow with Thermal Radiation and Mass Transfer Past a Moving Vertical Porous Plate”, Int. Communications on Heat and Mass Transfer, Vol. 32, pp. 1411-1419, 2005.

[12]. Ibrahim, F.S., Elaiw, A.M., Bakr, A.A., 2008, “Effect of the 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”, Communication in Nonlinear Science and Numerical Simulation, Vol. 13, pp. 1056-1066

[13]. Mostafa, A., Mahmoud, A., 2009, “Thermal radiation effect on unsteady MHD free convection flow past a vertical plate vertical plate with temperature-dependent viscosity”, The Canadian Journal of Chemical Engineering, Vol. 87, pp. 57-52.

[14]. G.V.R. Reddy And Y.Hari Krishna: ‘Soret And Dufour Effects On MhdMicropolar Fluid Flow Over A Linearly Stretching Sheet, Through A Non -Darcy Porous Medium’, Int. J. of Applied Mechanics and Engineering(Scopus), 2018, vol.23, No.2, pp.485-502,DOI: 10.2478/ijame-2018-0028.

[15]. G. V. Ramana Reddy And Y. Hari Krishna, MHDFree Convective Flow Of Casson Fluid Past Over An Oscillating Vertical Porous Plate, International Journal of Mathematical Archive-9(5), 2018, 119-126

[16]. N Vijaya, Y Hari Krishna, K Kalyani, GVR Reddy ,Soret And Radiation Effects On An Unsteady Flow Of A Casson Fluid Through Porous Vertical

Channel With Expansion And Contraction, - Frontiers in Heat and Mass Transfer (FHMT) (Scopus & WoS), 11,2018,1-11

[17]. G VRReddy: Numerical Solutions of Unsteady MHD Flow Heat Transfer over a Stretching Surface with Suction or Injection - FDMP-Fluid Dynamics & Materials Processing (Scopus),14(3),2018,213-222.

[18]. Y. Hari Krishna, G.VenkataRamana Reddy and O.D. Makinde: Chemical Reaction Effect on MHD Flow of Casson Fluid with Porous Stretching Sheet, Defect and Diffusion Forum(Scopus) ,Vol. 389,2018, pp 100-109

[19]. M. V. Ramana Murthy, G. VenkataRamana Reddy, B. Santhosha; 'Radiation and Chemical Reaction Effects on MHD Flow Past Semi-Infinite Porous Plate in the Presence of Heat and Mass Transfer', International Journal of Civil, Mechanical & Production Engineering,3(2), 2017

[20]. M.V.Ramana Murthy, G.V.Ramana Reddy; 'Radiation and Chemical Reaction Effects on Unsteady MHD Free Convective Periodic Heat Transport Modeling In a Saturated Porous Medium for A rotating System', International Journal on Recent and Innovation Trends in Computing and Communication ,5(6), 994 – 1001,2017

[21]. Ramana Murthy MV, Bhikshu NL and Venkata Ramana G; 'Effects of Radiation and Chemical Reaction on MHD Flow Past an Oscillating Inclined Porous Plate with Variable Temperature and Mass Diffusion', International Journal of Chemical Sciences, 15(3),1-12, 2017

[22]. Buggaramulu, J; Venkatakrishna, M; Harikrishna.Y; 'Unsteady MHD Free Convective Heat and Mass Transfer Flow Past a Vertical Porous Plate in the Presence of Radiation and Chemical Reaction', International Journal of Emerging Research in Management &Technology ,6(10),116-129, 2017.

[23]. Kamala, G; Murthy, MV Ramana; Bhagyya, D; 'MHD Free Convective Flow Past a Vertical Porous Plate in a Porous Medium in the Presence of Soret and Dofour Effects', International Journal of Emerging Research in Management &Technology ,6(8),1-18, 2017.

[24]. K Suneetha, SM Ibrahim, GVR Reddy :Radiation and heat source effects on MHD flow over a permeable stretching sheet through porous stratum with chemical reaction Multidiscipline Modeling in Materials and Structures 14 (5), 1101-1114,2018

[25]. P. Nagasantoshi, G. V. Ramana Reddy, M. Gnaneswara Reddy : Heat and Mass Transfer of Non-Newtonian Nanofluid Flow Over a Stretching Sheet with Non-Uniform Heat Source and Variable Viscosity PP J. Nanofluids 7 (5), 821–832,2018

[26]. Singh, A.K., Soundalgekar, V.M., "Transient free convection in cold water past an infinite vertical porous plate", International Journal of Energy Research, Vol. 14, pp. 413-420, 1990.