HEAT AND MASS TRANSFER IN MHD CASSON FLUID FLOW PAST AN INFINITE VERTICAL POROUS PLATE WITH HEAT SOURCE/SINK

[1] R. VIJAYARAGAVAN, [2] M. ANGELINE KAVITHA
[1] Associate Professor, [2] Research Scholar
[1] Department of Mathematics,
[1] Thiruvalluvar University, Vellore, India.

Abstract: The objective of this paper is to analyze the nonlinear MHD non-Newtonian fluid flow with heat and mass transfer of an incompressible, viscous and heat source/sink over an Infinite vertical porous plate in the presence of thermal radiation and chemical reaction. The governing partial differential equations are transformed as non-dimensional equations using suitable transformation and resulting equations are solved using Perturbation technique. The impact of a few physical parameters on the velocity, temperature and concentration field is communicated with the assistance of graphs.

***Index Terms*:** MHD, Thermal radiation, Chemical reaction, Casson fluid, heat source/sink.

I. INTRODUCTION

The effects of magnetic field on viscous incompressible flow of electrically conducting, radiative reactive fluid through porous surface associated with heat and mass transfer playing a key role in different areas of science and technology like cooling of nuclear reactions , chemical industry, MHD power generators, petroleum engineering etc., The problem on MHD convective boundary layer flow over a vertical plate in the presence of chemical reaction and thermal radiation was studied by Dulal Pal and Babulal Talukdar [1]. In this problem they used perturbation technique to solve the partial differential equations. Sheikholeslami and Ganji [2] investigated the heat transfer of nanofluid flow between parallel plates in the presence of squeezing effect. In this study they analyzed the effects of the nanofluid volume fraction. Heat and mass transfer of MHD Casson fluid flow past a rotating cone/plate in the presence of cross diffusion studied by Raju and Sandeep [3]. This paper they resulted that increase in magnetic field parameter increase the heat and mass transfer rates. Ramana Reddy et al. [4] analyzed on MHD nanofluid flow towards a flat plate with radiation and chemical reaction. In this study they found the behavior of various dimensionless parameters. Pushpalatha et al. [5] studied the unsteady MHD flow of a Casson fluid past a vertical flat plate with convective boundary conditions in heat and mass transfer. In this study they used perturbation technique to solve the equations. Ibrahim et al. [6] studied the effects of radiation absorption and chemical reaction on MHD flow over a semi-infinite vertical plate in the presence of chemical reaction and radiation. Ramesh and Devakar [7] analyzed the problem on flows of Casson fluid between parallel plates with slip boundary conditions. From this problem it is observed that the volume flow and velocity rate of fluid decreases in the presence of Casson number. Din et al. [8] studied the flow of a nanofluid between parallel plates on heat and mass transfer. In this study they used homotopy analysis method to solve the equations. The article on unsteady MHD free flow of Casson fluid over an oscillating vertical plate with porous medium studied by Asma Khalid et al. [9]. In this paper they analyzed the results for emerging flow parameters. Takhar et al. [10] studied the effects on MHD free flow of a gas towards a semi-infinite vertical plate in the presence of radiation and magnetic field. This article results that the radiation does not affect the velocity and temperature. Aboeldahab and Elbarbary [11] investigates the effects on MHD flow over a vertical plate with mass transfer in the presence of hall current and magnetic field. In this paper they used fourth-order Runge – Kutta method to obtain the results. Mbeledogu and Ogulu [12] studied the MHD natural convection flow over a vertical porous flat plate in the presence of chemical reaction and radiative heat transfer. In this study they concluded that the radiation affects the velocity and temperature. Rajesh Sharma et al. [13] analyzed the influence of heat absorption and magnetic field of micropolar fluid flow over semi-infinite moving plate with heat transfer and viscous dissipation. This article results that the velocity increases with increase of plate velocity. Very recently, the researchers [14-19] studied the heat transfer behavior of magnetic flows by considering the various channels. Jayachandra Babu and Sandeep [20] performed the cross-diffusion effects on the MHD non-Newtonian fluid flow towards a slandering stretching sheet. In this study they used Runge-Kutta based shooting process. Afikuzzaman et al .[21] illustrated theunsteady MHD non-Newtonian fluid flow over a parallel plate with Hall current. In this article they used Explicit Finite Difference technique to solve the equations. Raju and Sandeep [22] carried out the flow, heat and mass transfer of MHD Casson fluid flow past a vertical cone/plate with porous medium. There are many transport processes governed by the combined action of buoyance forces due to both thermal and mass diffusion in the presence of the chemical reaction effect. There are many applications of such transport processes in industry, heat exchangers, thermal protection systems and solar energy collectors. In all such classes of flows, force is provided by a combination of thermal and chemical reaction effects. Abo-Eldahab and Aziz [23], analyzed the problem on MHD free convection flow over a semi-infinite vertical plate with the influence of viscous and Joule heating in the presence of Hall and ion-slip currents. Effects of radiation and aligned magnetic field on ferrofluids past a flat plate in the presence of heat source and slip velocity was studied by Raju et al. [24] and concluded that when slip parameter increases the momentum boundary layer thickness enhance. Vedavathi et al. [25] studied the effects of MHD on Casson flow past a vertical plate with Dufour, radiation and chemical reaction. Sekhar et al. [26] studied the effects on MHD boundary layer slip flow of Jeffrey fluid past a flat plate with heat transfer. In this study they found that when the temperature increases the slip parameter increases. Rushi Kumar and Sivaraj [27] investigated the unsteady flow of MHD viscoelastic fluid past a vertical cone and a flat plate with magnetic field and chemical reaction. Chamkha [28] analyzed the problem of incompressible fluid flow over a semi-infinite vertical permeable moving plate with the influence of magnetic field and concentration buoyancy and he found that when Grashof number increased, the fluid velocity also increased. Umar Khan et al. [29] studied the squeezing flow of a viscous fluid between parallel plates in the presence of two-dimensional axisymmetric flow. In this study they used variation of parameters method and discussed the solutions. Afikuzzaman et al. [30] analyzed the problem on MHD Casson Fluid Flow over a parallel plate with heat transfer and Hall Current and analyzed the velocity and temperature distributions for various parameters.

In this paper, we analyzed the heat transfer nature of the magnetohydrodynamic Casson fluid flow over an infinite porous vertical plate in the presence of thermal radiation and heat source/sink. The governing partial differential equations are transformed as non-dimensional equations using suitable transformation and resulting equations are solved using Perturbation technique. The effect of non-dimensional parameters namely thermal radiation, heat source/sink, Grashof number, Chemical reaction and magnetic field parameters on the flow and heat transfer is analyzed and discussed.

II. MATHEMATICAL ANALYSIS

Thermal radiation and mass transfer effects on unsteady MHD flow of a viscous incompressible fluid past along a vertical oscillating plate with variable temperature and also with variable mass diffusion in the presence of transverse applied magnetic field has been discussed.

- The x-axis is taken along the plate in the vertical upper direction and the y-axis is taken normal to the plate. It is assumed that the plate and fluid are at the same temperature T_∞ in the stationary condition with concentration level C_∞ at all the points.
- At time t>0, the plate is given an oscillatory motion in its own plane with velocity $U_o\cos(\omega t)$.
- At the same time the plate temperature is raised linearly with time and also mass is diffused from the plate linearly with time.
- A transverse magnetic field of uniform strength B_0 is assumed to be applied normal to the plate.
- The induced magnetic field and viscous dissipation is assumed to be negligible as the magnetic Reynolds number of the flow is taken to be very small.
- The fluid considered here is gray, absorbing/emitting radiation but a non-scattering medium.

Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations.

$$\frac{\partial u}{\partial t}=v\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2}+g\beta\left(T-T_\infty\right)+g\beta^*\left(C-C_\infty\right)-\frac{u}{K}-\frac{\sigma B_0^2}{\rho}u \qquad (1)$$

$$\frac{\partial T}{\partial t}=\frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho C_p}\frac{\partial q_r}{\partial y}-\frac{Q_0}{\rho C_p}(T-T_\infty) \qquad (2)$$

$$\frac{\partial C}{\partial t}=D\frac{\partial^2 C}{\partial y^2}-K_r\left(C-C_\infty\right) \qquad (3)$$

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

$$\left.\begin{array}{l} t\le 0: u=0,\ T=T_\infty, C=C_\infty, \\ t>0\begin{cases} u=U_0\cos(\omega t), v=0, T=T_\infty+\varepsilon\left(T_w-T_\infty\right)e^{nt}, C=C_\infty+\varepsilon\left(C_w-C_\infty\right)e^{nt} & at\ \ y=0 \\ u\to 0, v\to 0, T\to T_\infty, C\to C_\infty & as\ \ y\to\infty \end{cases}\end{array}\right\} \qquad (4)$$

where u is the velocity in the x -direction, K is the permeability parameter, β is the volumetric coefficient of thermal expansion, β^* is the volumetric coefficient of expansion for concentration, ρ is the density, σ is the electrical conductivity, k - the thermal conductivity, g - the acceleration due to gravity, T is the temperature, T_ω - the fluid temperature at the plate, T_∞- the fluid temperature in the free stream, C is the species concentration, C_p is the specific heat at constant pressure, C_∞- Species concentration in the free stream, C_{ω}- Species concentration at the surface,D is the chemical molecular diffusivity, q_r is the radiative flux. The local radiant absorption for the case of an optically thin gray gas is expressed as

$$\frac{\partial q_r}{\partial y} = -4a^{*}\sigma\left(T_{\infty}^{4} - T^{4}\right) \tag{5}$$

where σ and a are the Stefan-Boltzmann constant and the Mean absorption coefficient, respectively. we assume that the temperature differences within the flow are sufficiently small so that T^4 can be expressed as a linear function of T after using Taylor's series to expand T^4 about the free stream temperature T and neglecting higher order terms. This results in the following approximation:

$$T^{4} \cong 4T_{\infty}^{3}T - 3T_{\infty}^{4} \tag{6}$$

Using equations (5) and (6), from equation (2) becomes

$$\frac{\partial T}{\partial t} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho C_p}\left[16a^{*}\sigma T_{\infty}^{3}\left(T - T_{\infty}\right)\right] - \frac{Q_0}{\rho C_p}\left(T - T_{\infty}\right) \tag{7}$$

The following non-dimensionless quantities are introduced to transform equations (1), (3) and (7) into dimensionless form:

$$\left.\begin{array}{l} y^{*} = \dfrac{yu_0}{v}, u^{*} = \dfrac{u}{u_0},\ \theta = \dfrac{\left(T - T_{\infty}\right)}{\left(T_w - T_{\infty}\right)}, Sc = \dfrac{v}{D},\ \Pr = \dfrac{\mu C_p}{k}, M = \dfrac{\sigma B_0^2 v}{\rho u_0^2}, \\ R = \dfrac{16a^{*}\sigma v^2 T_{\infty}^3}{k u_0^2}, \omega = \dfrac{\omega v}{u_0^2}, Gm = \dfrac{g\beta^{*}v\left(C_w - C_{\infty}\right)}{u_0^3}, \phi = \dfrac{\left(C - C_{\infty}\right)}{\left(C_w - C_{\infty}\right)}, Gr = \dfrac{g\beta v\left(T_w - T_{\infty}\right)}{u_0^3}, \\ t^{*} = \dfrac{tu_0^2}{v}, K^{*} = \dfrac{Ku_0}{v^2}, Kr^{*} = \dfrac{Krv}{u_0^2}, S = \dfrac{Q_0}{\rho C_p}\left(T - T_{\infty}\right) \end{array}\right\} \tag{8}$$

The basic field equations (1), (3) and (7) can be expressed in the non-dimensional form and dropping the stars (*) as:

$$\frac{\partial u}{\partial t} = v\left(1 + \frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2} + Gr\theta + Gm\phi - \left(M + \frac{1}{K}\right)u \tag{9}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 T}{\partial y^2} - \frac{R}{\Pr}\theta - S\theta \tag{10}$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - Kr\phi \tag{11}$$

The corresponding boundary conditions are:

$$\left.\begin{array}{ll} u = \cos(\omega t),\ \theta = t, \phi = t & at\ \ y = 0 \\ u \to 0,\ \theta \to 0, \phi \to 0 & as\ \ y \to \infty \end{array}\right\} \tag{12}$$

Where M, K, G_r, G_m, P_r, K_r, S_c, R and S are the magnetic parameter, permeability parameter, Grashof number for heat transfer, Grashof number for mass transfer, Prandtl number, chemical reaction, Schmidt number , radiation parameter and heat source parameter respectively.

III. METHOD OF SOLUTION

$$u\left(\mathrm{y}, t\right) = u_0\left(y\right)e^{i\omega t} \tag{13}$$

$$\theta(y,t)=\theta_0(y)e^{i\omega t} \tag{14}$$

$$\phi(y,t)=\phi_0(y)e^{i\omega t} \tag{15}$$

Substituting equations (13), (14) and (15) in equations (9), (10) and (11), we obtain:

$$u''_0 - A_3^2 u_0 = -Gr\theta_0 - Gm\phi_0 \tag{16}$$

$$\theta_0'' - A_2^2\theta_0 = 0 \tag{17}$$

$$\phi''_0 - A_1^2\phi_0 = 0 \tag{18}$$

Here the primes denote the differentiation with respect to y. The corresponding boundary conditions can be written as:

$$\left.\begin{array}{l} u_0 = e^{-i\omega t}\cos(\omega t),\ \theta_0 = te^{-i\omega t},\ \phi_0 = te^{-i\omega t}\ \ at\ y=0, \\ u_0 \to 0,\quad \theta_0 \to 0,\ \ \phi_0 \to 0 \qquad\qquad as\ y \to \infty, \end{array}\right\} \tag{19}$$

The analytical solutions of equations (16) - (18) with satisfying boundary conditions (19) are given by

$$u_0(y)=\left\{\left[\cos(\omega t)-A_4-A_5\right]e^{-A_3 y}+(A_4 e^{-A_1 y}+A_5 e^{-A_2 y})\right\}e^{-i\omega t} \tag{20}$$

$$\theta_0(y)=\left(te^{-A_2 y}\right)e^{-i\omega t} \tag{21}$$

$$\phi_0(y)=\left(te^{-A_1 y}\right)e^{-i\omega t} \tag{22}$$

In view of the above equations, the velocity, temperature and concentration distributions in the boundary layer become

$$u(y,t)=\left\{\left[\cos(\omega t)-A_4-A_5\right]e^{-A_3 y}+(A_4 e^{-A_1 y}+A_5 e^{-A_2 y})\right\} \tag{23}$$

$$\theta(y,t)=\left(te^{-A_2 y}\right) \tag{24}$$

$$\phi(y,t)=\left(te^{-A_1 y}\right) \tag{25}$$

IV. RESULTS AND DISCUSSION

The behavior of various governing parameters on the physical quantities are computed and represented in Figures below and discussed in detail. For numerical results we used M=1, $G_{m=}$2, Gr=5, S=0.6, Pr=5, Sc=0.6, R=1, t=1,K=0.2, S= 0.5, Kr=0.2. These values are treated as common throughout the study except varied values in respective figures. Figs.[1,2]. Shows that the effect of Magnetic field and Grashof number on velocity profiles. From this figures it is seen that the increasing values of M reduces the velocity profiles and an increasing values of Gr enhances the velocity profiles. Fig.3. depicts the various values of modified Grashof number Gm on velocity profile. It is observed that enhancing values of Gm enhances the velocity profiles .Fig.[4-5] represents the effects of chemical reaction and Schmidt number on velocity profile. From this figures it is seen that the velocity decreases as Chemical reaction parameter and Schmidt number increases. Figs.[6-7] illustrates the velocity profiles for different values of heat source parameter S and radiation parameter R. It is noticed that the velocity profiles increases as heat source parameter S and radiation parameter increases. Fig.8. shows the velocity profiles on permeability parameter K. It is observed that the increasing values of K declines the velocity profile.

Figs.[9,11]. Shows that the behavior of Chemical reaction parameter and Schmidt number on concentration profiles. It is clear that the increasing values of Kr and Sc reduce the concentration profiles. Fig.10. depicts that the enhancing values of t also enhances the concentration profile. The temperature profiles on different values of Pr, S and R are plotted in Figs.[12-14]. It is observed that an increasing value of Prandtl number Pr, Heat source parameter S and Radiation parameter R declines the temperature profiles. Fig.15. represents the effect of t on temperature profile. From this figure it shows that the increasing values of t enhance the temperature profile.

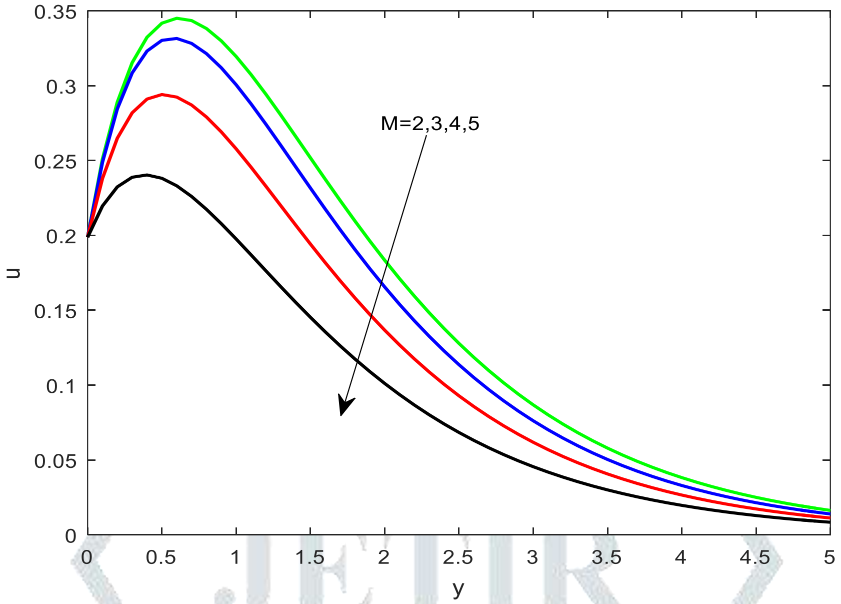

Fig.1. Velocity profile for different values of M.

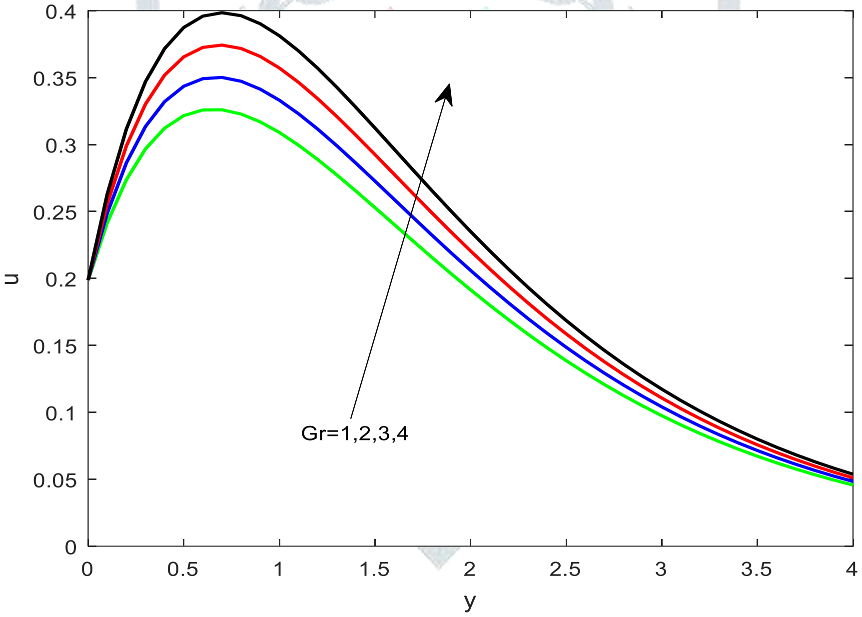

Fig.2. Velocity profile for different values of Gr.

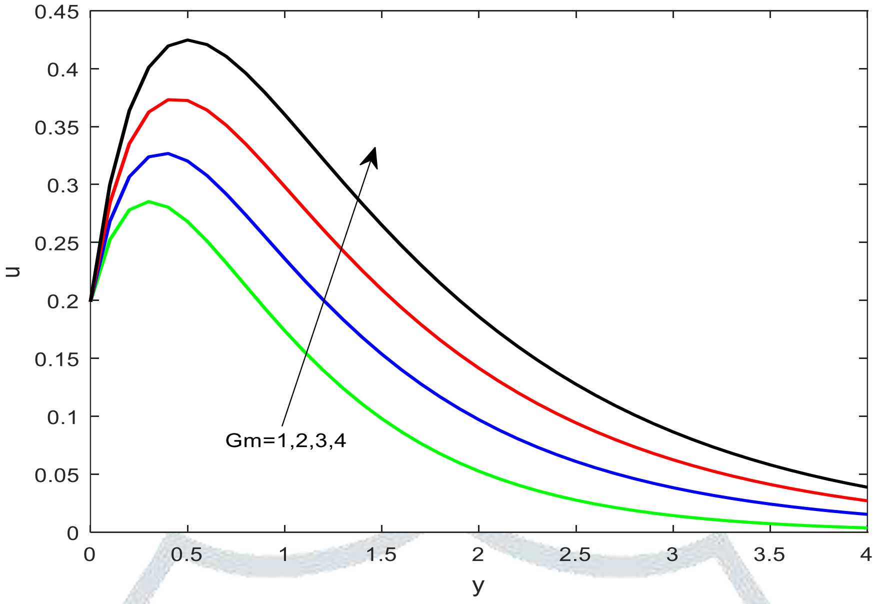

Fig.3. Velocity profile for different values of Gm.

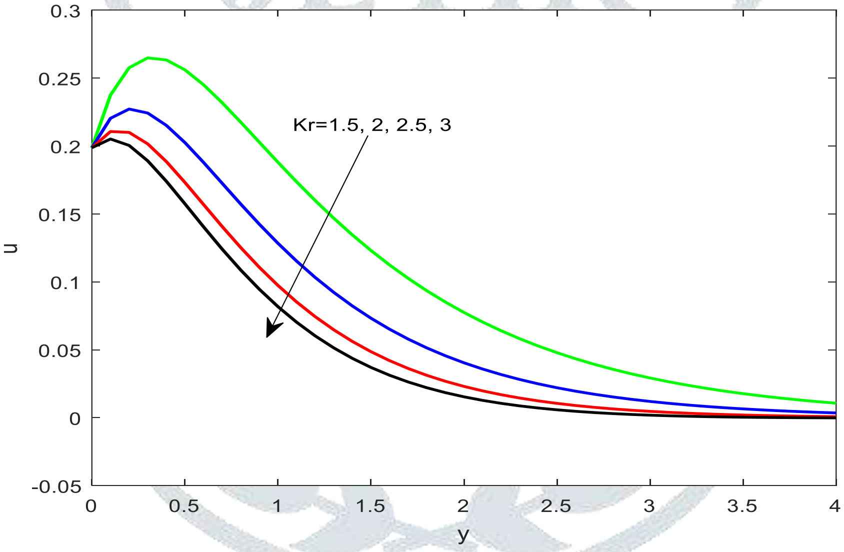

Fig.4. Velocity profile for different values of Kr.

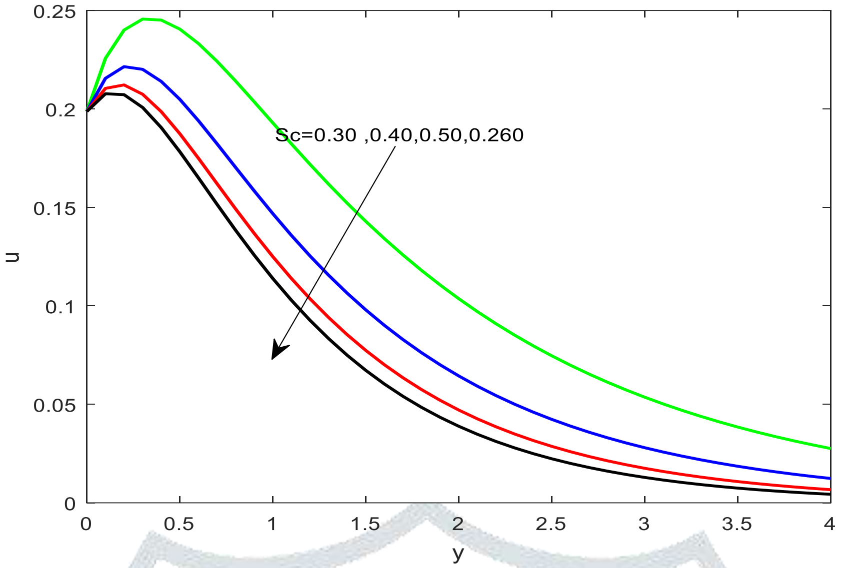

Fig.5. Velocity profile for different values of Sc.

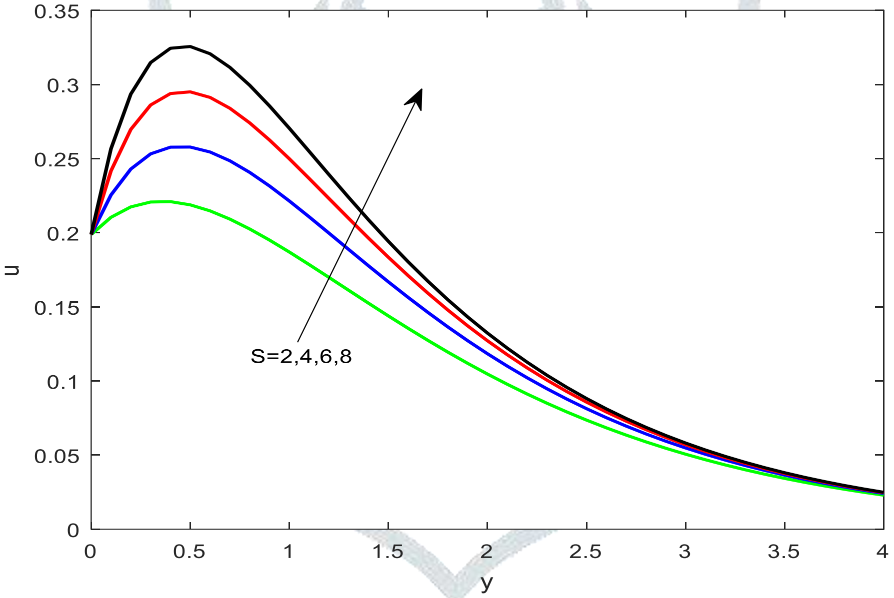

Fig.6. Velocity profile for different values of S.

JETIR

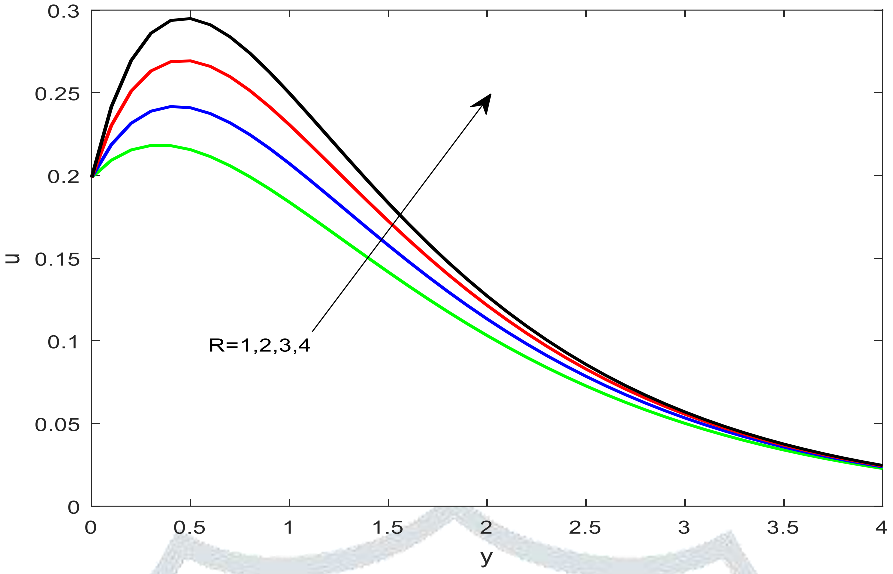

Fig.7. Velocity profile for different values of R.

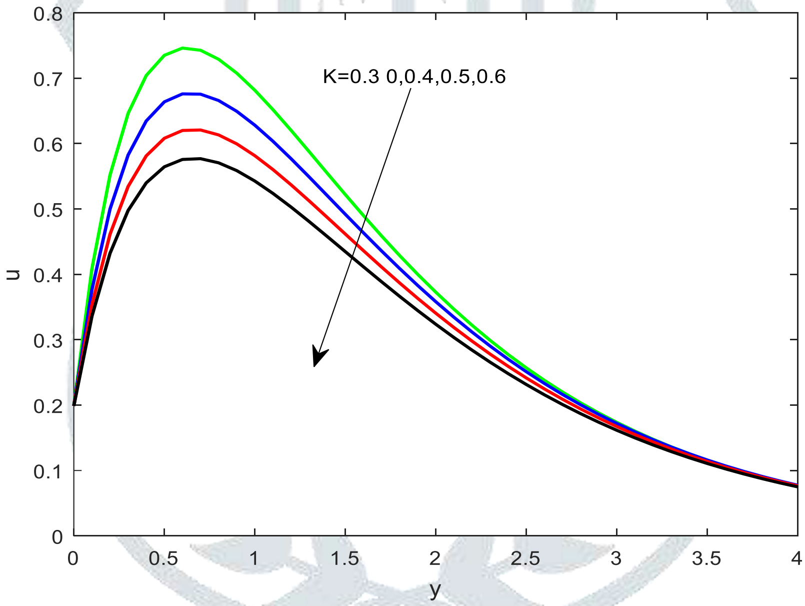

Fig.8. Velocity profile for different values of K.

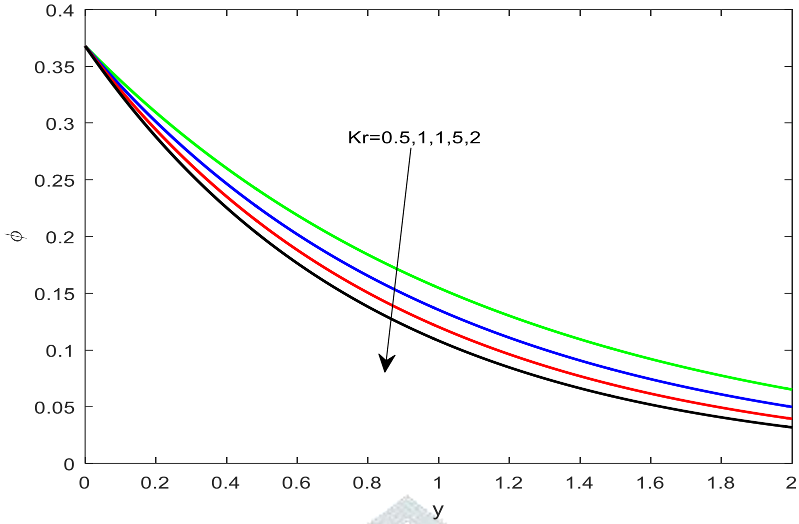

Fig.9. Concentration profile for different values of Kr.

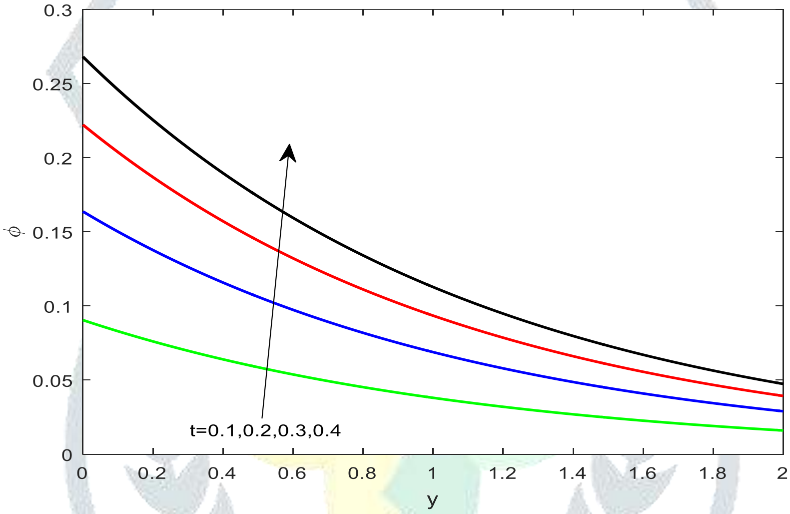

Fig.10. Concentration profile for different values of time t.

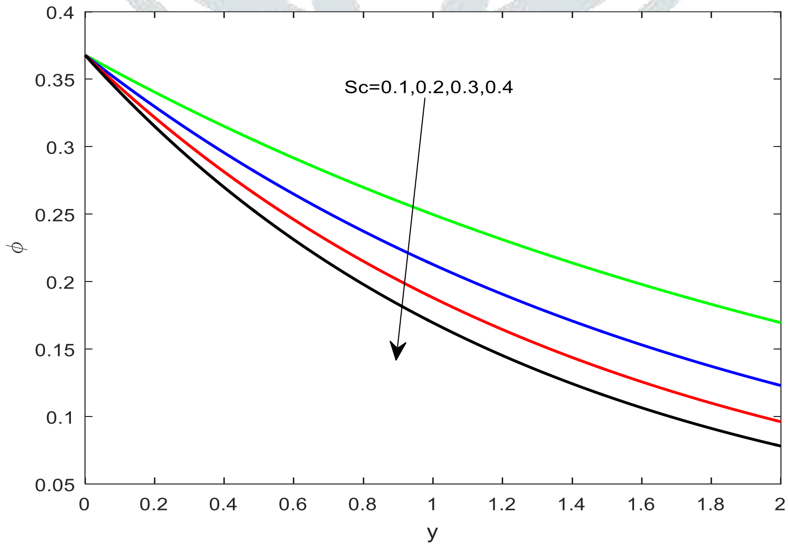

Fig.11. Concentration profile for different values of Sc.

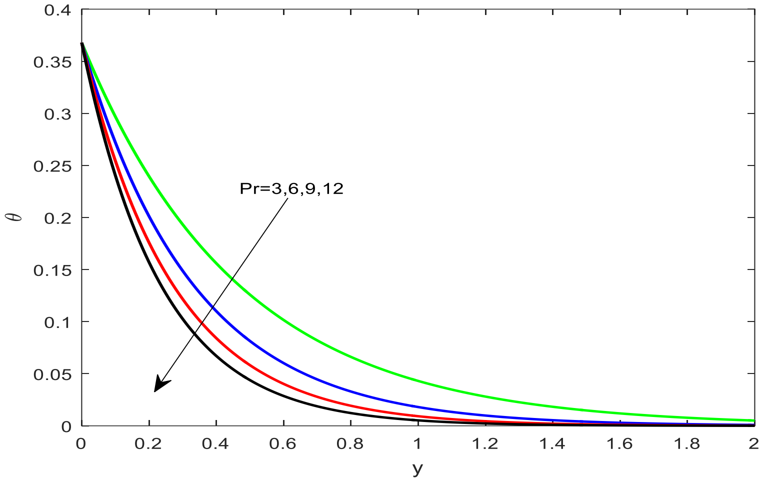

Fig.12. Temperature profile for different values of Pr.

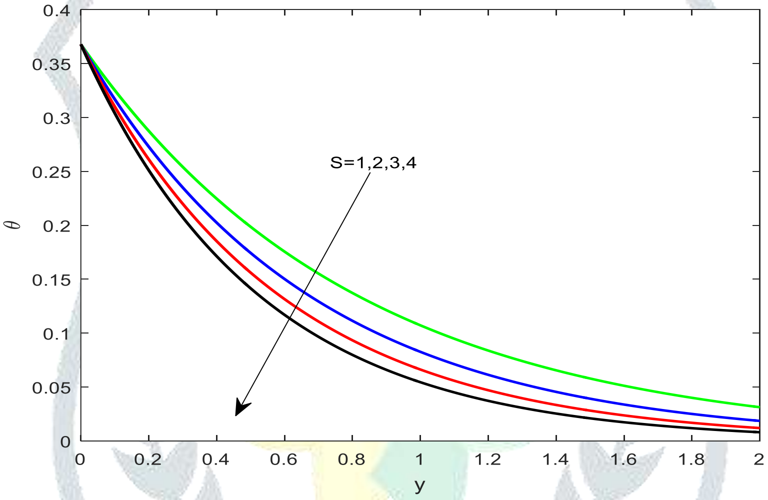

Fig.13. Temperature profile for different values of S.

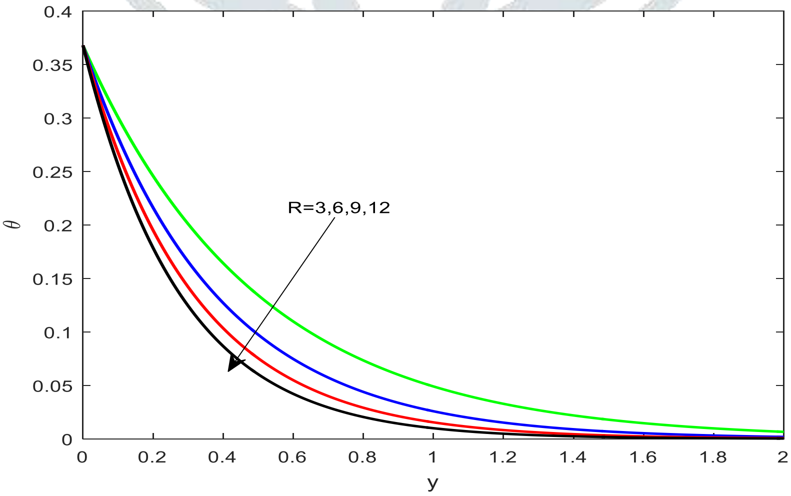

Fig.14. Temperature profile for different values of R.

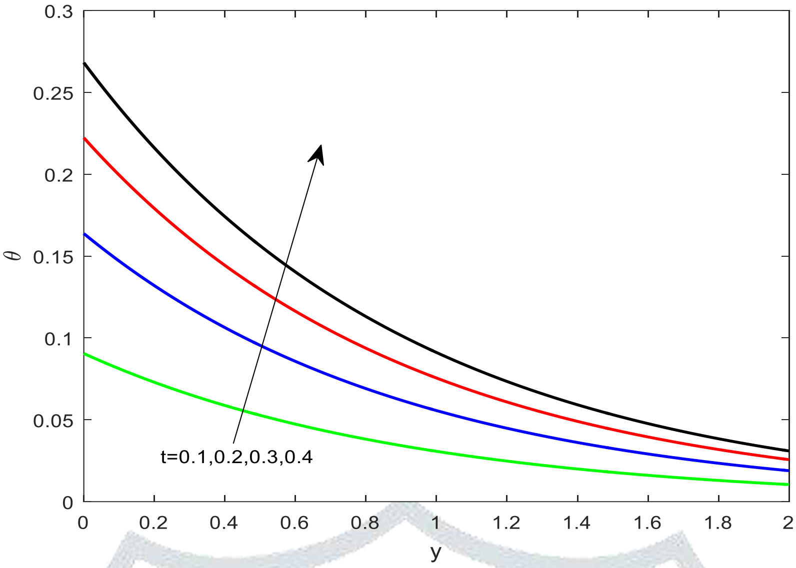

Fig.15. Temperature profile for different values of time t.

V. CONCLUSION

In this paper, heat transfer nature of the MHD Casson fluid flow past an Infinite vertical porous plate in the presence of chemical reaction, thermal radiation with heat source/sink is investigated. The effect of non-dimensional parameters namely, chemical reaction, Prandtl number, heat source/sink and magnetic field parameter on the flow and heat transfer is analyzed for Casson fluid case. Observations of the present study are as follows:

- The influence of thermal radiation non-Newtonian fluids is not uniform.
- Magnetic field parameter have tendency to control the flow field.
- Momentum and Thermal boundary layers of Casson fluids are not uniform.
- Increasing the thermal radiation and heat source parameter reduces the heat transfer rate.
- The concentration decreases with the increase in Schmidt number and Chemical reaction parameter.

VI. REFERENCES

[1] Dulal Pal and Babulal Talukdar, 2010. Perturbation analysis of unsteady magnetohydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Commun Nonlinear Sci Numer Simulat, 15:1813- 1830.

[2] Sheikholeslami, M. and Ganji, D.D. 2013. Heat transfer of cu-water nanofluid flow between parallel plates. Powder Technology, 235:873-879.

[3] Raju, C.S.K. and Sandeep, N. 2016. Journal of Molecular Liquids, 215:115-126.

[4] Ramana Reddy, J.V. Sugunamma, V. Sandeep, N. and Sulochana, C. 2016. Influence of chemical reaction, radiation and rotation on MHD nanofluid flow past apermeable flat plate in porous medium. Journal of the Nigerian Mathematical Society, 35:48-65.

[5] Pushpalatha, K. Sugunamma, V. Ramana Reddy, J.V. and Sandeep, N. 2016. Heat and Mass Transfer in Unsteady MHD Casson fluid flow with Convective Boundary Conditions. Int. J. of Sci. and Technology, 91:19-38.

[6] Ibrahim, F. S. Elaiw, A. M. and Bakr, A. A. 2008. Effects 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, 13:1056-1066.

[7] Ramesh, K. and Devakar, M. 2015. Some analytical solutions for flows of Casson fluid with slip boundary conditions, Ain Shams Engineering Journal, 6:967-975.

[8] Syed Tauseef Mohyud-Din, Zulfiqar Ali Zaidi, Umar Khan and Naveen Ahmed, 2015. On heat and mass transfer analysis for the flow of a nanofluid between rotating parallel plates. Aerospace Science and Technology, 46:514-522.

[9] Asma Khalid, Ilyas Khan, Arshad Khan and Sharidan Shafie, 2015. Unsteady MHD free convection flow of Casson fluid past over an oscillating vertical plate embedded in a porous medium. Engineering Science and Technology, an International Journal, 18:309-317.

[10] TakharRama Subba Reddy, H. S. and Gorla V. M. Soundalgekar, 1996. Short Communication radiation effects on MHD free convection flow of a gas past a semi-infinite vertical plate. International Journal of Numerical Methods for Heat and Fluid Flow, 6:77-83.

[11] Emad M. Aboeldahab and Elsayed M. E. Elbarbary, 2001. Hall current effect on magnetohydrodynamics free-convection flow past a semi-infinite vertical plate with mass transfer. Int. J. of Eng. Sci., 39:1641-1652.

[12] Mbeledogu, I. U. and Ogulu, A. 2007. Heat and mass transfer of an unsteady MHD natural convection flow of a rotating fluid past a vertical porous flat plate in the presence of radiative heat transfer, International Journal of Heat and Mass Transfer, 50:1902-1908.

[13] Rajesh Sharma, Bhargava, R. and Singh, I. V. 2010. Combined effect of magnetic field and heat absorption on unsteady free convection and heat transfer flow in a micropolar fluid past a semi-infinite moving plate with viscous dissipation using element free Galerkin method. Applied Mathematics and Computation, 217:308-321.

[14] Sulochana, C. Sandeep, N. 2016. Flow and heat transfer behavior of MHD dusty nanofluid past a porous stretching/shrinking cylinder at different temperatures. Journal of Applied Fluid Mechanics, 9(2):543- 553.

[15] Sandeep, N. Sugunamma, V. 2014. Radiation and inclined magnetic field effects on unsteady hydromagnetic free convection flow past an impulsively moving vertical plate in a porous medium. Journal of Applied and Fluid Mechanics, 7(2):275-286.

[16] Animasaun, I.L. Sandeep, N. 2016. Buoyancy induced model for the flow of 36nm alumina-water nanofluid along upper horizontal surface of a paraboloid of revolution with variable thermal conductivity and viscosity. Powder Technology, 301:858-867.

[17] Ramana Reddy, J.V. Sugunamma, V. Sandeep, N. 2016. Cross diffusion effects on MHD flow over three different geometries with Cattaneo-Christov heat flux. Journal of Molecular Liquids, 223:1234-1241.

[18] Jayachandra Babu, M. Sandeep, N. 2016. 3D MHD slip flow of a nanofluid over a slendering stretching sheet with thermophoresis and Brownian motion effects. J. of Molecular liquids, 222:1003-1009.

[19] Sandeep, N. Malvandi, A. 2016. Enhanced heat transfer in liquid thin film flow of non-Newtonian nanofluids embedded with graphene nanoparticles, Advanced Powder Technology.

[20] Jayachandra Babu, M. Sandeep, N. 2016. MHD non-Newtonian fluid flow over a slendering stretching sheet in the presence of Cross-diffusion effects. Alexandria Engineering Journal, 55(3):2193-2201.

[21] Afikuzzaman, Md. Ferdows, M. Mahmud Alam, Md. 2015.Unsteady MHD Casson fluid flow through a parallel plate with Hall Current. Procedia Engineering, 105:287-293.

[22] Raju, C.S.K. Sandeep, N. 2016. Heat and Mass transfer in MHD non-Newtonian bio-convection flow over a rotating cone/plate with cross diffusion. Journal of Molecular Liquids, 215:115-126.

[23] Emad M. Abo-Eldahab and Mohamed A. El Aziz, 2005. Viscous dissipation and Joule heating effects on MHD-free convection from a vertical plate with power-law variation in surface temperature in the presence of Hall and ion-slip currents. Applied Mathematical Modeling, 29:579-595.

[24] Raju, C.S.K. Sandeep, N. Sulochana, C. and Sugunamma, V. 2015. Effects of aligned magneticfield and radiation on the flow of ferrofluids over a flat plate with non-uniform heat source/sink. Int. j. sci. and Eng., 8(2):151-158.

[25] Vedavathi, N. Dharmaiah, G. Balamurugan, K.S. and Charan Kumar, G. 2016. Chemical Reaction, Radiation and Dufour Effects on Casson MHD fluid flow over a Vertical Plate with Heat Source/Sink. Global Journal of Pure and Applied Mathematics, 12(1):191-200.

[26] Kuppala, Sekhar, R. Krishna Murthy, M. and Viswanatha Reddy, G. 2016. Effect of Heat Transfer on MHD Boundary Layer Slip Flow of Jeffrey Fluid over a Flat plate. Middle-East Journal of Scientific Research, 24(4): 1135-1140.

[27] Rushi Kumar, B. and Sivaraj, R. 2013. Heat and Mass Transfer in MHD viscoelastic fluid flow over a vertical cone and flat plate with variable viscosity. Int. J. of Heat and Mass Transfer, 56:370-379.

[28] Ali J. Chamkha, 2004. Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption. Int. J. of Eng. Sci., 42:217-230.

[29] Umar Khan, Naveed Ahmed, Sheikh Irfanullah Khan, Zulfiqar Ali Zaidi, Yang Xiao-Jun and Syed Tauseef Mohyud-Din, 2014.OnUnsteady two-dimensional and axisymmetric squeezing flow between parallel plates. Alexandria Engineering Journal, 53:463-468.

[30] Afikuzzaman, Md. Ferdows, M. and Mahmud Alam, Md. 2015. Unsteady MHD Casson Fluid Flow through a Parallel Plate with Hall Current. Procedia Engineering, 105:287-293.