Heat and Mass Transfer Effects on MHD free convective laminar flow over a Moving Vertical Porous Plate with Heat Source and Viscous Dissipation

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Abstract- This paper is focused on the study of effect of heat and mass transfer on chemically reacting boundary layer flow of a Casson fluid over a porous stretching sheet in the differential equations are transformed by introducing similarity variable and solved numerically by using R-K Method of 4th order along with Shooting Technique. The velocity, temperature and concentration distributions for different parameters graphically.

Keywords – Mass Transfer, MHD, Casson Parameter, suction, heat generation, chemical reaction, radiation effect, Soret and Dufour effects, viscous dissipation

I. INTRODUCTION

The combined effects of heat and mass transfer with chemical reaction have attracted many researchers due to its wide range of applications in Engineering and Science. Double diffusion occur concurrently in the processes of drying and evaporation at the surface of an energy transfer, water body in a wet cooling tower as well as the flow in a desert cooler. The investigation of MHD flow of an electrically conducting fluid flow is significant concentration owning to its application in several manufacturing problems for instance MHD generators, nuclear reactors, plasma studies and geothermal energy extractions. The examination of boundary layer flow over a stretching sheet has finds applications in chemical engineering, particularly in manufacture artificial film, artificial fibers, polymer extrusion, drawing of plastic films and wires, glass fiber and paper production. Anjalidevi & Kandaswamy (1999) analysed the double diffusion on steady MHD flow along a semi-infinite parallel plate in the influence of chemical reaction (Ch). The Soret as well as Dufour effects on heat and mass transfer about perpendicular surfaces in permeable have been discussed by Postelnicu (2004). Radiation on boundary layer flow over a moving normal porous plate was denominated by Makinde (2005). Muthucumaraswamy et al. (2006) in this paper it was observed that the governing equations are solved numerically, and it was conclude that the enhancement of dissimilar estimators of chemical reaction leads to decline in concentration as well as velocity. Hossian and Mandal (1985) investigated mass transfer effects on unsteady hydromagnetic free convection flow past an accelerated vertical porous plate. Jha (1991) investigated the influence of magnetic field on mass transfer flow past a uniformly accelerated through a permeable non-parallel plate. Elbashbeshy (1997) reported influence of double diffusion on MHD natural convective flow through a vertical porous plate in the presence of magnetic field. The Ohmic heating effect on MHD natural convection flow as of a non-parallel plate in presence of viscous dissipation has been considered by (Chen (2004) & Crane (1970)). The fluid flow over a stretching sheet has been examined in wide range among investigators. Rajagopal et al. (1984), Anderson *et al.* (1992), Abel *et al.* (2005) & Abel *et al.* (2005) discussed the flow of second order, viscoelastic fluid over a continuously stretched sheet with magnetic fields in presence of buoyancy force. Mukhopadyaya et al. (2008), Pal (2009) the influence of thermal radiation on MHD natural convective boundary layer flow by means of variable velocity over a stretching surface has been studied. Ahmed (2009) analysed the effect of Soret on MHD free convective of double diffusion fluid over a stretching sheet in the company of suction velocity by means of Dufour effects. Merill et al. (1965) and McDonald (1974) conducted research on the performance of blood as a Casson fluid. Eldabe (1995) investigated Casson fluid flow between two rotating cylinders in presence on heat and mass transfer. The flow of Casson fluid in a tube and an annular geometry was studied by and Nagarani *et al.* (2004 & (2009) and Dash *et al.* (2000). Hayat *et al.* (2012) studied Casson fluid model on mixed convection stagnation point the flow. Attia (2010) investigated the transient Couette flow of a Casson fluid among equivalent plates with magnetic field and heat transfer. Sarojamma *et al.* (2014), Mustafa *et al.* (2011) and Shehzad (2013) examined significance of Casson fluid and double diffusion on MHD boundary layer Non-Newtonian flow over a Stretching sheet with chemically reacting as well as suction. Ramalingeswara Rao *et. al* (2018) considered Casson fluid and double diffusion on boundary layer flow of a moving non-parallel porous plate by means of heat generation as well as chemical reaction with of Soret Effect. Vidyasagar & Ramana (2017) analyzed Non Newtonian fluid as well as Soret effect effects on MHD natural convective flow over a moving perpendicular porous plate by means of heat generation as well as radiation in the occurrence of chemically reacting.

II. FORMULATION OF THE PROBLEM

Consider the steady, incompressible flow of a Casson fluid over a porous stretching surface at y = 0. Choose the coordinate system such that x-axis is parallel to the surface and y-axis normal to the surface. The fluid occupies half space y > 0. A uniform magnetic field B_0 is applied in the y direction. The transverse applied magnetic field and magnetic Reynolds number are assumed to be very small, so that the induced magnetic field and Hall effects becomes negligible. We also considered the heat and mass transfer processes in the presence of chemical reaction and heat generation. The rheological equation of state for an isotropic and incompressible flow of a Casson fluid can be written as (Nakamura and Sawada (1988), Mustafa et al. (2012)).

$$\tau_{ij} = \begin{matrix} 2(\mu_B + P_y/\sqrt{2\pi})e_{ij}, \pi > \pi_c \\ 2(\mu_B + P_y/\sqrt{2\pi_c})e_{ij}, \pi < \pi_c \end{matrix}$$

Where μ_B is the plastic dynamic viscosity of the non-Newtonian fluid, Py is the yield stress of the fluid, e ij denotes the (i, j) - th component of the deformation rate, π = e ij, e ij is the product of the component of deformation rate with itself, πc is the critical value of π based on the non-Newtonian model.

The continuity, momentum and energy equations are

Continuity Equation:

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

Momentum Equation:

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

Energy Equation:

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y} + \frac{Q_0}{\rho C_p}(T-T_\infty) + \frac{\sigma B_0^2}{\rho}u^2 + \frac{\upsilon}{C_p}\left(\frac{\partial u}{\partial y}\right)^2 + \frac{D_M K_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2} \tag{3}$$

Concentration Equation:

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2}-k_1(C-C_\infty)+D_1\frac{\partial^2 T}{\partial y^2} \tag{4}$$

$$\frac{\partial q_r}{\partial y}=4\alpha^2(T-T_\infty)$$

Where u and v are the velocity components in x and y directions, γ is the kinematic Viscosity, $\beta=\mu_B\sqrt{2\pi_c}/P_Y$ is the Casson fluid parameter, σ is the electric Conductivity of the fluid, ρ is the density of the fluid, T is the temperature of the fluid, C is the Concentration field, α is the thermal diffusivity, D is the mass diffusivity, k_1 is the reaction rate.

The Boundary Conditions for the Velocity, Temperature and Concentration fields are

$u=u_w$, $v=-V_0$, $T=T_w, C=C_W$ when y=0

$u\to 0$, $T\to T_\infty$, $C\to C_\infty$ as $y\to\infty$ (5)

We define the following non dimensional variables

$$\eta=\sqrt{\frac{c}{\gamma}}y,\ f(\eta)=\frac{\psi}{x\sqrt{c\gamma}},\theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty},\phi(\eta)=\frac{C-C_\infty}{C_W-C_\infty}$$

$$B=\frac{Q_0}{C\rho C_P},Ec=\frac{kU^3}{C_p\upsilon q},Du=\frac{D_M K_T(C_W-C_\infty)}{C_S C_P(T_W-T_\infty)} \tag{6}$$

Where Ψ is the stream function with $u=\frac{\partial\psi}{\partial y},v=-\frac{\partial\psi}{\partial x}$

η is the similarity variable substituting the non-dimensional variables

In view of the Equations (2) to (4) take the form

$$(1+\frac{1}{\beta})f+ff''-(f')^2-(M+K)f'=-(Gr\theta+Gc\phi) \tag{7}$$

$$\frac{1}{\Pr}\theta''+f\theta'-(Ra-B)\theta+M^2u^2+Du\phi''+Ec\left(\frac{\partial u}{\partial y}\right)^2=0 \tag{8}$$

$$\phi''-Scf\theta'-ScK_1\phi+\theta''SrSc=0 \tag{9}$$

where the primes denote the differentiation with respect to η, M is the magnetic parameter, K is the permeability parameter, Gr is the temperature Grashof number, Gc is the Modified Grashof number, $\Pr$ is the Prandtl number, Ra is the Radiation parameter, B is the Heat Generation, Ch is the Chemical Parameter, Ec is the Eckert number, Du is the Dufour effect, Sr is the Soret effect and Sc is the Schmidt number.

The Corresponding non –dimensional boundary conditions are

$f'=1,\ f=S,\theta=1,\phi=1,$ when η=0

$$f'(\infty)\to 0,\ \theta(\infty)\to 0,\phi(\infty)\to 0 \quad as \quad y\to\infty \tag{10}$$

III. SOLUTION OF THE PROBLEM

The governing boundary layer equations (7) to (9) subject to boundary conditions (10) are solved numerically by using shooting method. First of all, higher order non-linear differential equations (7) to (9) are converted into simultaneous non-linear differential equations of first order and they are further transformed into initial value problem by applying the Range Kutta method of 4th order along with shooting technique. From the process of numerical computation are respectively proportional to $f''(0)$, $-\theta'(0)$ and $-\phi'(0)$ are also sorted out and their numerical values are presented in a tabular form.

IV.RESULT AND DISCUSSON

In order to get a physical insight into the problem, a representative set of numerical results is shown graphically in Figs.1-20.

Fig 1: Illustrated that the influence of non-Newtonian fluid i.e Casson fluid (*β*) on fluid velocity. From this figure the results indicates that the incremental values of *β* leads to rise in velocity distribution. Due to highest value on the surfaces to zero as $\eta\rightarrow\infty$. **Fig.2, Fig.8 & Fig 14** represents the dissimilarity of chemical reaction (*Ch*) on velocity, temperature as well as concentration. The enhancement of dissimilar estimators of chemical reaction leads to rise in fluid velocity but reverse outcome was occurred in case of temperature as well as concentration. **Fig 3, Fig.10 & Fig.16** demonstrated that the consequence of *Gr* on velocity and temperature as well as concentration. From this figure it was observed that the velocity diminished with the rise in of Grashof number, but reverse effect was occurred in case of temperature and concentration. **Fig 4 & Fig. 9** shows that the effect of modified Grashof number (*Gc*) on velocity as well as temperature. From this figure the outcomes indicates that the fluid velocity is declined with the rise in modified Grashof number (*Gc*) but inverse effect was shown in case of temperature. **Fig 5, Fig. 11 & Fig 17** illustrated that the effect of porous parameter (*K*) on velocity and temperature as well as concentration. Here the results indicate that the velocity diminished with the accelerated in porous parameter *(K*).But reverse effect was happened in case of the temperature as well as concentration. The effect of magnetic field (*M*) on velocity is presented in the **Fig 6 & Fig 18** this figures witnesses that, velocity reduced with the enhancement of magnetic field (*M*) but inverse effect was occurred in case of concentration. **Fig 7** shows the temperature for dissimilar estimators of heat generation (*B*). It was evident that dissimilar incremental estimators of *B* lead to rise in heat generation (*B*). **Fig 12** confirms that the temperature distribution for diverse physical values of Prandtl number (Pr). It is seen that the temperature diminished with the rise in Prandtl number (Pr). **Fig 13** demonstrated that the temperature for various values of radiation parameter (Ra). From this figure it was cleared that temperature reduced by means of the rise in radiation parameter (Ra). **Fig 19** gives evidence for the concentration profile for diverse estimators of Schmitt number (*Sc*). It was perceived that the concentration declined by means of the rise of Schmitt number (*Sc*). **Fig 20** explained that the concentration for dissimilar values of Soret number (*Sr*). It was observed that the concentration diminished with the enhancement of Soret number (*Sr*). Fig 15 shows the concentration for different values of modified Grashof number (Gc). It is seen that the temperature decreases with the increase of modified Grashof number (Gc).

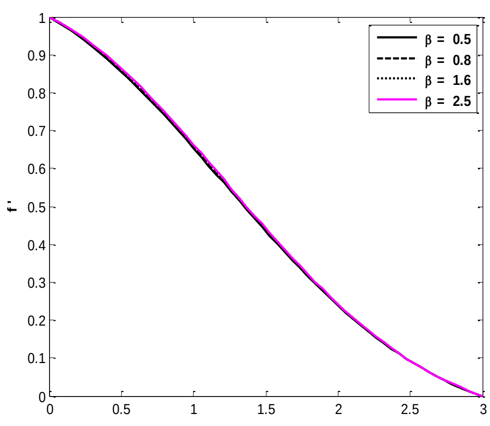

Fig 1: The Velocity Profile for different values for Casson Parameter (β)

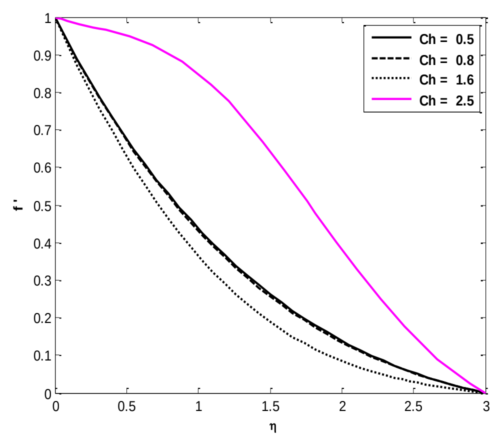

Fig 2: The velocity profile for the different values for chemical reaction Ch

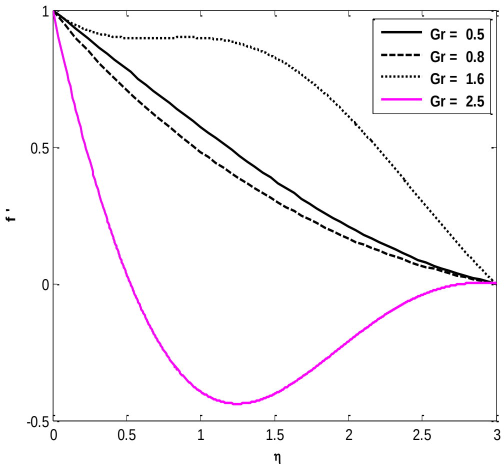

Fig 3: The velocity profile for the different values for Grashof number (Gr)

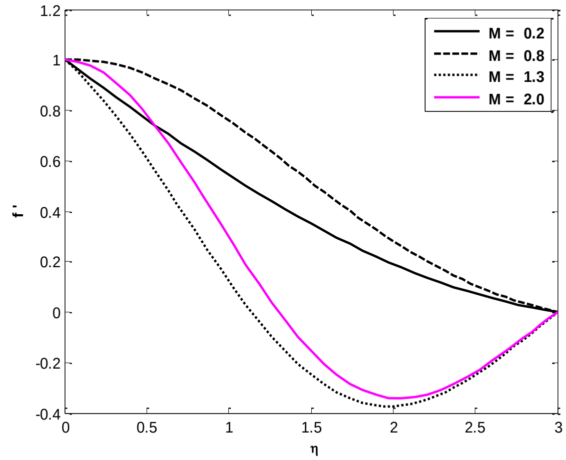

Fig 6: The velocity profile for the different values for magnetic field (M)

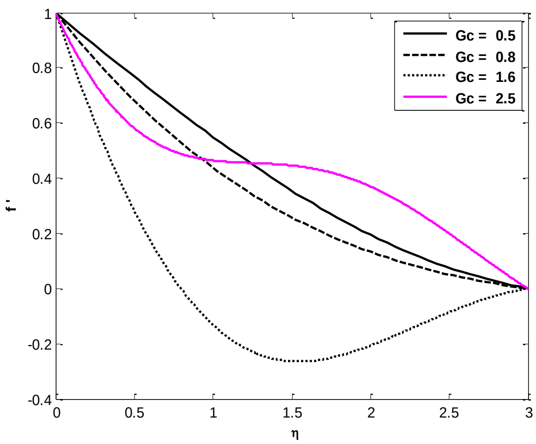

Fig 4: The velocity profile for the different values for modified Grashof number (Gc)

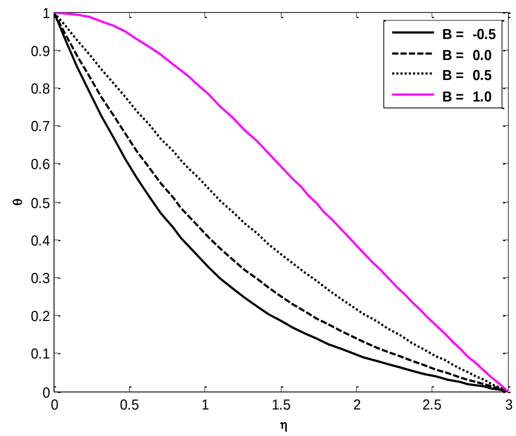

Fig 7: The temperature profile for the different values for heat generation (B)

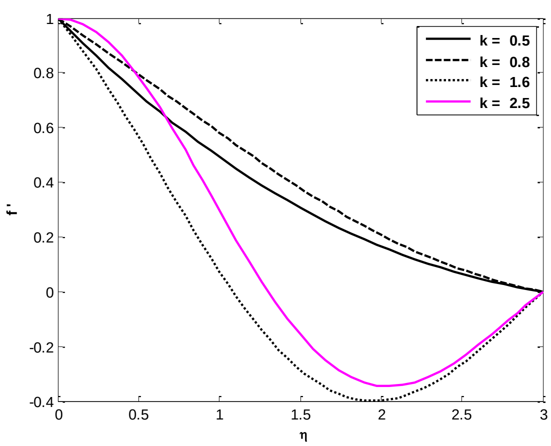

Fig 5: The velocity profile for the different values for porous parameter (K)

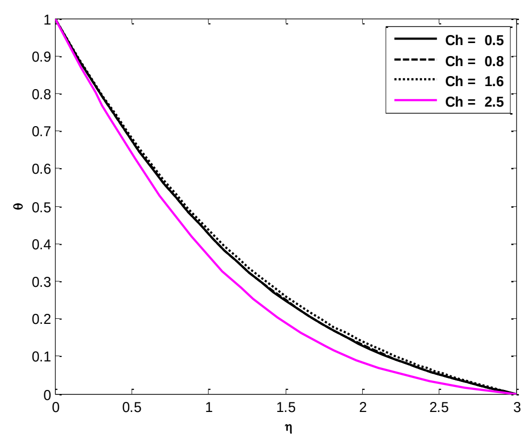

Fig 8: The temperature profile for the different values for Chemical Reaction (Ch)

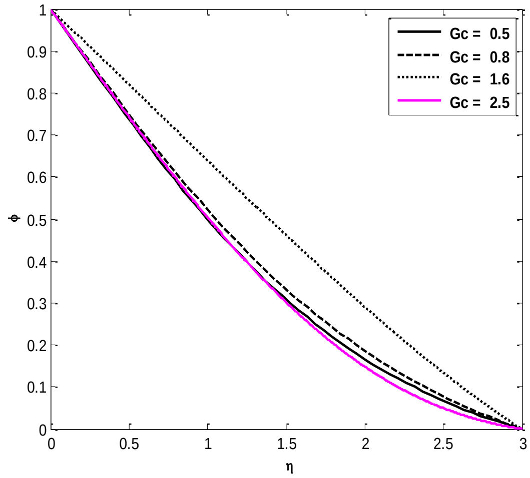

Fig 9: The temperature profile for the different values for modified Grashof number (Gc)

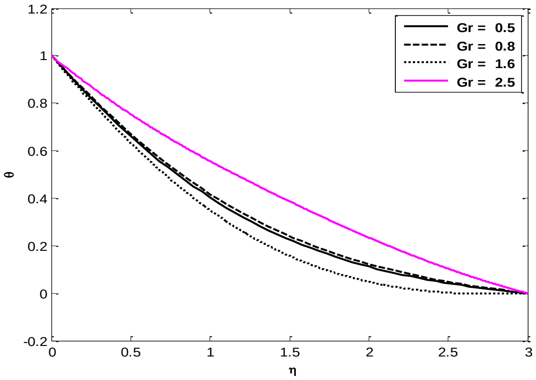

Fig 10: The temperature profile for the different values for Grashof number (Gr)

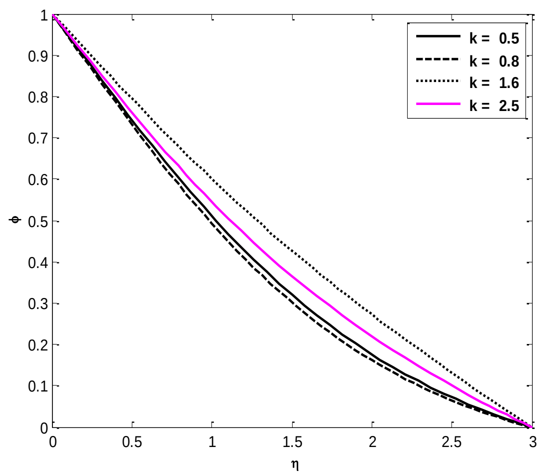

Fig 11: The temperature profile for the different values for porous parameter (K)

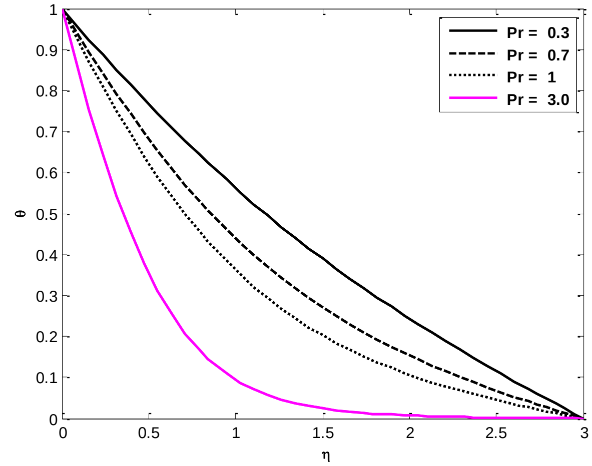

Fig 12: The temperature profile for the different values for Prandtl number (Pr)

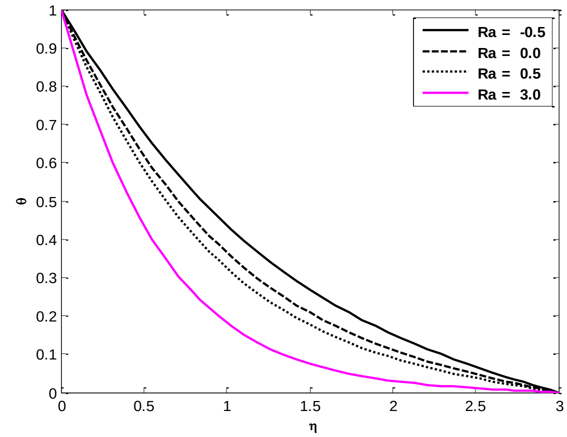

Fig 13: The temperature profile for the different values for radiation parameter (Ra)

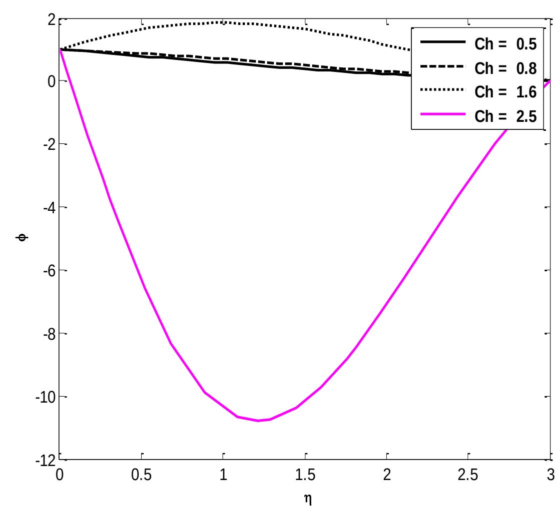

Fig 14: The Concentration profile for the different values for Chemical reaction (Ch)

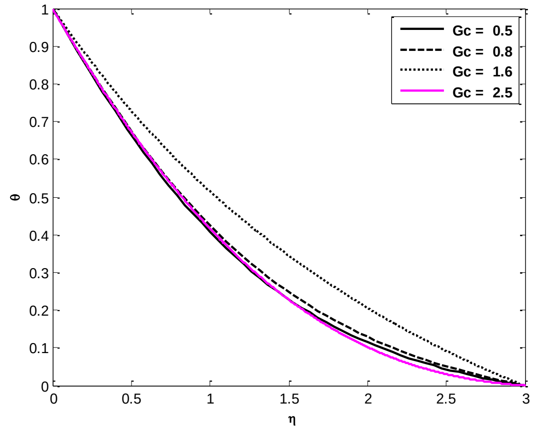

Fig 15: The Concentration profile for the different values for modified Grashof number (Gc)

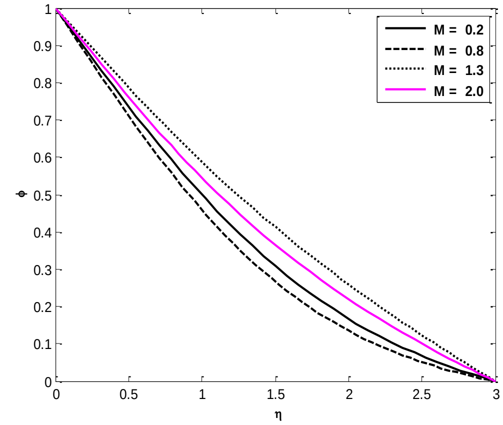

Fig 18: The Concentration profile for the different values for magnetic parameter (M)

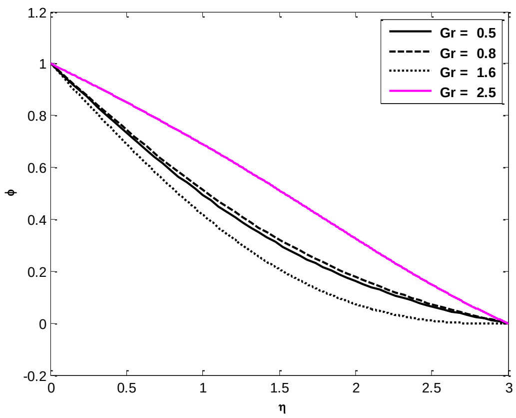

Fig 16: The Concentration profile for the different values for Grashof number (Gr)

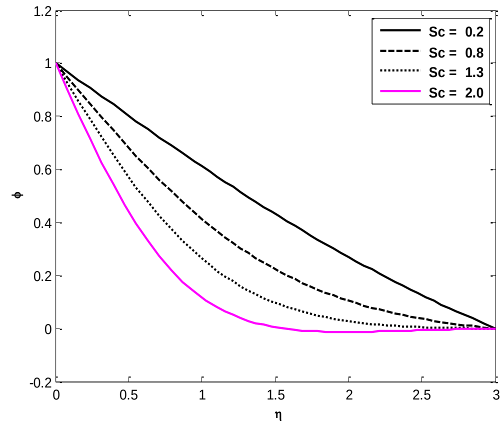

Fig 19: The Concentration profile for the different values for Schmitt number (Sc)

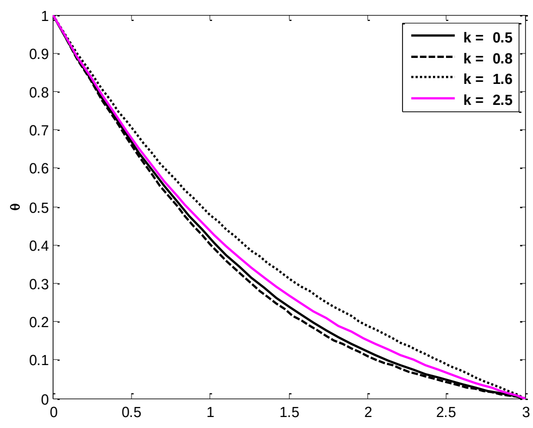

Fig 17: The Concentration profile for the different values for porous parameter (K)

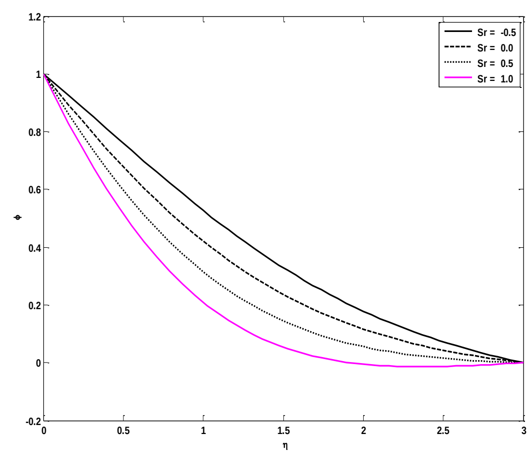

Fig 20: The Concentration profile for the different values for Soret effect (Sr)

V. CONCLUSION

This paper gives the effect of Heat and mass transfer on MHD boundary layer flow for a Casson fluid over a stretching sheet in presence of heat generation and chemical reaction. The governing equations are solved by shooting technique.

- The velocity declined with the accelerated in Grashof number (Gr) as well as modified Grashof number (Gc)
- The enhancement of temperature leads to rise in heat generation (B), but reverse effect was occurred in case of chemical reaction parameter (Ch)
- The concentration profile is amplified with enhance the Grashof number (Gr), but inverse effect was shown in case of Soret (Sr).

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