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Transference of Thermal Energy Escorted by Constant Suction, Radiation and Mass Transfer on Viscous Fluid Stream Past a Surface

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Abstract

Repercussions of two-dimensional viscous fluid stream past a vertical surface in existence of chemical reaction and radiation have been analyzed. Contemporaneous transmit of heat and mass are accounted in amalgamation of diffusion thermo effects. The suction at the surface is presumed to be constant. The problem is interpreted by numerical technique. The results are elucidated graphically. The implementation of such type of problems are found in petroleum industries and chemical industries.

Keyword: MHD, suction, heat transfer, mass transfer, chemical reaction, radiation, diffusion thermo

1.Introduction

From technical viewpoint, the magnetohydrodynamic convective viscous flow problems are exceptionally salient as they have enormous connection in abundant fields such as compact heat exchangers, casting, filtration, metallurgy, cooling of nuclear reactors and fusion, crystal growth, petroleum industries etc. Analysis of flow over a vertical surface with heat and mass transfer along with chemical reaction plays notable part in chemical industries like production, food processing etc. Cussler[1] has pointed out the scheme of first order chemical reaction where the rate of reaction is directly proportional to the concentration itself. Chambre and Young [2] have studied the model of first order chemical reaction in neighborhood of a horizontal plate. Gupta *et al*.[3], Kafousias and Raptis [4], Muthucumaraswamy [5], Rajesh and Verma [6], Saxena and Dubey [7], Kumar *et al*.[8], Raveendra Babu *et al*.[9],etc. have investigated in the above mentioned area with various fluid flow models. Besides them Choudhury and Dhar[10], Raju and Venkataramana[11], Niranjan *et al*. [12], Kesaraiah [13], Das and Dorjee [14], Kesaraiah and Ikramuddin [15], Kesaraiah and Srinathuni[16],Bibi and Padma [17],Kalita *et al*.[18]have contributed with more properties of fluid and the results obtained by them are really praiseworthy.

The objective of this paper is to study numerically the problem of flow, heat and mass transfer over a vertical surface with constant suction in presence of the thermal radiation, the chemical reaction and Dufour effect. The differential equation are solved using MATLAB'S built in solver bvp4c.The solutions are depicted graphically with suitable justification.

2.Mathematical Formulation:

Consider two dimensional free convective, electroconducting incompressible fluid flow across a vertical plate in occurrence of radiation and constant suction. An uniform magnetic field B_0 is applied to the transverse direction of the plate. In this paper, we have investigated the concurrent heat and mass transfer mechanism of governing fluid in associate with diffusion thermo effects and chemical reaction. The x'-axis is taken along the plate,which is vertically upwards and y'-axis is normal to it. Here, the effect of induced magnetic field is neglected. Using boundary layer approximation, the governing equations are composed as follows:

Equation of continuity:

$$\frac{\partial v'}{\partial y'} = 0 \qquad (1)$$

Equation of momentum:

$$\rho v'\frac{\partial u'}{\partial y'} = \rho g\beta\left(T' - T'_\infty\right) + \rho g\beta'\left(C' - C'_\infty\right) + \mu\frac{\partial^2 u'}{\partial y'^2} - \sigma B_0^2 u' \quad (2)$$

Equation of Energy:

$$\rho C_p\left(v'\frac{\partial T'}{\partial y'}\right) = k_T\left(\frac{\partial^2 T'}{\partial y'^2}\right) - \frac{\partial q_r}{\partial y'} + \left[\rho\frac{DmK_T}{C_s}\frac{\partial^2 C'}{\partial y'^2}\right] \quad (3)$$

Equation of concentration:

$$v'\frac{\partial C'}{\partial y'} = D\left(\frac{\partial^2 C'}{\partial y'^2}\right) - k_l\left(C' - C'_\infty\right) (4)$$

where u' and v' are the respective fluid velocity component along and normal to the plate respectively, ρ is density of the fluid, g is acceleration due to gravity, β is coefficient of volume expansion for heat transfer, β' is coefficient of expansion with species heat at constant pressure, T' is the fluid temperature, T'_∞ is far field temperature, C' is species concentration, C'_∞ is the far field concentration, μ is viscosity, σ is thermal conductivity, C_p is specific heat at constant pressure, k_T is thermal conductivity, Dm is coefficient of mass diffusivity, K_T is the thermal diffusion ratio, C_s is the concentration susceptibility, D is chemical molecular diffusivity k_l is rate of chemical reaction.

The relevant boundary conditions:

$$y' = 0: \quad u' = U, v' = -v_0(constant), T' = T'_w, C' = C'_w$$

$$y' \to \infty: \qquad u' \to 0 \quad , T' \to T'_\infty \quad , C' \to C'_\infty \ (5)$$

We introduce the following non dimensional quantities:

$$u = \frac{u'}{U}, y = \frac{y'U}{\nu}, \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \phi = \frac{C' - C'_\infty}{C'_w - C'_\infty}, \lambda = \frac{v_0}{U}, M = \frac{\sigma B_0^2 \nu}{\rho U^2}, Gr = \frac{\nu g\beta\left(T'_w - T'_\infty\right)}{U^3},$$

$$Gm = \frac{\nu g\beta^*(C'_w - C'_\infty)}{U^3}, Pr = \frac{\eta_0 C_p}{K_T}, \gamma = \frac{\nu K_l}{U^2}, Sc = \frac{\nu}{D}, R = \frac{16a^*\nu^2\sigma T'^3_\infty}{k_T U^2}, Du = \frac{D_m K_T(C'_w - C'_\infty)}{C_s C_p \nu(T'_w - T'_\infty)} (6)$$

where Gr is thermal Grashof number, Gm is the solutal Grashof number, Pr is the Prandtl number, M is the Hartmann number, Sc is the Schmidt number , Du is the coefficient of mass diffusivity, R is the radiation parameter,γ is chemical reaction parameter.

The non-dimensional equations are:

$$\frac{d^2u}{dy^2} + \lambda\frac{du}{dy} - Mu = -(Gr\theta + Gm\phi) \quad (7)$$

$$\frac{1}{Pr}\frac{d^2\theta}{dy^2} + \lambda\frac{d\theta}{dy} - \frac{R}{Pr}\theta = -Du\frac{d^2\phi}{dy^2} \quad (8)$$

$$\frac{1}{Sc}\frac{d^2\phi}{dy^2} + \lambda\frac{d\phi}{dy} - \gamma\phi = 0 \quad (9)$$

The modified boundary conditions are:

$$y = 0: \; u = 1, \theta = 1, \phi = 1$$

$$y \to \infty: \; u \to 0, \theta \to 0, \phi \to 0 \quad (10)$$

3.Method of Solution:

The equations (7) to (9) have been solved numericallysubject to the boundary conditions(10). To solve these ordinary differential equations, MATLAB’s built in solver bvp4c is used.

4.Results and Discussions:

In this paper, an attempt is made to analyze the problem of steady two -dimensional free convective MHD flow of a viscous fluid across a vertical porous plate in occurrence of radiation, chemical reaction and Dufour effect. The influences of various physical parameters on fluid velocity, temperature and concentration are illustrated graphically. For clear penetrate of physical situation of velocity, temperature and concentration; we allocate numerical values to the various parameters like Magnetic parameter (M),Chemical reaction parameter(γ), Schmidt number(Sc), Prandtl number(Pr), Solutal Grashof number (Gm) in figure 1to 10 for the externally cooling plate Gr>0 . Fig 1 excels the effect of magnetic parameter(M) on the fluid velocity.In Fig 1 it is observed that the growth of magnetic parameter (M) lesser the velocity in the case of externally cooled plate (Gr>0). It happens due to appearance of magnetic field normal to the direction of electrically conducting fluid which produces a resistance (Lorentz force)against the flow.

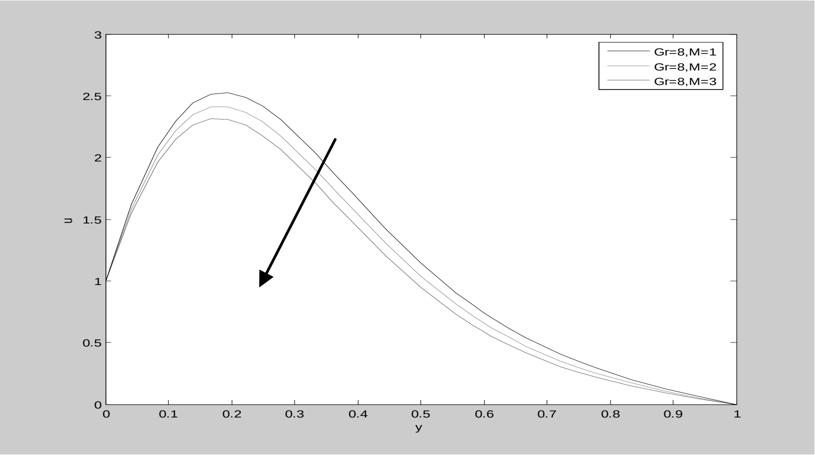

Fig1: Velocity Profile u against y for Pr=6, R=12, Gr=8,Gm=10, Sc=6, γ=2,Du=0.6,λ=2

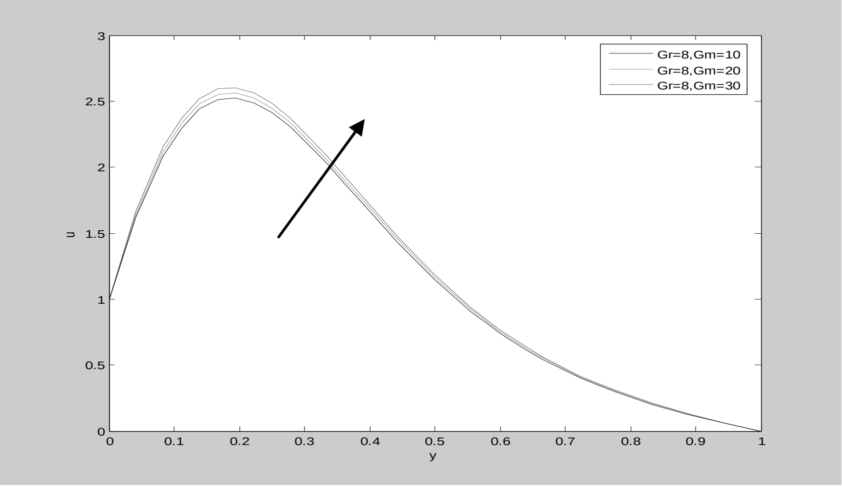

Fig2: Velocity Profile u against y for Pr=6, R=12,M=1, Gr=8, Sc=6, γ=2,Du=0.6,λ=2

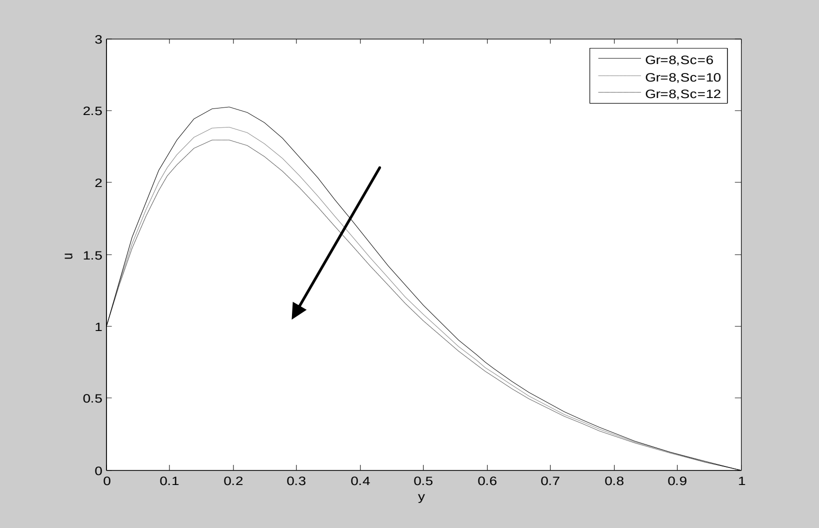

Fig3: Velocity Profile u against y for Pr=6, R=12,M=1,Gr=8,Gm=10, Sc=6,γ=2,Du=0.6,λ=2

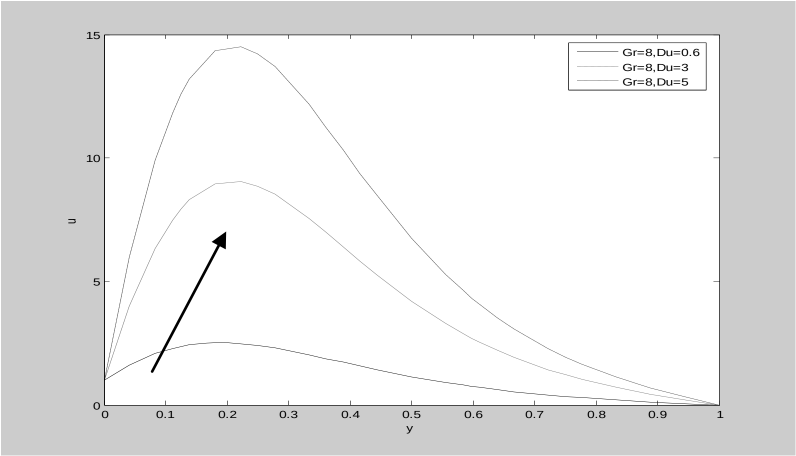

Fig4: Velocity Profile u against y for Pr=6, R=12,M=1, Gr=8,Gm=10, Sc=6, γ=2,λ=2

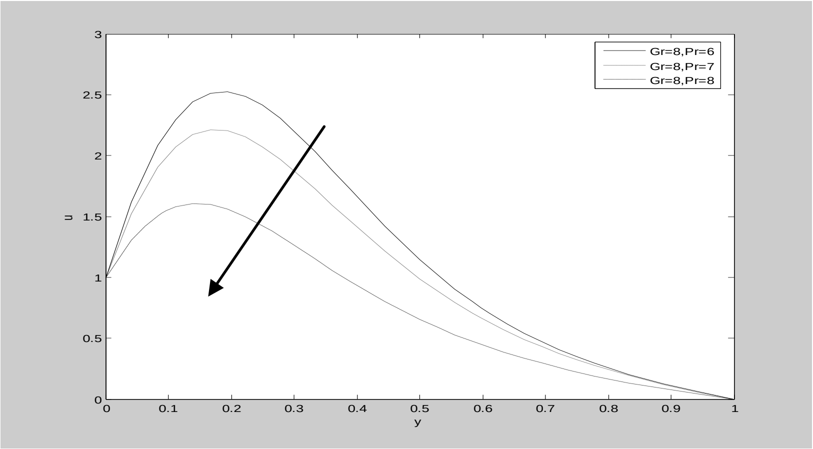

Fig5: Velocity Profile u against y for R=12,M=1,Gm=10,Gr=8,Sc=6, γ=2,Du=0.6,λ=2

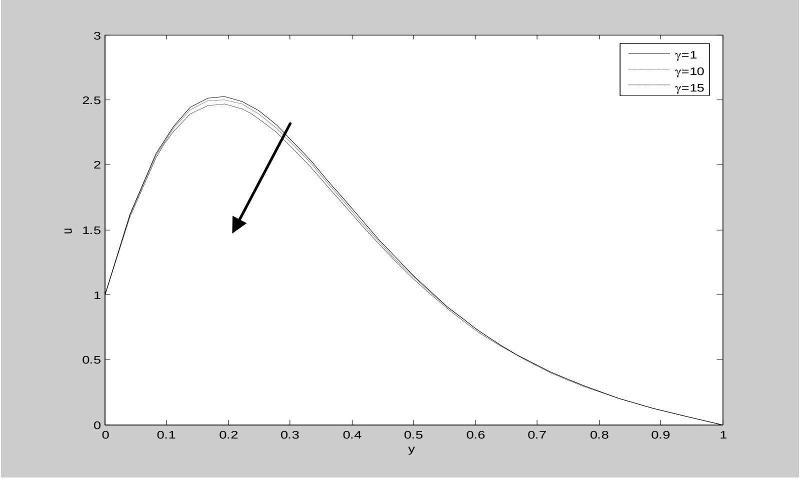

Fig6: Velocity Profile u against y for Pr=6, R=12,M=1,Gm=10, Gr=8, Sc=6, Du=0.6,λ=2

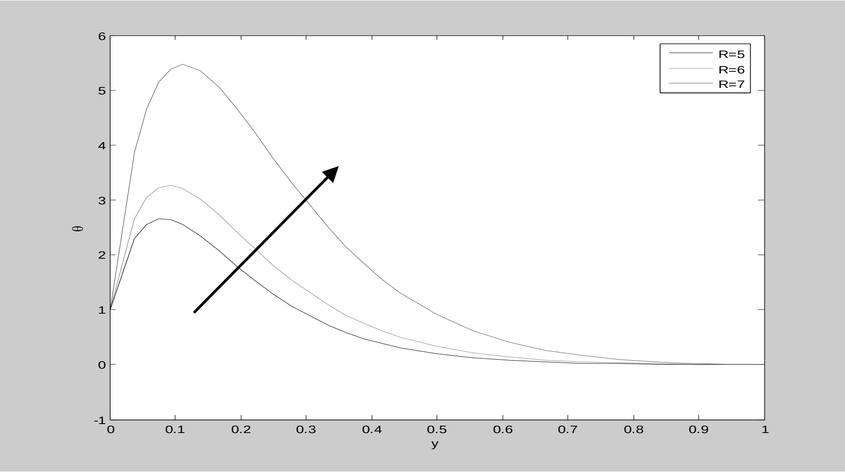

Fig7: Temperature Profile against y for Pr=6, M=1,Gm=10, Gr=8, Sc=6, γ=2,Du=0.6,λ=2

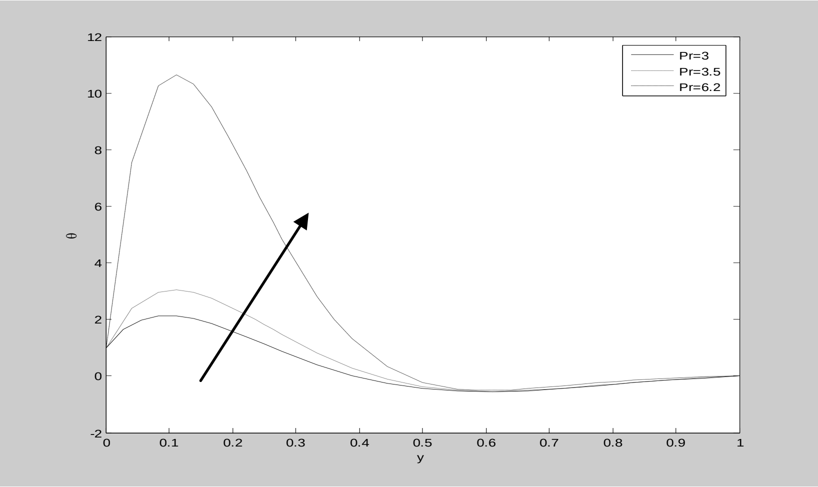

Fig8: Temperature Profile against y for R=12,M=1,Gm=10, Gr=8, Sc=6, γ=2,Du=0.6,λ=2

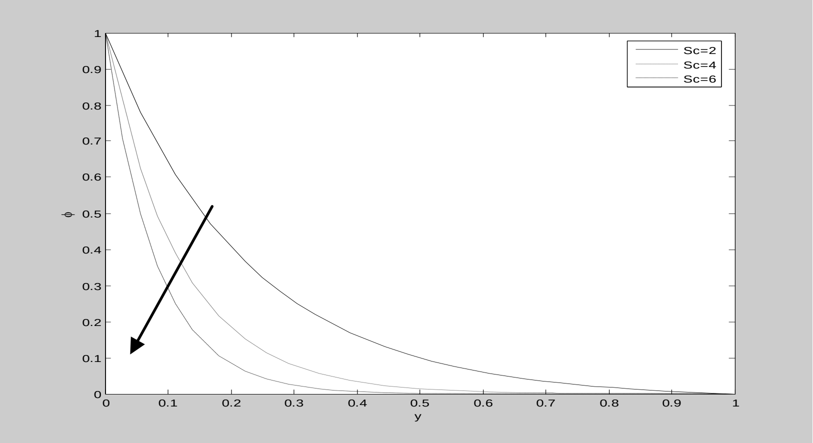

Fig9: Concentration Profile against y for Pr=6, R=12,M=1,Gm=10, Gr=8, γ=2,Du=0.6,λ=2

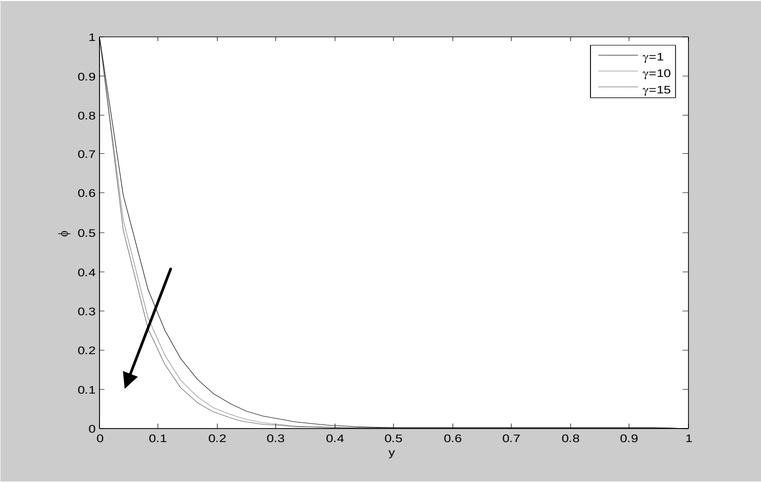

Fig10: Concentration Profile against y for Pr=6, R=12,M=1,Gm=10, Gr=8, Sc=6, Du=0.6,λ=2

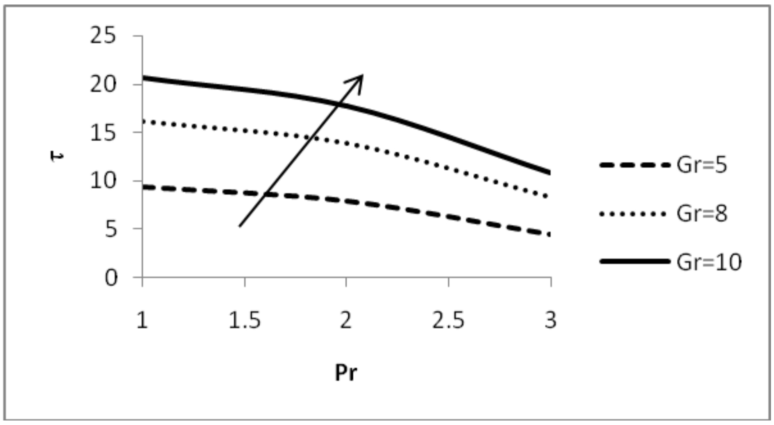

Fig11: Shearing stress against Pr for M=1, R=12,Gm=10,Sc=6,Du=0.6,γ=1,λ=2

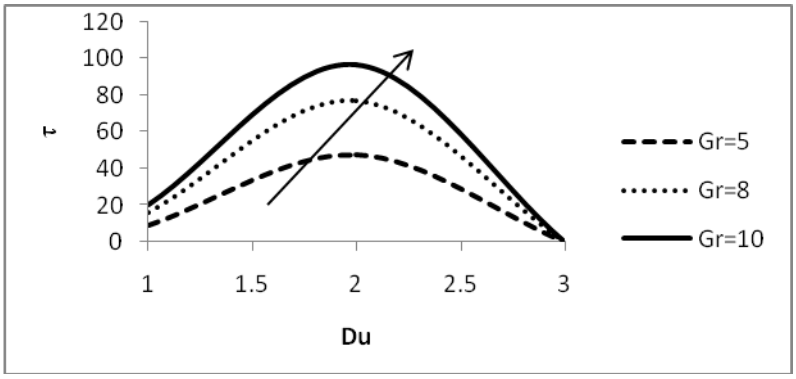

Fig12: Shearing stress against Du for M=1, R=12,Gm=10,Sc=6 ,Pr=6,,γ=1,λ=2

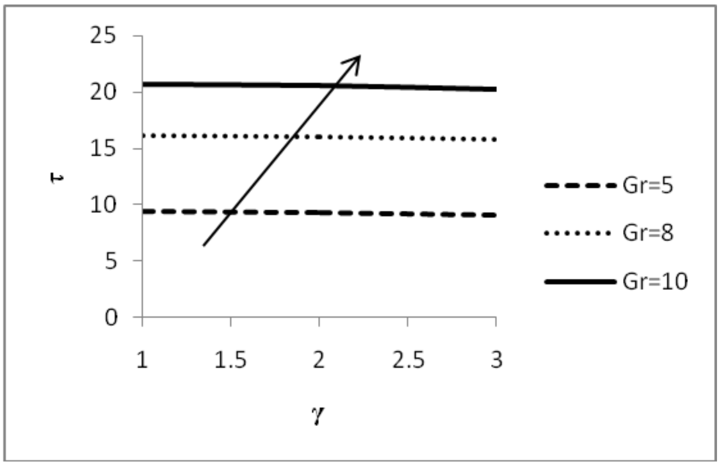

Fig13: Shearing stress against γ for M=1,R=12,Gm=10,Sc=6,Pr=6,Du=0.6,λ=2

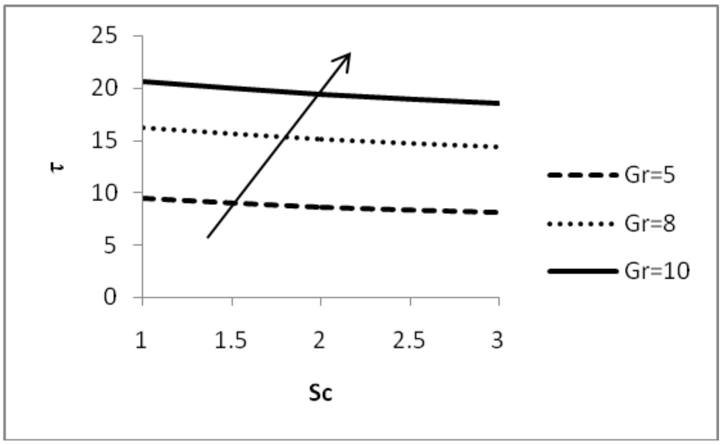

Fig14: Shearing stress against Sc for M=1, R=12,Gm=10,Pr=6,Du=0.6,γ=1,λ=2

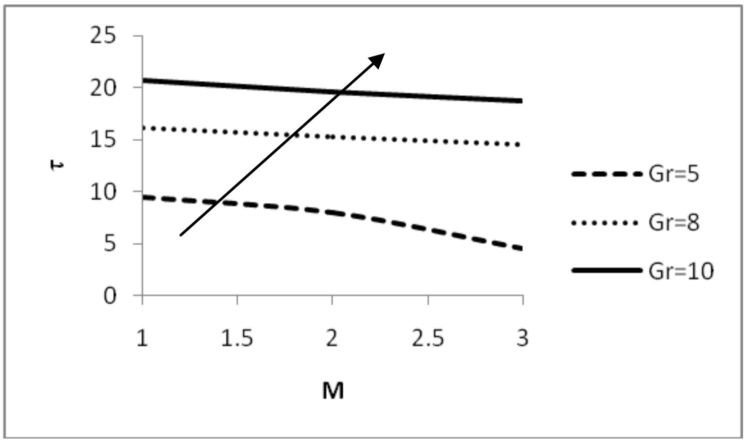

Fig15: Shearing stress against M for R=12,Gm=10,Sc=6,Pr=6,Du=0.6,γ=1,λ=2

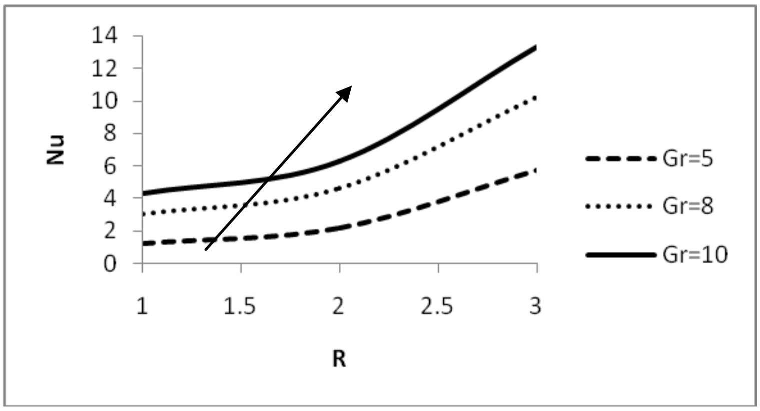

Fig16: Nusselt number against R for M=1, Gm=10,Sc=6,Pr=6,Du=0.6,γ=1,λ=2

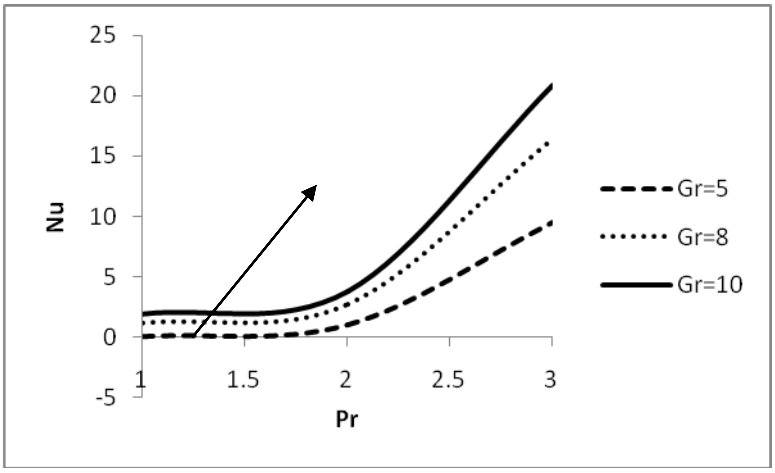

Fig17: Nusselt number against Pr for M=1, R=12,Gm=10,Sc=6,Du=0.6,γ=1,λ=2

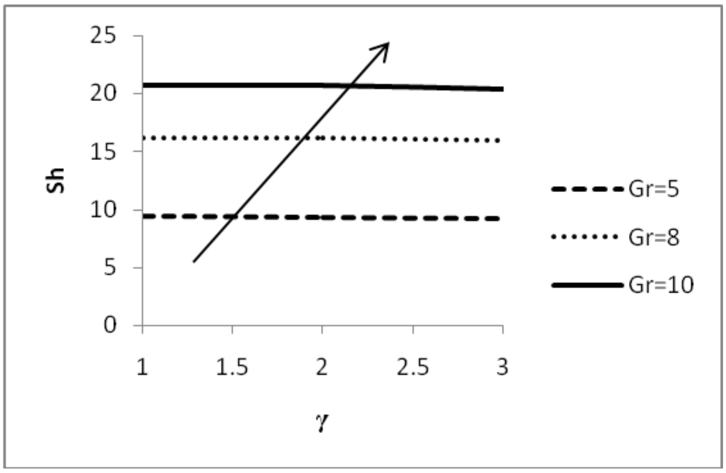

Fig18: Sherwood against γfor M=1, R=12,Gm=10,Sc=6,Pr=6,Du=0.6,λ=2

In all the cases, the velocity rises near the plate but gradually diminishes far away from the plate.The velocity rises with expansion of Gm & Du(Fig 2 and 4), reverse effect is perceived for the enhancement of Sc, Pr and γ (Fig 3,5 and 6).

The temperature profiles are portrayed in figures 7 and 8 respectively with variation of R and Pr. The temperature ascents near the plate but moderately reduces far away from the plate. Also, with the growth of R and Pr the temperature accelerates.

Figure 9 and 10 depicts the concentration profiles for change in various values of Sc andγ. The concentration profiles exhibits reduction trend with the hike of Sc andγ.

Figure 11 to 15 manifest the upshots of thermal Grashofnumber (Gr) on shearing stress against Pr, Du,γ, Sc and M. The shearing stress gets up with the advancement of theparameters in all the cases. The Nusselt number reveals the rising nature with the increasing values of R and Pr [Fig16 and 17]. Figure 18 excels the development of Sherwood number (Sh) against the chemical reaction parameter (γ) with the growth of Gr.

5.Conclusions:

From the above discussion, some salient points are concluded as follows:

- The velocity, temperature and concentration fields are appreciable pretentious in the fluid flow region by the fluctuations of the flow parameters.
- The velocity profile takes a diminishing trend with the rise of magnetic parameter and this is in agreement with the physical situation.
- The shearing stress exhibits acceleration against the selected flow parameter of the Grashof number for externally cooling plate.
- The Nusselt number fluctuates significantly by the variation of flow parameter.
- The Sherwood number against chemical reaction parameter reveals an increasing trend with the rise of Grashof number.

References:

[1]Cussler E.L., “Diffusion mass transfer in fluid system”, Cambridge University Press(1988).

[2]Chamber P.L. and Young J.D. “On the diffusion of chemically reactive species in a laminar boundary layer flow ”, The physics of fluid,vol.1(1958), pp.48-54.

[3]Gupta A.S., Pop I. and Soundalgekar V.M., “Free convection effects on the flow past an accelerated vertical plate in an incompressible dissipative fluid”, Rev .Roum. Sci. Techn. Mec. Apl. Vol.24(1979), pp. 561-568.

[4]Kafousias N.G. and Raptis A, “Mass transfer and free convection effects on the flow past an accelerated vertical infinite plate with variable suction or injection”, Rev. Roum.Sci.Techn.Mec. Apl. Vol. 26(1989), pp.11-22

[5]Muthucumaraswamy., “First order chemical reaction on exponentially accelerated isothermal vertical plate with mass diffusion ,”Annals Faculty of engineering, Hunedoara,Tome Vll (2009), pp. 47-50.

[6]Rajesh V. and Varma S.V.K., “Chemical reaction and radiation effects on MHD flow past an infinite vertical plate with variable temperature”, Far East Journal of Mathematical Sciences, Vol.32 (1)(2009),pp. 87-106.

[7]Saxena S.S. and Dubey G.K., “Unsteady mhd heat and mass transfer free convection flow of a polar fluid past a vertical moving porous plate in porous medium with heat generation and thermal diffusion”, Advances in Applied Science Research,Vol.(24) (2011), pp. 259-278.

[8]Kumar A.G.V., Goud Y. R. nad Varma S.V.K.” Thermal diffusion and radiation effects on unsteady mhd flow through porous medium with variable temperature and and mass diffusion in the presence of heat source/sink”, Advances in Applied Science Research ,vol.3(3) (2012),pp. 1494-1506.

[9]Raveendra Babu K., Kumar A.G.V. and Varma S.V.K., “Diffusion-thermo and radiation effects on mhd free convective heat and mass transfer flow past an infinite vertical plate in presence of a chemical reaction of first order” Advances in Applied Science Research , Vol.3(4) (2012), pp.2446-2462

[10] Rita Choudhury and Paban Dhar, “Diffusion Thermo effects of visco-eleastic fluid past a porous surface in presence of magnetic field and radiation”, International Journal of Innovative Research in Science, Engineering and Technology,vol.2(3)(2013).

[11]H.Niranjan, S . Sivasankaran,M. Bhuvaneswari, “Chemical reaction, Soret and Dufour effect on MHD mixed convection stagnation point flow with radiation and slip condition”, Scientia Iranica,vol24(2)(2017),pp. 698-706.

[12]S.K Nuslim bibi, G.Padma, “Chemical reaction and soret ,Dufour effect on radiation convection flow with porous medium”, AIP Conference Proceedings,Vol2269(1)(2020),101063/50019641.

[13]DCD Chenna Kesaraiah, Srinathuni Lavanya “Chemical reaction effects on MHD flow over vertical surface through porous medium”,Asian Journal of Applied Sciences,33(2)(2020),134-51,

[14]RSJ D Chenna kesaraiah ,Ikramuddin Sohaib Md, “Radiation on slip flow regime with heat generation”, Cikitusi Journal of multidisciplinary Research ,6(1)(2019), 2-18.

[15] RSD Chenna kesaraiah , “MHD free convection flow through porous medium under the effects of radiation and chemical reaction” ,Journal of information and computational sciences ,vol5(10) (2018),1125-1140.

[16]K.V.S Raju, S.Venkataramana, “MHD Convective flow through porous medium in a horizontal channel with insulated and impermeable bottom Walls in the presence of viscous dissipation and joule heating”, Ain shars Engineering Journal, Vol5(2), (2014) ,543-551.

[17]Utpal Jyoti Das and Sonam Dorjee, “Magnetohydrodynamics Boundary layer flow with Soret/Dufour effects in presence of heat source and chemical reaction”, International Journal of Applied Engineering Research ,vol 14(2) (2019),pp. 485-490**.**

[18]Bhrigu Kumar Kalita, Rita Choudhury and Paban Dhar,”Elucidation of MHD Boundary Layer Flow past a plate with Viscous Dissipation”,International Journal of Engineering Research and Technology, Vol13(11) (2020),pp.3321-3327.