THERMAL RADIATION WITH SORET AND DUFOUR EFFECT FOR MHD FLOW PASSING THROUGH POROUS MEDIUM

Danial Habib[1], Sajjad Hussain[2], Bagh-e-Ali[3], [4,*] Shan-E-Farooq
[1]Department of Mathematics, Virtual University of Pakistan,(danisheikh4006@gmail.com)
[2, 3]Department of Mathematics, Govt. Postgraduate College Layyah, Pakistan, *(sajjadgut@gmail.com)*
[4]Department of Mathematics, University of the Punjab, Lahore, Pakistan (baghalisewag@gmail.com)
[*]Corresponding author (shanefarooq@gmail.com)

ABSTRACT*: Computational analysis of magneto hydrodynamic flow of viscous fluids is considered owing to moving boundary vertical and parametric. The problem examines the thermal radiations sort and Dufour effects along with other influential parameters due to magnetic field. Thermal diffusivity and porosity of surfaces and medium. The computational results for flow speed, temperature and specie concentrations are determines for various values of above mentioned parameters. The computational techniques ND solve instruction in Mathematica has been employed on the transformed set of ordinary differential equations. The results are presented graphical patterns and have been discussed.*

Key words: Mixed convection, Porous medium, Magnetohydrodynamic, Soret and Dufour effects, Porous plate, Thermal radiation.

1. INTRODUCTION

Most of beneficial studies have been found in useful manner to analyze the influence of the combined heat and mass transfer process by natural convection in a thermal radiation with Soret and Dufour effect passing through porous medium. This is due to its various applications, such as development of advanced technologies as well as fluid flow in MHD with Soret and Dufour effects through pours medium and also use in nuclear waste management, etc. Here stratified porous medium means that the ambient concentration of dissolved constituent and the temperature is not uniform and varies as a linear function. It has been found that an energy flux can be generated not only by temperature gradients but by composition gradients and also radiation as well. The mass fluxes can be created by temperature gradient and this is the Soret or thermal–diffusion effect. On the other hand, The energy flux caused by a composition gradient is called the Dofour or diffusion-thermo effect. These effects are considered as second-order phenomena, on the basis that they are of smaller order of magnitude than the effects described by Fourier's and Fick's laws, but they may become significant in areas such geosciences or hydrology. Madhusudhana *et al* [1] studied magneto hydrodynamic transient free convection and chemically reactive flow past a porous vertical plate with radiation and temperature gradient dependent heat source with the boundary conditions in slip flow regime. [2] analyze the effects of Dufour and Soret and magneto hydrodynamic on Darcy-Forchheimer mixed convection flow with heat and mass transfer from a vertical flat plate embedded in a saturated porous medium taking into the influence thermophoresis, viscous dissipation and radiation. Other relevant work to this paper could be found in [3].

Magneto hydrodynamic flow and heat and mass transfer processes occur in many industrial applications such as the geothermal system, aerodynamic processes, chemical catalytic reactors and processes, electromagnetic pumps, and magneto hydrodynamic power generators. Many studies have been carried out to investigate the magneto hydrodynamic transient free convective flow. Gupta [4] first studied transient free convection of an electrically conducting fluid from a vertical plate in the presence of magnetic field. Free convection effects on flow past an exponentially accelerated vertical plate was studied by Singh and Kumar [5]. Jha et al. [6] analyzed mass transfer effects on exponentially accelerated infinite vertical plate with constant heat flux and uniform mass diffusion. Muthucumaraswamy *et al.* [7] studied the flowpast an exponentially accelerated infinite vertical plate in the presence of variable surface temperature. Again Muthucumaraswamy *et al*. [8] analysed the combined effects of heat and mass transfer on exponentially accelerated vertical plate in presence of uniform magnetic field. Rajesh et all. Hassan *et al.* [9] studied the micropolar fluids near the stagnation point flow of electrically conducting due to a surface with the boundary in motion (stretching/shrinking). Ali *et al*.[10] obtained numerical solution of a viscous, incompressible, electrically conducting fluid flow and heat transfer over porous stretching sheet with injection. Sajjad *et al.* [11] studied MHD stagnation point flow of micropolar fluids towards a stretching sheet is studied in the presence of variable surface temperature. Reddy [12] analysed the effects of magnetohydrodynamic force and buoyancy on convective heat and mass transfer flow past a moving vertical porous plate in the presence of thermal radiation and chemical reaction. Hayat *et al* [13] analyzed the effects of thermal-diffusion and diffusion-thermo on MHD three-dimensional axisymmetric flow of a viscous fluid between radially stretching sheets in the presence of Hall and ion-slip currents, viscous dissipation, Joule heating and first order chemical reaction. Babu *et al.* [14] studied the effects of radiation and heat source/sink on the steady two dimensional magnetohydrodynamic (MHD) boundary layer flow of heat and mass transfer past a shrinking sheet with wall mass suction. Hassan *et al.* [15] worked on mathematical analysis and numerical solution for micropolar fluids flow due to a shrinking porous surface in the presence of magnetic field and thermal radiation.

This computational study examines thermal radiation with Soret and Dufour effect for MHD flow passing through porous medium to extend the problem already discussed by Okedoye and Akinrinmade.[16].

2. MATHEMATICAL ANALYSIS

Consider the mixed convection flow in a porous medium saturated with a Newtonian fluid on a vertical flat plate. The temperature of the ambient medium is T_∞ and the wall temperature is T_w. The flow along the vertical flat plate contains a species, slightly soluble in the fluid, The concentration at the plate surface is C_w and the solubility far away fromthe plate is $C\infty$. Several assumptions are used in the present paper viz, the fluid and the porous medium are in local thermodynamic equilibrium, The flow is laminar, steady-state and two-dimensional, The porous medium is isotropic and homogeneous, The properties of the fluid and porous medium are constant, The Boussinesq approximation is valid and the boundary layer approximation is applicable.

In-line with these assumptions, the governing equations describing the conservation of mass, momentum, energy and concentration can be written as follows:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad (1)$$

$$U\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}-\frac{\sigma\beta_0^2}{\rho}u-\frac{\upsilon}{K'}u+\frac{g\beta}{\rho}(T-T_\infty)+\frac{g\beta}{\rho}(C-C_\infty) \quad (2)$$

$$\rho C_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=K_1\frac{\partial^2 T}{\partial y^2}-\frac{\partial q_r}{\partial y}+\frac{D_m K_T}{C_S}\frac{\partial^2 C}{\partial y^2} \quad 3)$$

$$\rho\left(u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}\right)=D_m\frac{\partial^2 C}{\partial y^2}+\frac{D_m K_T}{D_T}\frac{\partial^2 C}{\partial y^2}+A(C-C_\infty) \quad (4)$$

Where all quantities are defined in the list of symbols. K_1 is thermal diffusivity, ρ is density, T is temperature of fluid, u,v are velocity components, x, y are Cartesian coordinates, ϴ is dimensionless temperature, C is concentration function of specie, D_m is mass diffusivity. The boundary conditions of the problem are

$y=0, \quad v=-V_0, T=T_W, \quad C=Cw$

$y\to\infty, \quad u\to 0, \quad T\to T\infty, \; C\to C\infty \quad (5)$

WhereT_W,C_W, T_∞ and C_∞ have constant values , V_0 is velocity due to suction at wall.

Equations (1) to (4), are now nondimensionalized using the following quantities,

$$\psi=\sqrt{\upsilon U0}\,x^{\frac{3}{4}}f(\eta),\quad \eta=\sqrt{\frac{U0}{\upsilon}}\,x^{-\frac{1}{4}}y,\quad \theta(\eta)=\frac{T-T\infty}{Tw-T\infty},\quad \emptyset(\eta)=\frac{C-C\infty}{Cw-C\infty},$$

$$\alpha=\frac{K_1}{\rho C_p},\qquad q_r=-\left(\frac{4\sigma}{3\delta}\right)\frac{\partial T^4}{\partial y}$$

Where σ is the Stefan Boltzmann constant and δ is the Rosseland mean absorption coefficient. Temperature differences in the flow are assumed to be sufficiently small such that T^4 may be expressed as a linear function of temperature. Expanding T^4about T_∞in Taylor's series and neglecting higher order yield

$$T^4\cong 4T_\infty^3T-3T_\infty^3$$

And also stream function ψ satisfied continuity equation (1) The Eq. (2) to Eq.(4) become as below:

$$f'''=\frac{1}{2}f'^2-\frac{3}{4}ff''+(M+K)f'-Gr(\theta+N\emptyset) \quad (6)$$

$$\theta''=-\frac{1}{(1+R_n)}\left[\frac{3}{4}Prf\theta'+Du\emptyset''\right] \quad (7)$$

$$\emptyset''=-\frac{3}{4}Scf\emptyset'-Du\theta'' \quad (8)$$

The boundary conditions (5) become:

$$f(0)=f_w,\; f'(0)=1, \theta(0)=1, \phi(\eta)=1,$$
$$f'(\eta)=0,\quad \theta(\eta)=0\to, \phi(\eta)=0 \text{ as } \eta\to\infty \quad (9)$$

Where

$$M=\frac{\beta_{0\sigma}^2}{U_0\rho},\quad G_r=\frac{g\beta(T_w-T_\infty)}{\rho U_0^2},\; N=\frac{\beta c(C_w-C_\infty)}{\beta(T_w-T_\infty)},$$
$$K=\frac{\upsilon}{U_0K'}, Pr=\frac{\upsilon}{\alpha},\quad Sc=\frac{\mu}{D_m},$$
$$D_u=\frac{D_m(C_w-C_\infty)}{C_S(T_w-T_\infty)}, S_r=\frac{K_T(T_w-T_\infty)}{T_m(C_w-C_\infty)}$$

We notice that N is positive for thermally assisting flows, negative for thermally opposing flows and zero for thermal-driven flows. G_r is Grashof number, Sr is Soret number, D_u is Duffer number, K is the porosity parameter, P is Prandtl nimber, M is magnetic parameter, R_n is radiation parameter, f_w is suction parameter and Sc is Schmidt number.

3. RESULTS AND DISCUSSION

In the above section of this study the finally governing equation of the problem namely Eq. (6) to Eq. (8) with associated condition of boundary Eqs.(9)required some viable solution these completed equation involve nonlinear terms and Larger order derivatives any close form solutions of these equations seems difficult to find. Therefore, a numerical treatment by namely NDsolve command of computational software Wolfram Mathematica (11.1.0) has been harnessed. A vigorous parametric analysis has been carried out for computational results of flow speed heat and mass distributions

The effect of mass buoyancy parameter N (N>0) and Grashof number Gr (Gr>0) are served on zero dimensional flow velocity $f'(\eta)$ respectively in Fig. 1 and Fig. 2. Both these parameters show increasing influence on $f'(\eta)$. But the porosity parameter 'K' and magnetic parameter 'M' indicate decreasing effects on $f'(\eta)$ as depicted respectively in Fig. 3 and fig. 4. Fig. 5 is shown that the increasing in Dufore number Du implies increasing in flow speed $f'(\eta)$ but the flow speed $f'(\eta)$ decreases with rise in the values of Pr as seen in Fig. 6. The increasing in radiation parameter Rn shows slight increment in Sc indicates slight reduction in $f'(\eta)$ as parameter respectively in Fig.7 and Fig. 8. Fig. 9 demonstrates the decreasing impacts of suction variable Fw (Fw>0) on $f'(\eta)$. The specie concentration $\phi(\eta)$ decreases with increment in the values of mass buoyancy parameter N and Grashof number Gr as demonstrated respectively in fig. 10 and Fig. 11. Fig. 12 and Fig. 13 respectively show that rise in curve of $\phi(\eta)$ with increment in the value of parameter K and M. The dufore number Du implies slight increases in $\phi(\eta)$ but Schmidt number Sc causes significant decreases in $\phi(\eta)$ as shown respectively in Fig. 14 and Fig.15. The increment in suction at boundary (Fw>0) causes decreases in the values of $\phi(\eta)$ as shown in Fig. 16. Both mass buoyancy parameters N and Grashof number Gr both show a decreasing effect on $\theta(\eta)$ as demonstrated respectively in Fig. 17 and Fig. 18. The temperature $\theta(\eta)$ increases with increment in Dufore number as shown in Fig. 19. Fig 20 indicates that the increases in Prandtl number causes reduction in $\theta(\eta)$. The temperature function $\theta(\eta)$ reduces with increment in suction Fw as depicted in Fig.21

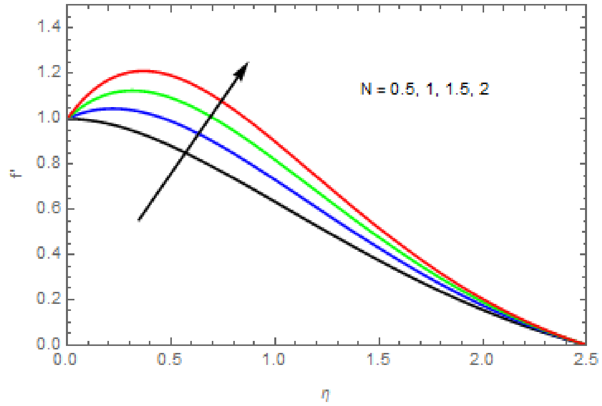

Fig 1: Graph of $f'(\eta)$ under the effect of N

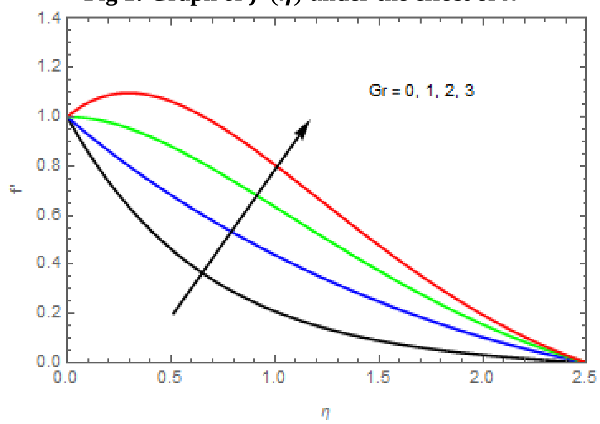

Fig 2: Graph of $f'(\eta)$ under the effect of Gr

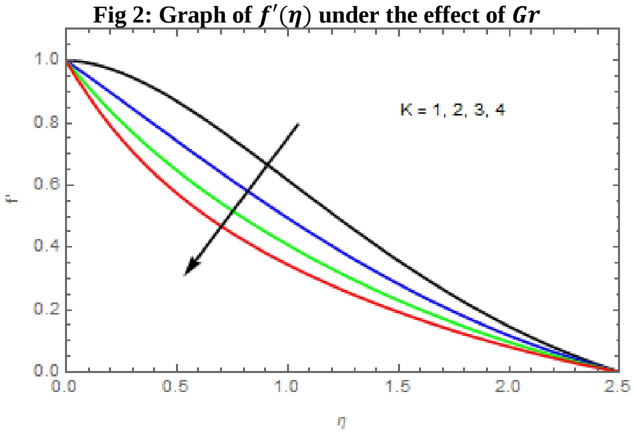

Fig 3: Graph of $f'(\eta)$ under the effect of K

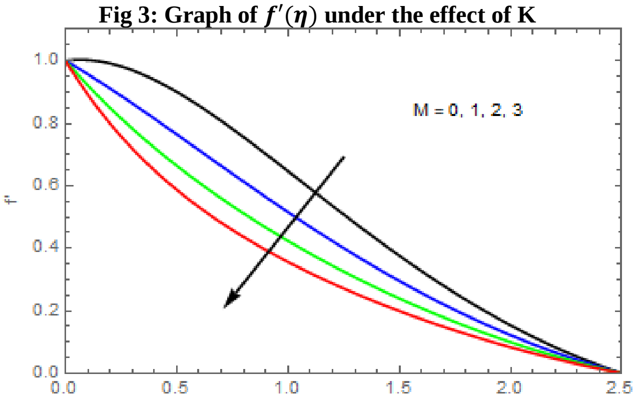

Fig 4: Graph of $f'(\eta)$ under the effect of M

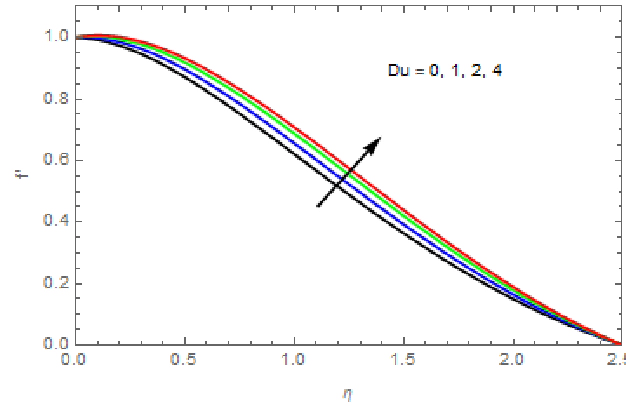

Fig 5: Graph of $f'(\eta)$ under the effect of Du

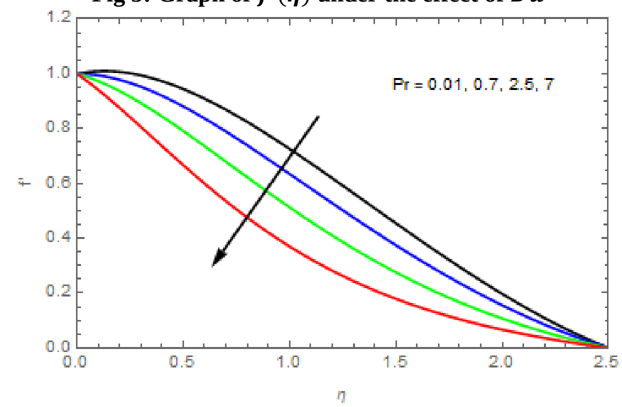

Fig 6: Graph of $f'(\eta)$ under the effect of Pr

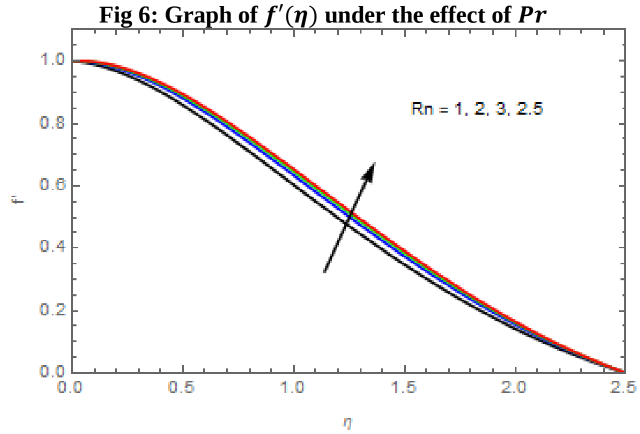

Fig 7: Graph of $f'(\eta)$ under the effect of Rn

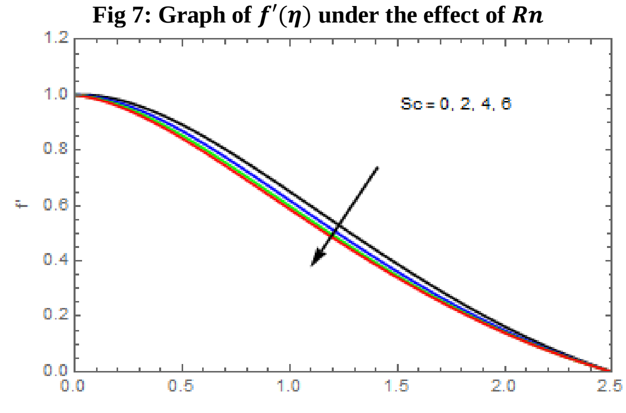

Fig 8: Graph of $f'(\eta)$ under the effect of Sc

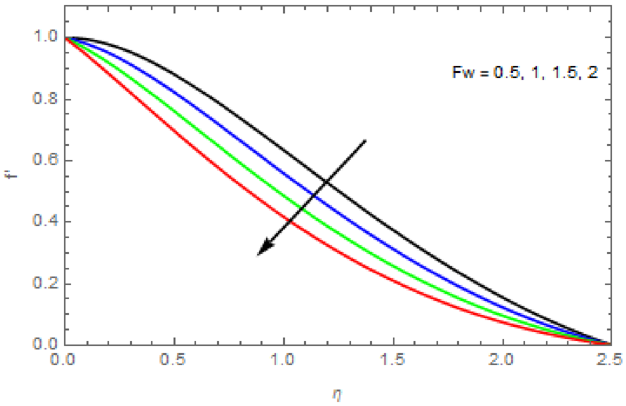

Fig 9: Graph of $f'(\eta)$ under the effect of Fw

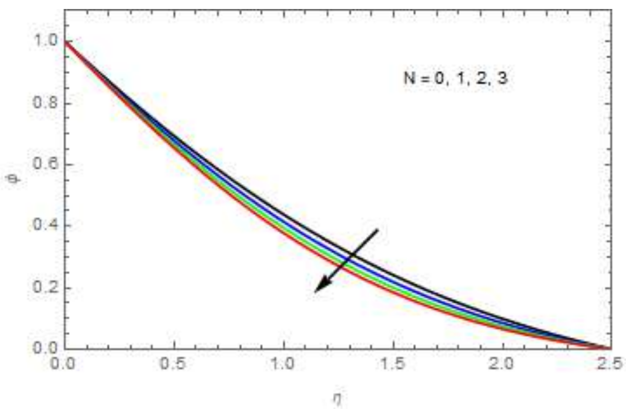

Fig 10: Graph of $\phi(\eta)$ under the effect of N

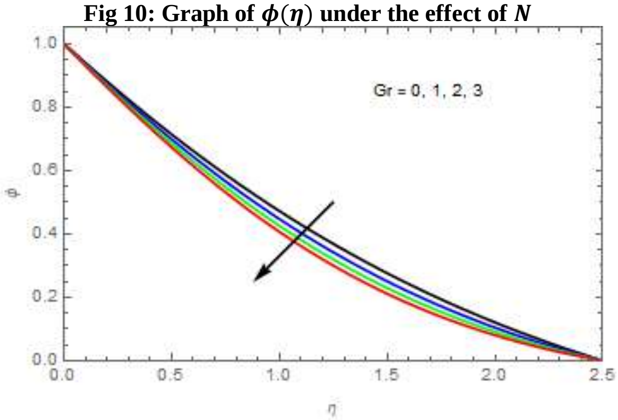

Fig 11: Graph of $\phi(\eta)$ under the effect of Gr

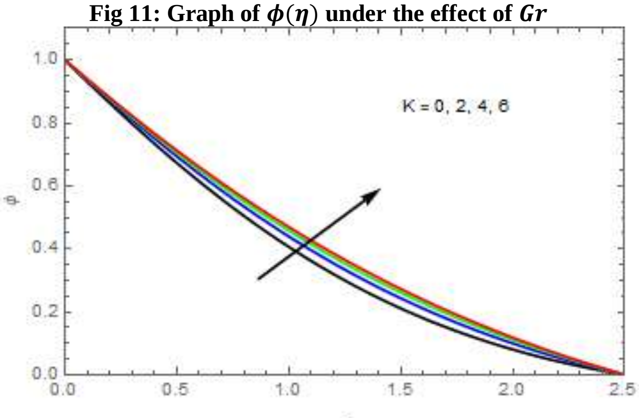

Fig 12: Graph of $\phi(\eta)$ under the effect of K

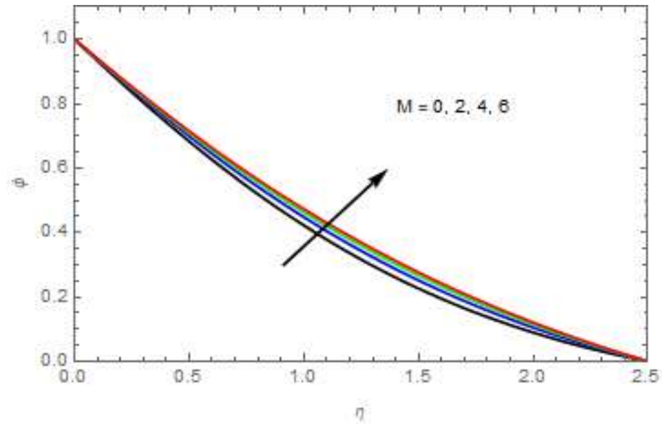

Fig 13: Graph of $\phi(\eta)$ under the effect of M

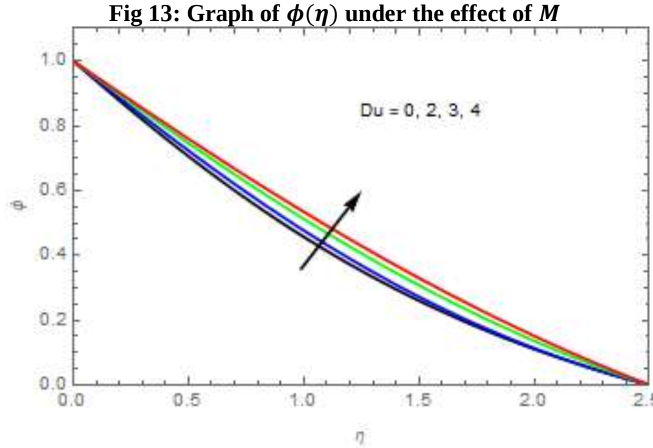

Fig 14: Graph of $\phi(\eta)$ under the effect of Du

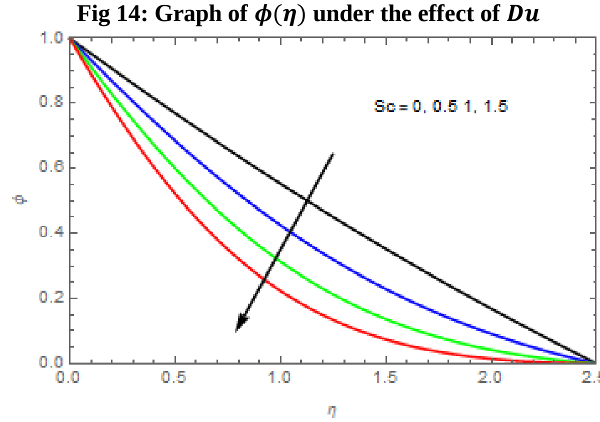

Fig 15: Graph of $\phi(\eta)$ under the effect of Sc

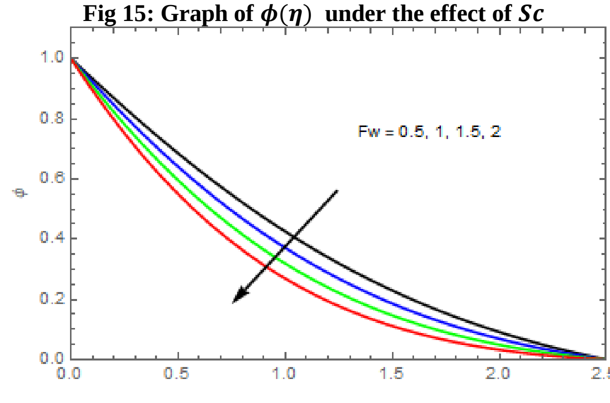

Fig 16: Graph of $\phi(\eta)$ under the effect of Fw

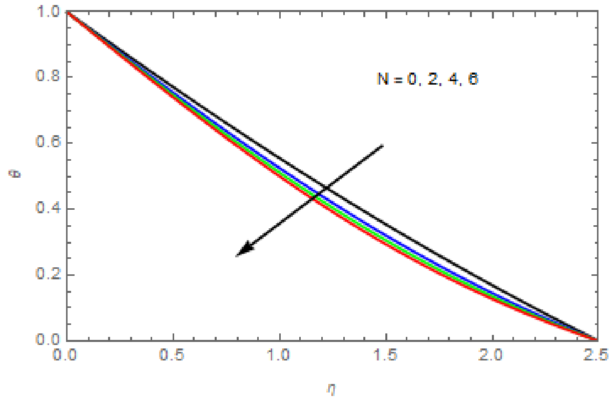

Fig 17: Graph of $\theta(\eta)$ under the effect of N

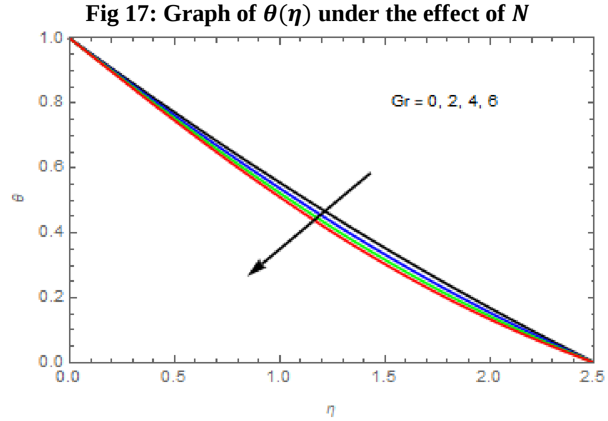

Fig 18: Graph of $\theta(\eta)$ under the effect of Gr

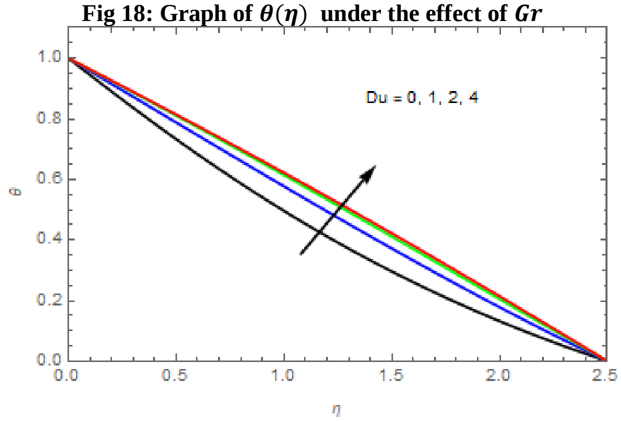

Fig 19: Graph of $\theta(\eta)$ under the effect of Du

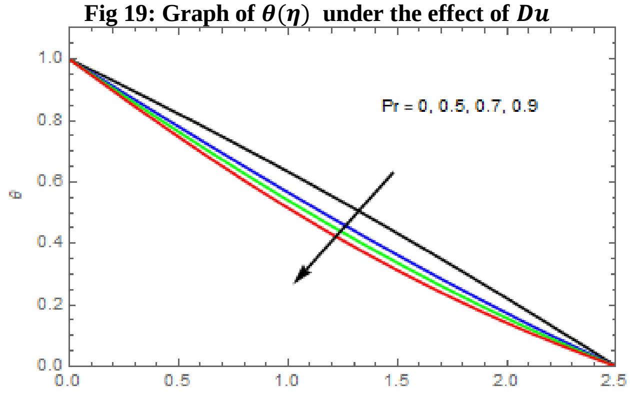

Fig 20: Graph of $\theta(\eta)$ under the effect of Pr

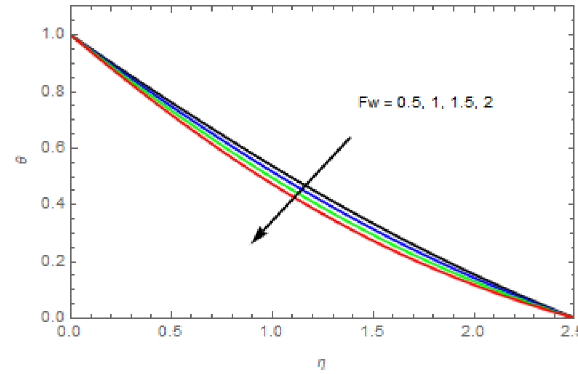

Fig 21: Graph of $\theta(\eta)$ under the effect of Fw

REFERENCES

[1]. Madhusudhana Rao, B., G. Viswanatha Reddy and M.C. Raju, 2013. “MHD transient free convection and chemically reactive flow past a porous vertical plate with radiation and temperature gradient dependent heat source in slip flow regime”, IOSR Journal of Applied Physics, 6l 22-32.

[2]. Jagadha S. and Kishan N. (2015). Soret and Dufour effects on MHD mixed convective heat and mass transfer flow with thermophoresis past a vertical flat plate embedded in a saturated porous medium in the presence of radiation and viscous dissipation. Advances in Applied Science Research, 2015, 6(8):67-81 ISSN: 0976-8610 CODEN (USA).

[3]. S. Karthikeyan , M. Bhuvaneswari , S. Sivasankaran and S. Rajan (2016) Soret and Dufour Effects on MHD Mixed Convection Heat and Mass Transfer of a Stagnation Point Flow towards a Vertical Plate in a Porous Medium with Chemical Reaction, Radiation and Heat Generation. Journal of Applied Fluid Mechanics, Vol. 9, No. 3, pp. 1447-1455, 2016. Available online at www.jafmonline.net, ISSN 1735-3572, EISSN 1735-3645

[4] A. S. Gupta, “Steady and transient free convection of an electrically conducting fluid froma vertical plate in the presence of a magnetic field,” Applied Scientific Research, vol. 9, no. 1, pp. 319–333, 1960.

[5] A. K. Singh and N. Kumar, “Free-convection flow past an exponentially accelerated vertical plate,” Astrophysics and SpaceScience, vol. 98, no. 2, pp. 245–248, 1984.

[6] B. K. Jha, R. Prasad, and S. Rai, “Mass transfer effectsonthe flow past an exponentially accelerated vertical plate with constant heat flux,” Astrophysics and Space Science, vol. 181, no. 1, pp. 125–134, 1991.

[7] R.Muthucumaraswamy, K. Sathappan, and R. Natarajan, “Heat transfer effects on flow past an exponentially accelerated vertical plate with variable temperature,” Theoretical and AppliedMechanics, vol. 35, no. 4, pp. 323–331, 2008.

[8] R. Muthucumaraswamy, K. E. Sathappan, and R. Natarajan, “Heat and mass transfer effects on exponentially accelerated vertical plate with uniform magnetic field,” Journal of Engineering,Annals, vol. 6, no. 3, pp. 188–193, 2008.

[9] Hassan. W, Sajjad. H, Abdul. S, Shamila. K. Micropolar Fluids Flow Over A Shrinking Porous Surface In The Presence Of Magnetic Field And Thermal Radiation. Sci.Int.(Lahore),28(1),53-57,2016

[10] M. Ali, F. Ahmad, S. Hussain, Numerical solution of MHD flow of fluid and heat transfer over porous stretching sheet, J. Basic. Appl. Sci. Res., 4(5), 146-152, 2014

[11] Hassan. W, M. A. Kamal, , Farooq .A, Shamila. K, Sajjad. H. The Radiation Effect of MHD Stagnation Point Flow Of Micropolar Fluids Due To A Porous Shrinking Sheet With Heat Generation. Sci.Int.(Lahore),28(5),4271-4275, 2016.

[12] Reddy, G.V. R Radiation And Chemical Reaction Effects On Mhd Flow Along A Moving Vertical Porous Plate. Int. J. of Applied Mechanics and Engineering,vol.21, No.1, pp.157-168, 2016

[13] T. Hayat and F. A. Hendi Thermal-diffusion and diffusion-thermo effects on MHD three-dimensional axisymmetric flow with Hall and ion-slip currents. Journal of American Science, 8(1). pp.284-294. 2012

[14] P. R. Babu, J. A. Rao and S. Sheri. Radiation Effect on Mhd Heat and Mass Transfer Flow over a Shrinking Sheet with Mass Suction. Journal of Applied Fluid Mechanics, Vol. 7, No. 4, pp. 641-650, 2014.

[15] S. Hussain, M. A. Kamal, F. Ahmad and M. Shafique, MHD stagnation point flow of micropolar fluids towards a stretching sheet, Sci.Int.(Lahore), 26(5),1921-1929, 2014

[16] Okedoye A.M., Akinrinmade V.A. MHD Mixed Convection Heat and Mass Transfer Flow from Vertical Surfaces in Porous Media with Soret and Dufour Effects. *Journal of Scientific and Engineering Research*, 4(9):75-85, 2017