DUAL SOLUTIONS OF HEAT AND MASS TRANSFER IN MHD RADIATIVE CASSON FLUID FLOW WITH DUFOUR EFFECT AND CHEMICAL REACTION

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Abstract: In this article we have investigated the Dufour effect on unsteady Magnetohydrodynamic flow past a semi-infinite vertical permeable moving plate in the presence of thermal radiation, heat absorption and first order homogeneous chemical reaction are reported. The governing equations are transformed into a non-linear ordinary differential equations and the solved analytically by using perturbation technique. The velocity, the temperature and the concentration, as well as the local skin-friction coefficient, local Nusselt number and the local Sherwood number are also presented graphically results with matlab package. The solution is found to be dependent on various physical parameters.

Index Terms: MHD, Casson fluid, Dufour effect, Heat absorption, Chemical reaction.

I. INTRODUCTION

Convective flows with concurrent heat and mass transfer under the influence of a magnetic field, chemical reaction and thermal radiation arise in many transport processes that has applications in many branches of science and engineering. This phenomenon that has role in the chemical industry, chemical vapor deposition on surface, cooling of nuclear reactors, power and cooling industry for drying, and petroleum industries.

Ramana Murthy and Chandra Sekhar [1] analyzed various flow entities on the flow past a semi-infinite inclined porous plate with viscous dissipation under the influence of gravitational force has been exhaustively. Suresh et al. [2] investigated the problem of MHD slip flow of Casson fluid past a vertically inclined plate in a porous medium in presence of chemical reaction, heat absorption and an external magnetic field. A mathematical model is developed and analyzed by finite difference method. The problem of unsteady, two-dimensional, laminar, boundary-layer flow of a viscous, incompressible, electrically conducting and heat-absorbing fluid along a semi-infinite vertical permeable moving plate in the presence of a uniform transverse magnetic field and thermal and concentration buoyancy effects is considered and the dimensionless governing equations for this Investigation are solved analytically using two-term harmonic and non-harmonic functions analyzed by Chamkha [3]. The non-linear MHD flow with heat and mass transfer characteristics of an incompressible, viscous, electrically conducting and Boussinesq fluid on a vertical stretching surface with thermal stratification and chemical reaction by taking in to account the viscous dissipation effects. Adopting the similarity transformation, governing nonlinear partial differential equations of the problem are transformed to nonlinear ordinary differential equations. The non-linear momentum equation and then the numerical solution of the problem is derived using implicit finite difference technique studied by Kishan and Amrutha [4]. Joseph et al. [5] examined the problem of unsteady MHD mixed convictive oscillatory flow of an electrically conducting optically thin fluid through a planer channel filled with saturated porous medium. Beg et al. [6] studied the heat and mass transfer characteristics of natural convection flow of a chemically-reacting Newtonian fluid along vertical and inclined plates in the presence of diffusion-thermo (Dufour) and thermal-diffusion (Soret) effects and the conservation equations for mass, momentum, heat and concentration are normalized and then solved using the local Non-similarity method and a shooting scheme. A generalized model of Casson fluid over an infinite vertical flat plate together with heat and mass transfer and Exact solutions via Laplace transform are obtained and plotted in figures and tables is studied by Nadeem Ahmad Sheikh et al. [7]. Kumaran et al. [8] reported the Magnetohydrodynamic chemically reacting Casson and Maxwell fluids past a stretching sheet with cross diffusion, non-uniform heat source/sink, thermophoresis and Brownian motion effects. Imran Ullah et al. [9] investigate combined effects of slip condition and Newtonian heating on MHD free convectional flow of Casson fluid over a nonlinearly stretching sheet in saturated porous medium. The governing coupled nonlinear partial differential equations are converted to nonlinear coupled ordinary differential equations using suitable transformations. The system of equations is solved numerically by using Keller box method. The flow, heat and mass transfer behavior of Casson fluid past an exponentially permeable stretching surface in presence of thermal radiation, uniform magnetic field, viscous dissipation, heat source and chemical reaction analyzed by Raju et al.[10]. Ibrahim et al. [11] analyzed the mixed convection on MHD boundary layer flow of Casson Nano fluid which obtains from the nonlinear stretching of a sheet using HAM. Adrian Postelnicu [12] studied simultaneous heat and mass transfer by natural convection from a vertical surface embedded in a fluid saturated Darcian porous medium, in the presence of a chemical reaction, including Soret and Dufour effects. Sunita Rani et al. [13] attempted a mathematical model of heat and mass transfer in Jeffrey fluid flow over a permeable moving plate with heat and mass transfer in the presence of applied magnetic field and heat absorption. The study has importance in many metallurgical processes including magma flows, polymer and food processing, and blood flow in micro-circulatory system. The flow and heat transfer characteristic of Williamson Nano fluid over a variable thickness stretching sheet investigate by Srinivas Reddy et al. [14]. Prabhakar Reddy [15] studied the effect of a first order homogeneous chemical reaction, thermal radiation, viscous dissipation and thermal diffusion on the unsteady MHD double diffusive free convection fluid flow past a vertical porous plate.

A uniform magnetic field which is normal to the stretching surface with heat generation, which have been of interest to the engineering community and to the investigators dealing with the problem in geophysics, astrophysics, electrochemistry and polymer processing considered by Mohebujjaman et al.[16]. Makinde and Aziz [17] considered MHD mixed convection from a vertical plate with heat and mass transfer and a convective boundary condition at the plate. It is assumed that the plate is embedded in a uniform porous medium and is exposed to a transverse magnetic field. The problem is solved numerically and results are presented for the velocity, temperature, and concentration profiles together with the local skin friction, the plate surface temperature and the local heat and mass transfer rates. The consequences of Brownian motion and thermophoresis diffusion in non- Newtonian Nano fluid through an inclined stretching sheet in the presence of chemical reaction and radiation examined by Sumit Gupta et al. [18]. Jayachandra Babu and Sandeep [19] analyzed the heat and mass transfer characteristics of Williamson fluid flow across a stretching sheet with variable thickness bearing Soret and Dufour effects. The effects of Hall current on an unsteady boundary layer slip flow and heat transfer of Casson fluid along a vertical permeable plate with heat absorption in the presence of variable suction. The perturbation technique is used to control the governing coupled non-linear partial differential equations and get the expression for velocity, temperature, skin friction, and Nusselt number studied by Mohamed Abd El-Aziz and Aishah S. Yahya. [20]. Babu et al. [21] analyzed the steady magnetohydrodynamic (MHD) boundary layer flow due to an exponentially stretching sheet with radiation in the presence of mass transfer and heat source or sink. The governing boundary layer equations have been transformed to a two-point boundary value problem in similarity variables and the resultant problem is solved numerically using the finite difference using the quasilinearization technique.

In this study to investigated the Dufour effect on unsteady Magnetohydrodynamic flow past a semi-infinite vertical permeable moving plate in the presence of thermal radiation, heat absorption and first order homogeneous chemical reaction are reported. The governing equations are transformed into a non-linear ordinary differential equations and the solved analytically by using perturbation technique. The velocity, the temperature and the concentration, as well as the local skin-friction coefficient, local Nusselt number and the local Sherwood number are also presented graphically results with matlab package. The solution is found to be dependent on various physical parameters are also studied.

II. FORMULATION OF THE PROBLEM

We have considered unsteady MHD two dimensional flows of a laminar, incompressible, viscous, electrically conducting, double diffusive and absorbing fluid past a semi-infinite vertical permeable moving plate with Dufour and chemical reaction effects and subject to a uniform transverse magnetic field in the presence of thermal radiation and homogeneous chemical reaction. It is assumed that there is no applied voltage which implies the absence of an electrical field. The transversely applied magnetic field and magnetic Reynolds number are assumed to be very small so that the induced magnetic field and the Hall effects are negligible.

$x^{/}$ -axis is taken in the upward direction along with the flow and $y^{/}$ -axis is taken perpendicular to it. Initial the plate is assumed to be moving with a uniform velocity $U_p^{/}$ in the direction of the fluid flow, and free stream velocity follows the exponentially increasing small perturbation law. Besides that, it is assumed that the temperature and the concentration at the wall as well as the suction velocity are exponentially varying with time.

By considering the above assumptions, the governing equations are given by

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

$$\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = -\frac{1}{\rho}\frac{\partial p'}{\partial x'} + \nu\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u'}{\partial y'^2} + g\beta_T\left(T' - T'_\infty\right) + g\beta_C\left(C' - C'_\infty\right) - \frac{\sigma B_0^{\,2} u'}{\rho} \tag{2}$$

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_p}\frac{\partial q'_r}{\partial y'} - \frac{Q'}{\rho C_p}\left(T' - T'_\infty\right) + \frac{D_m K_T}{C_s C_p}\frac{\partial^2 C'}{\partial y'^2} \tag{3}$$

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - K_r\left(C' - C'_\infty\right) \tag{4}$$

Under the above assumptions, the appropriate boundary conditions for the distributions of velocity, temperature and concentration are given by

$$u' = u'_p, T' = T'_w + \varepsilon\left(T'_w - T'_\infty\right)e^{n't'}, C' = C'_w + \varepsilon\left(C'_w - C'_\infty\right)e^{n't'} \text{ at } y' = 0 \tag{5}$$

$$u' \to U'_\infty = U_0\left(1+\varepsilon e^{n't'}\right), T' \to T'_\infty, C' \to C'_\infty \text{ at } y \to \infty \tag{6}$$

It is known from Eq. (1) that the suction velocity at the plate surface is a function of time only and it is assumed in the following form,

$$v' = -V_0\left(1+\varepsilon A e^{n't'}\right) \tag{7}$$

Outside the boundary layer Eq. (2) modifies as

$$-\frac{1}{\rho}\frac{dp'}{dx'} = \frac{dU'_\infty}{dt'} + \frac{\nu}{k'}U'_\infty + \frac{\sigma}{\rho}B_0^2 U'_\infty \tag{8}$$

We consider a mathematical model, for an optically thin limit gray gas near equilibrium in the form

$$\frac{\partial q'_r}{\partial y'} = 4\left(T' - T'_\infty\right)I' \tag{9}$$

Where $I' = \int_0^\infty K_{\lambda w}\left(\frac{\partial e_{b\lambda}}{\partial T}\right)_w d\lambda$, $K_{\lambda w}$ is the absorption coefficient at the wall and $e_{b\lambda}$ is Planck's function.

By introducing the following non-dimensional variables and parameters

$$\left.\begin{aligned}
& u = \frac{u'}{U_0},\ v = \frac{v'}{V_0},\ \eta = \frac{V_0 y'}{\nu},\ U_\infty = \frac{U'_\infty}{U_0},\ U_p = \frac{U'_p}{U_0},\ t = \frac{t' V_0^2}{\nu},\ \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \\
& C = \frac{C' - C'_\infty}{C'_w - C'_\infty},\ n = \frac{n'\nu}{V_0^2},\ k = \frac{k' V_0^2}{\nu^2},\ \Pr = \frac{\mu C_p}{k},\ Sc = \frac{\nu}{D},\ M = \frac{\sigma B_0^2 \nu}{\rho V_0^2}, \\
& Du = \frac{D_m K_T\left(C'_w - C'_\infty\right)}{C_s C_p \nu\left(T'_w - T'_\infty\right)},\ F = \frac{4I'\nu}{\rho C_p V_0^2},\ Gr = \frac{\nu\beta_T g\left(T'_w - T'_\infty\right)}{U_0 V_0^2},\ \nu = \frac{\mu}{\rho}, \\
& Gm = \frac{\nu\beta_C g\left(C'_w - C'_\infty\right)}{U_0 V_0^2},\ \phi = \frac{Q'\nu}{\rho C_p V_0^2},\ Kc = \frac{Kr'\nu}{V_0^2},
\end{aligned}\right\} \tag{10}$$

In view of Eqs.(7)-(10), (2)-(4) are reduced to the following non-dimensional form,

$$\frac{\partial u}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial u}{\partial \eta} = \frac{dU_\infty}{dt} + B\frac{\partial^2 u}{\partial \eta^2} + Gr\theta + GmC + NU_\infty - Mu \tag{11}$$

$$\frac{\partial \theta}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial \theta}{\partial \eta} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial \eta^2} - \chi\theta + Du\frac{\partial^2 C}{\partial \eta^2} \tag{12}$$

$$\frac{\partial C}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial C}{\partial \eta} = \frac{1}{Sc}\frac{\partial^2 C}{\partial \eta^2} - KcC \tag{13}$$

Where $B=1+\frac{1}{\beta}, N=M+\frac{1}{k}, \chi=F+\phi$

The dimension less form of the boundary conditions (5) and (6) becomes

$$u=U_p, \theta=1+\varepsilon e^{nt}, C=1+\varepsilon e^{nt} \text{ at } \eta=0 \tag{14}$$

$$u\to U_\infty=1+\varepsilon e^{nt}, \theta\to 0, C\to 0 \text{ as } \eta\to\infty \tag{15}$$

III. SOLUTION OF THE PROBLEM

The set of Eqs.(11)-(13) are partial differential equations which cannot be solved in closed form. However, these can be solved by reducing them into a set of ordinary differential equations using the following perturbation method. We now represent the velocity, the temperature and the concentration distributions in terms of harmonic and non-harmonic functions as

$$u=u_0(\eta)+\varepsilon\exp(nt)u_1(\eta)+o(\varepsilon^2)+\ldots\ldots \tag{16}$$

$$\theta=\theta_0(\eta)+\varepsilon\exp(nt)\theta_1(\eta)+o(\varepsilon^2)+\ldots\ldots \tag{17}$$

$$C=C_0(\eta)+\varepsilon\exp(nt)C_1(\eta)+o(\varepsilon^2)+\ldots\ldots \tag{18}$$

Substituting Eqs. (16)-(18) into Eqs.(11)-(13), and equating the harmonic and non-harmonic terms, and neglecting the higher order terms of ε, we obtain the following pairs of equations of order zero and order one.

$$Bu_0''+u_0'-Mu_0=-Gr\theta_0-GmC_0-N \tag{19}$$

$$Bu_1''+u_1'-(M+n)u_1=-(N+n)-Au_0'-Gr\theta_1-GmC_1 \tag{20}$$

$$Bu_1''+u_1'-(M+n)u_1=-(N+n)-Au_0'-Gr\theta_1-GmC_1 \tag{21}$$

$$\theta_1''+\Pr\theta_1'-\Pr(\chi+n)\theta_1=-A\Pr\theta_0'-Du\Pr C_1'' \tag{22}$$

$$C_0''+ScC_0-ScKcC_0=0 \tag{23}$$

$$C_1''+ScC_1'-Sc(Kc+n)C_1=-AScC_0' \tag{24}$$

Where the prime denotes differentiation with respect to η. The corresponding boundary conditions are now given by

$$u_0=U_p,\ u_1=0,\ \theta_0=1, \theta_1=1, C_0=1, C_1=1 \text{ at } \eta=0 \tag{25}$$

$$u_0=1,\ u_1=1,\ \theta_0\to 0,\ \theta_1\to 0,\ C_0\to 0,\ C_1\to 0 \text{ as } \eta\to\infty \tag{26}$$

Now by using the boundary conditions (25)-(26) and solving the set of Eqs. (19)-(24), we get the following solutions.

$$u_0=c_5\exp(-m_5\eta)+k_{13}\exp(-m_1\eta)+k_{12}\exp(-m_3\eta)+k_9 \tag{27}$$

$$\begin{aligned}u_1=&c_6\exp(-m_6\eta)+k_{24}\exp(-m_1\eta)+k_{25}\exp(-m_2\eta)+k_{26}\exp(-m_3\eta)+k_{21}\exp(-m_4\eta)\\&+k_{22}\exp(-m_5\eta)+k_{23}\end{aligned} \tag{28}$$

$$\theta_0=c_3\exp(-m_3\eta)+k_2\exp(-m_1\eta) \tag{29}$$

$$\theta_1=c_4\exp(-m_4\eta)+k_6\exp(-m_3\eta)+k_7\exp(-m_1\eta)+k_5\exp(-m_2\eta) \tag{30}$$

$$C_0=\exp(-m_1\eta) \tag{31}$$

$$C_1=c_2\exp(-m_2\eta)+k_1\exp(-m_1\eta) \tag{32}$$

In view of the above solutions, the velocity, the temperature and the concentration distributions in the boundary layer becomes

$$\begin{aligned}u(\eta,t)=&c_5\exp(-m_5\eta)+k_{13}\exp(-m_1\eta)+k_{12}\exp(-m_3\eta)+k_9\\&+\varepsilon\exp(nt)\begin{pmatrix}c_6\exp(-m_6\eta)+k_{24}\exp(-m_1\eta)+k_{25}\exp(-m_2\eta)+k_{26}\exp(-m_3\eta)\\+k_{21}\exp(-m_4\eta)+k_{22}\exp(-m_5\eta)+k_{23}\end{pmatrix}\end{aligned} \tag{33}$$

$$\theta(\eta,t)=c_3\exp(-m_3\eta)+k_2\exp(-m_1\eta)+\varepsilon\exp(nt)\begin{pmatrix}c_4\exp(-m_4\eta)+k_6\exp(-m_3\eta)\\+k_7\exp(-m_1\eta)+k_5\exp(-m_2\eta)\end{pmatrix} \tag{34}$$

$$C(\eta,t)=\exp(-m_1\eta)+\varepsilon\exp(nt)\left(c_2\exp(-m_2\eta)+k_1\exp(-m_1\eta)\right) \tag{35}$$

3.1 Skin friction

Very important physical parameter at the boundary is the skin-friction which is given in the non-dimensional form and derives as

$$C_f = \frac{\tau_w^{/}}{\rho U_0 V_0} = \left.\frac{\partial u}{\partial \eta}\right|_{\eta=0} = \left(-m_5 c_5 - m_1 k_{13} - m_3 k_{12}\right) + \varepsilon \exp(nt)\left(-m_6 c_6 - m_1 k_{24} - m_2 k_{25} - m_3 k_{26} - m_4 k_{21} - m_5 k_{22}\right) \quad (36)$$

Another physical parameter like rate of heat transfer in the form of Nusselt number and the rate of mass transfer in the form of Sherwood number are also derived and given below respectively

$$Nu = x \frac{\left.\frac{\partial T^{/}}{\partial y^{/}}\right|_{y=0}}{T_w^{/} - T_\infty^{/}} \Rightarrow Nu\,\mathrm{Re}_x^{-1} = \left.\frac{\partial \theta}{\partial \eta}\right|_{\eta=0} = \left(-m_3 c_3 - m_1 k_2\right) + \varepsilon \exp(nt)\left(-m_4 c_4 - m_3 k_6 - m_1 k_7 - m_2 k_5\right) \quad (37)$$

$$Sh = x \frac{\left.\frac{\partial C^{/}}{\partial y^{/}}\right|_{y=0}}{C_w^{/} - C_\infty^{/}} \Rightarrow Sh\,\mathrm{Re}_x^{-1} = \left.\frac{\partial C}{\partial \eta}\right|_{\eta=0} = -m_1 + \varepsilon \exp(nt)\left(-m_2 c_2 - m_1 k_1\right) \quad (38)$$

IV. RESULTS AND DISCUSSION

In order to get a physical insight into the problem, factor such a velocity u, Temperature θ, Concentration C, Skin friction C_f, Nusselt number Nu and Sherwood number Sh have been discussed by assigned numerical values to various parameter like then Sc =0.60, Kc =0.50, $\Pr$ =7.0, Du =0.50, F =1.0, ϕ =1.0, β =0.50, M =3, K =0.50, U_p =0.20, Gr =5.0, Gm =3.0.

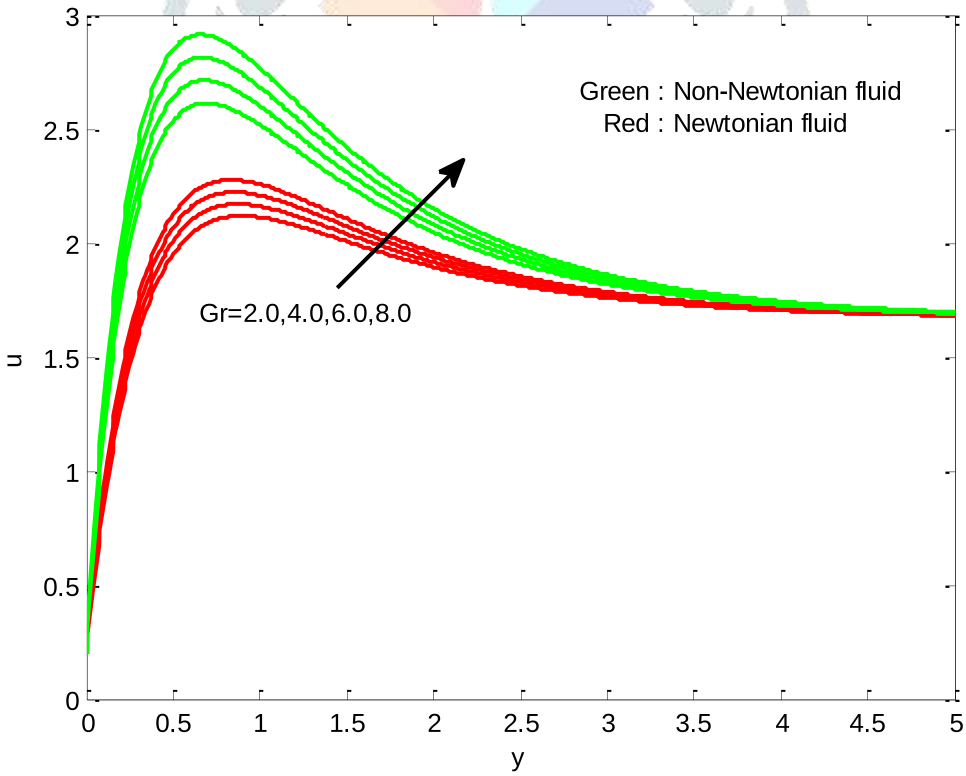

Fig.1. velocity profile for different values of Grashof number

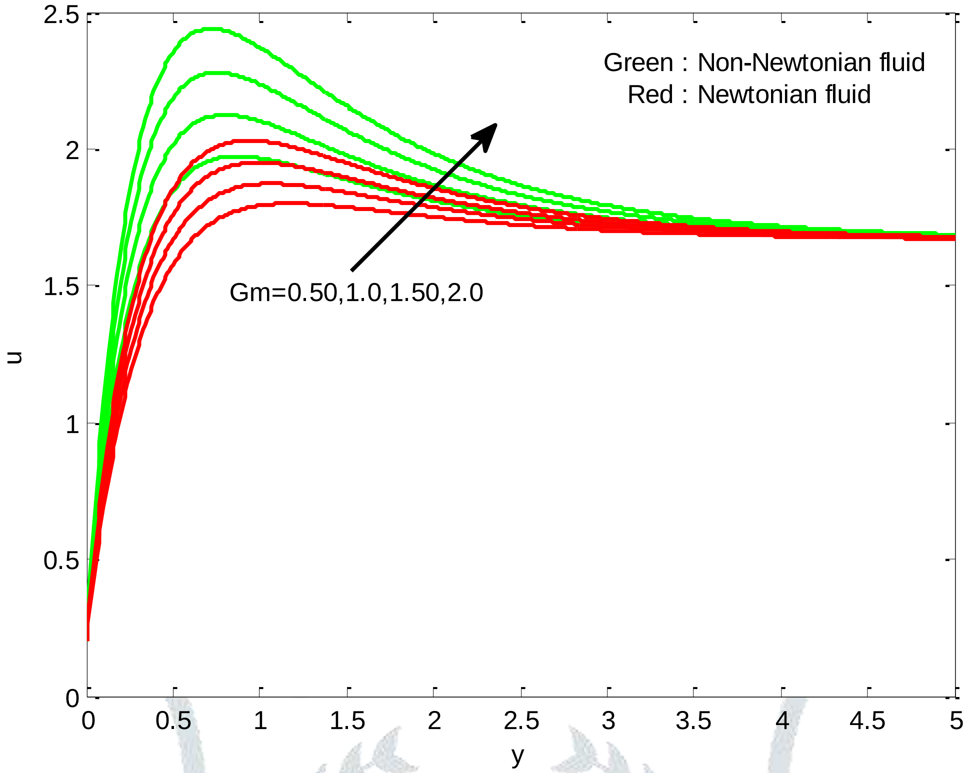

Fig.2. velocity profile for different values of modified Grashof number

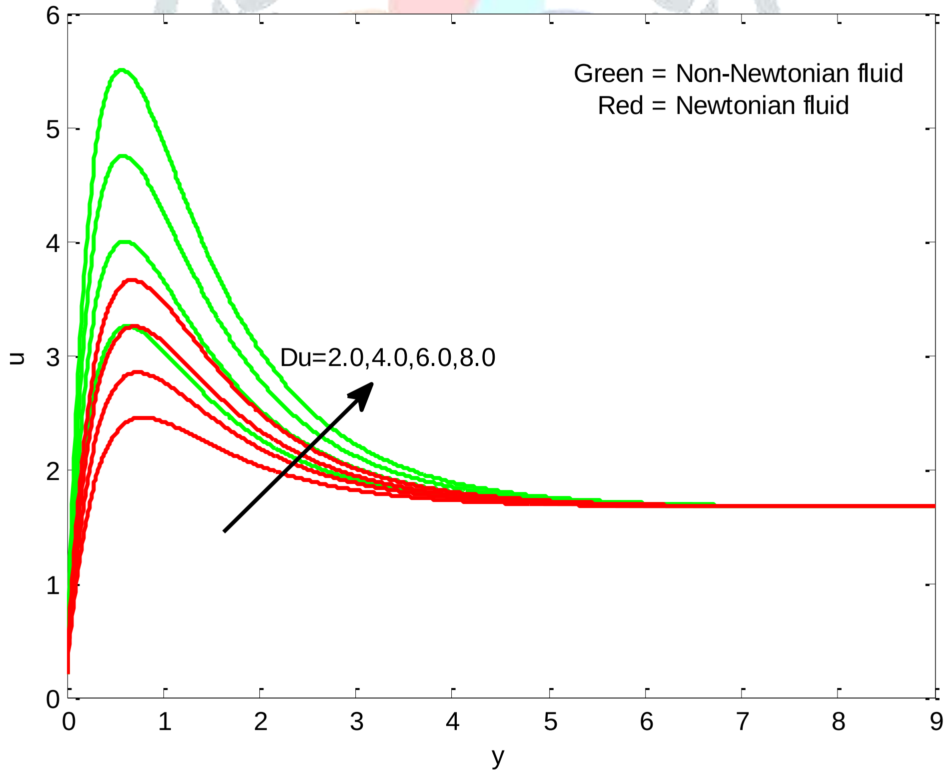

Fig.3. velocity profile for different values of Dufour parameter

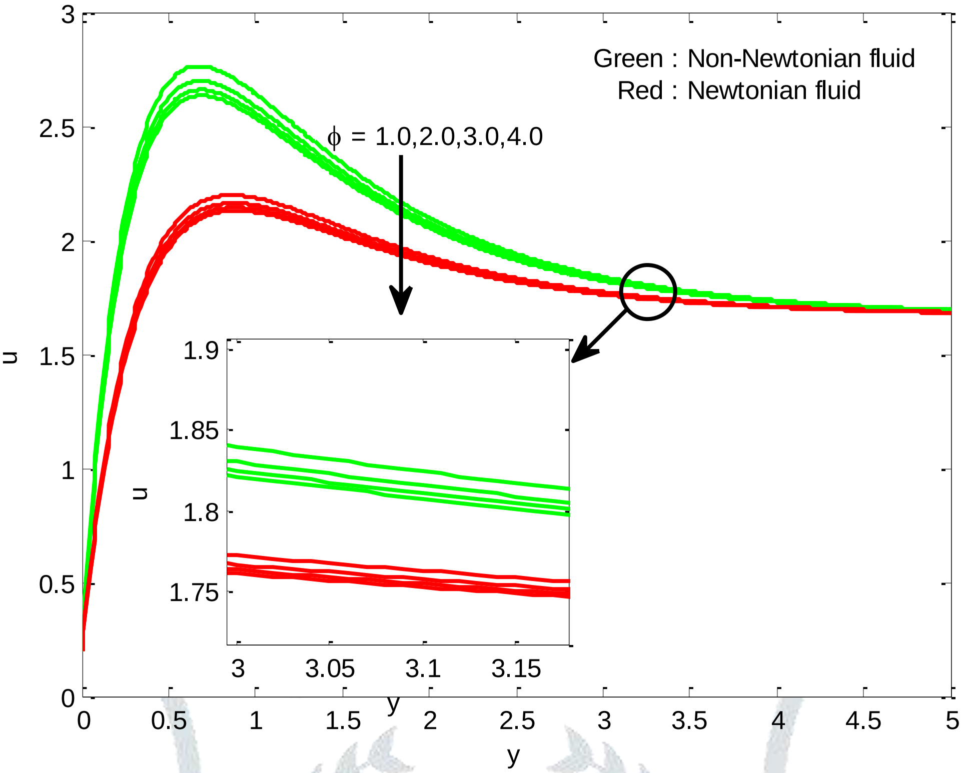

Fig.4. velocity profile for different values of Heat absorption parameter

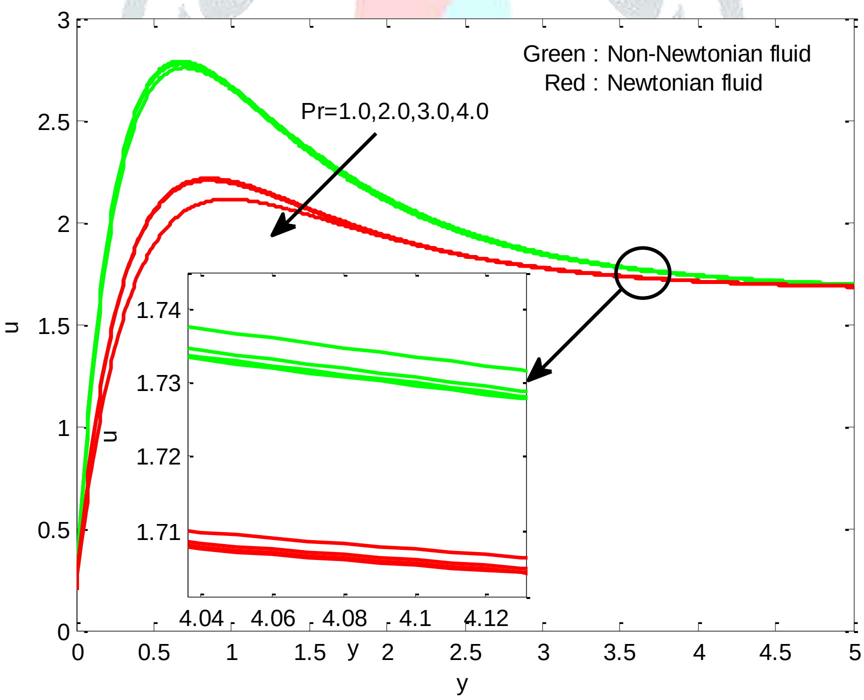

Fig.5. velocity profile for different values of Prandtl number

Figure.1. represents the velocity profile for different values of Grashof number (Gr). It is observed that ‘ u ’ increase when Gr increases and these results are found to be in good agreement with the existing results of many researchers. Figure.2. reveals the effects of modified Grashof number (Gm) on the velocity distribution. As expected, velocity is observed to increase with an increase in Gm . Figure.3and8. displays the effects of Dufour parameter (Du) on the velocity and temperature fields. It is found that the velocity and temperature profile increases with increase in Du . The effect of heat absorption parameter ϕ on the velocity field is depicted Figure.4. From this figure it is observed that ‘ u ’ decreases with an increase in ϕ . Figure.5 and 6.depicts the influence of Prandtl number effect on velocity and temperature fields. This figure witness that velocity and temperature decreases with an increase in the value of Prandtl number (Pr).

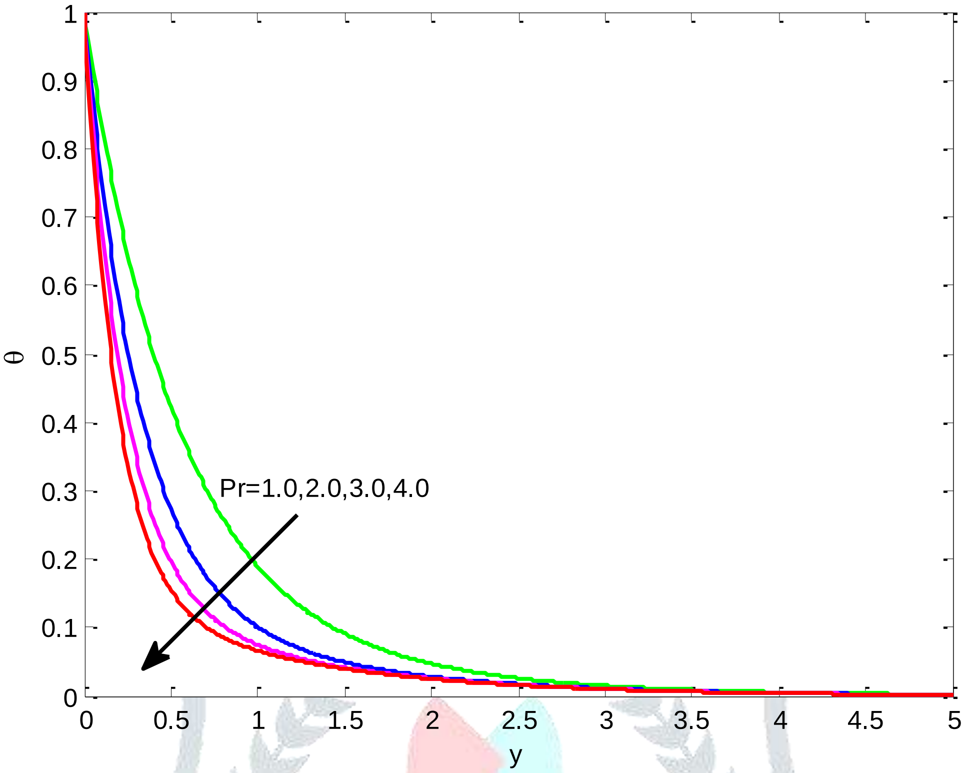

Fig.6. Temperature profile for different values of Prandtl number

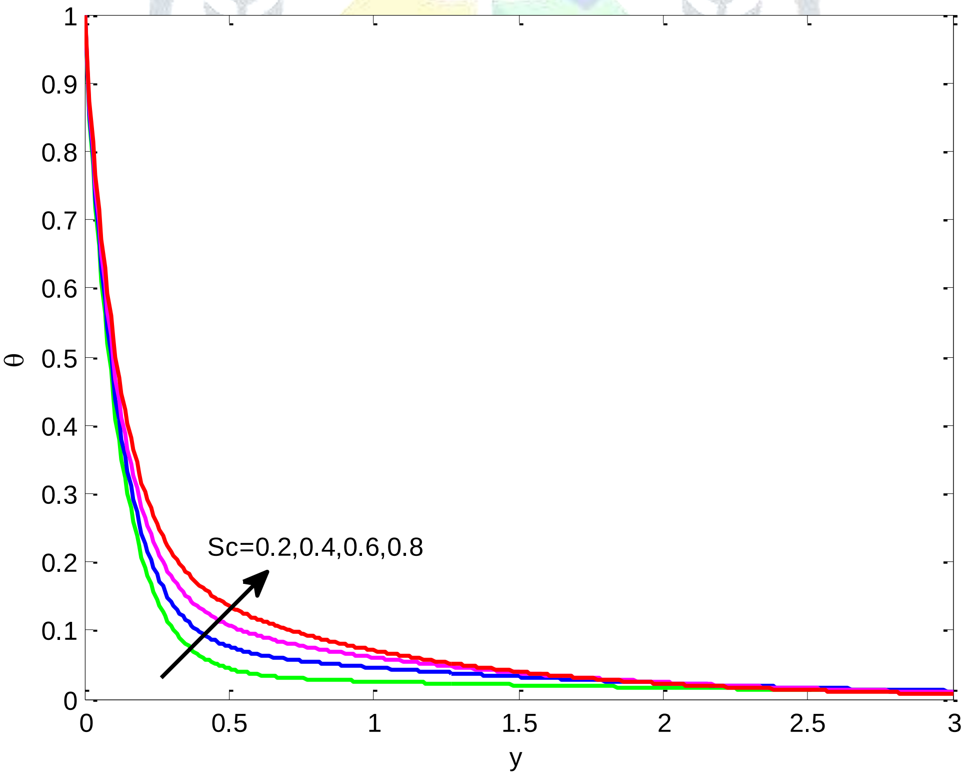

Fig.7. Temperature profile for different values of Schmidt number

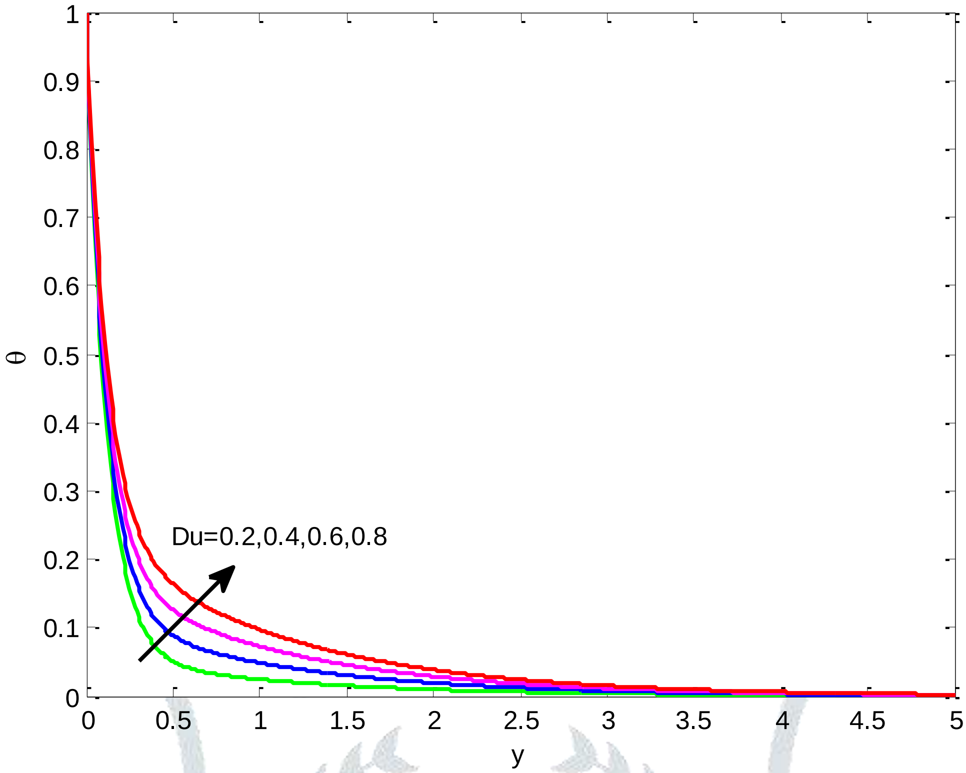

Fig.8. Temperature profile for different values of Dufour parameter

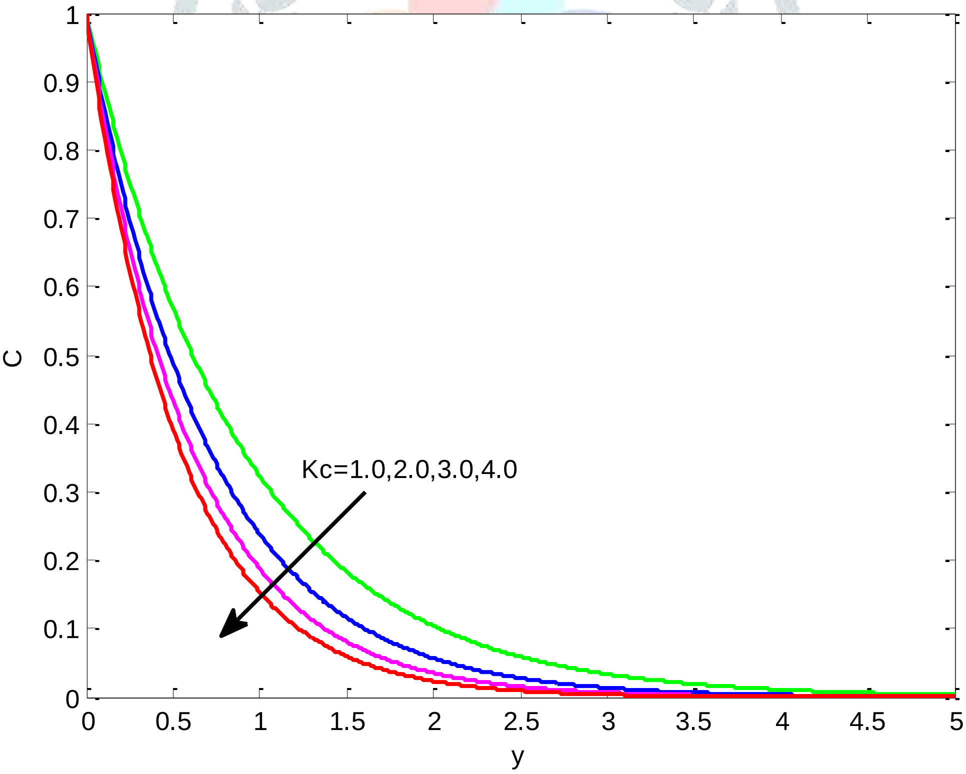

Fig.9. Concentration profile for different values of Chemical reaction parameter

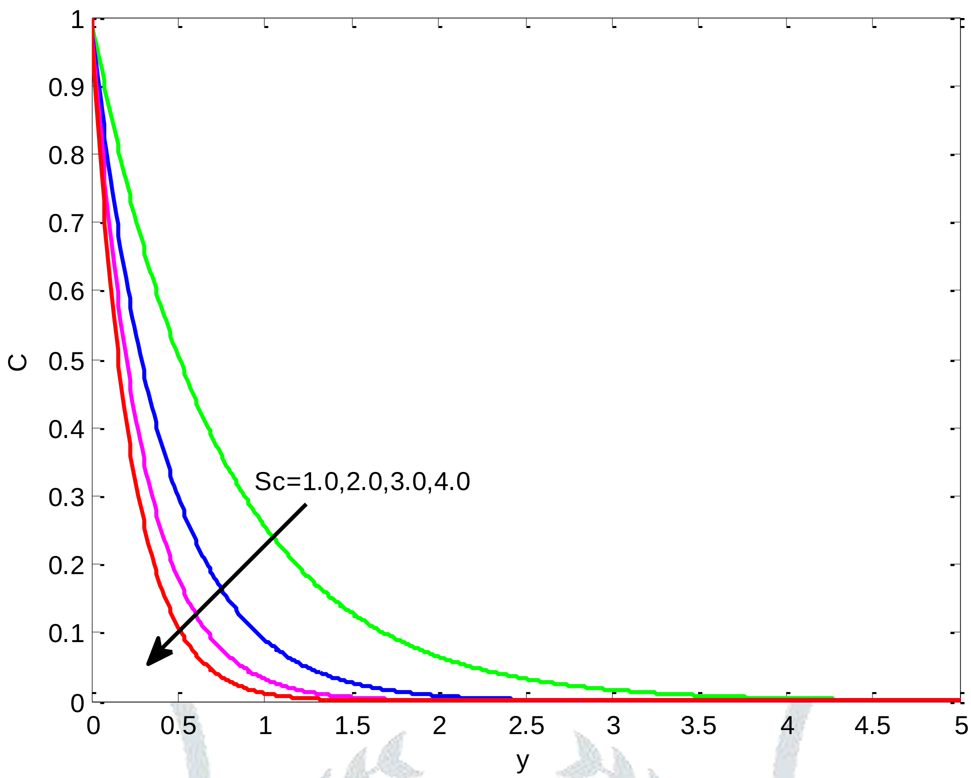

Fig.10. Concentration profile for different values of Schmidt number

Figure.7and10. illustrates the influence of Schmidt number (Sc) on the temperature and concentration profiles. It is clear that the temperature field is increases and the concentration decreases with increase in the value of Schmidt number (Sc). Figure.9. shows that the influence of chemical reaction effect on concentration. This figure delivered that concentration decreases with an increase in the value of chemical reaction parameter.

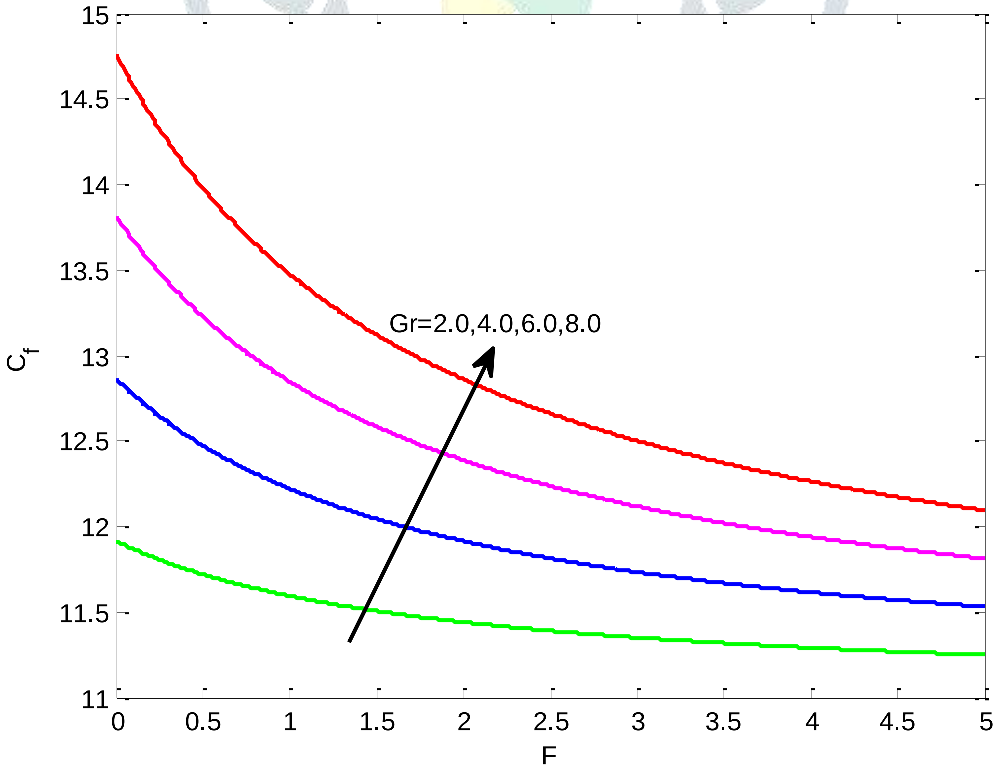

Fig.11. Skin friction coefficient for different values of Grashof number

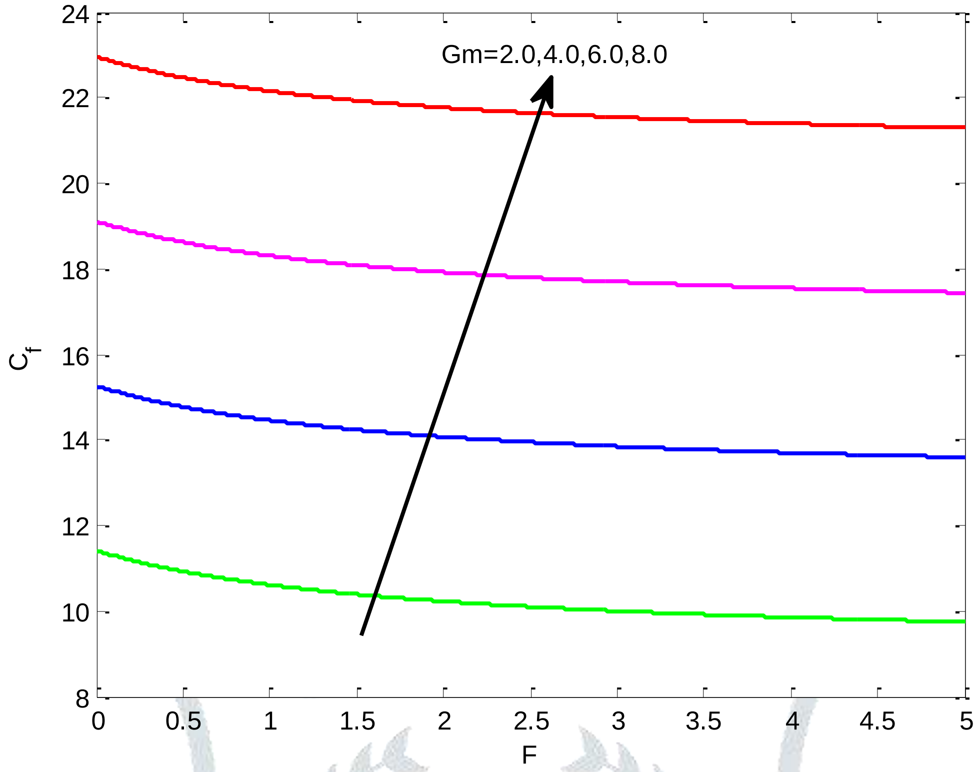

Fig.12. Skin friction coefficient for different values of modified Grashof number

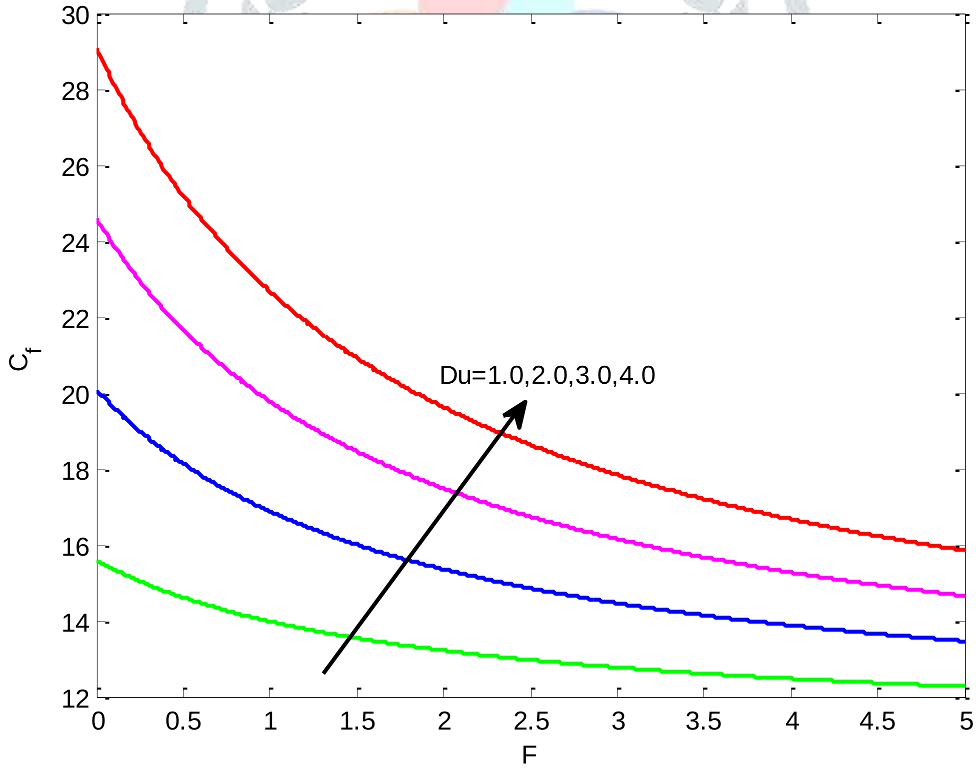

Fig.13. Skin friction coefficient for different values of Dufour parameter

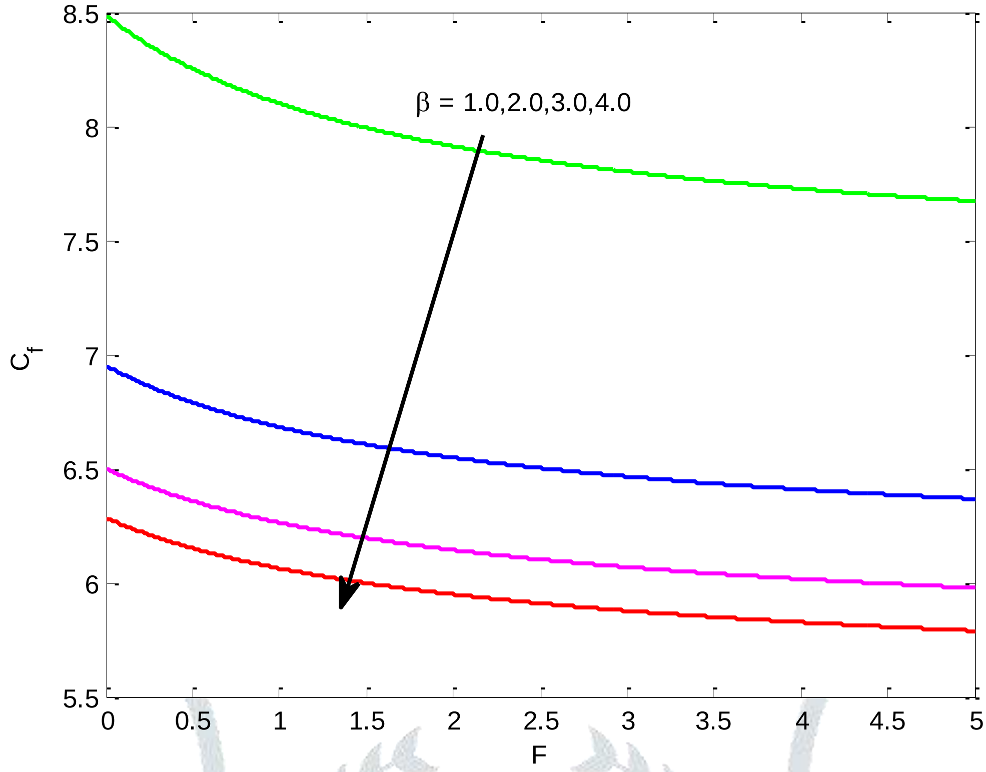

Fig.14. Skin friction coefficient for different values of Casson parameter

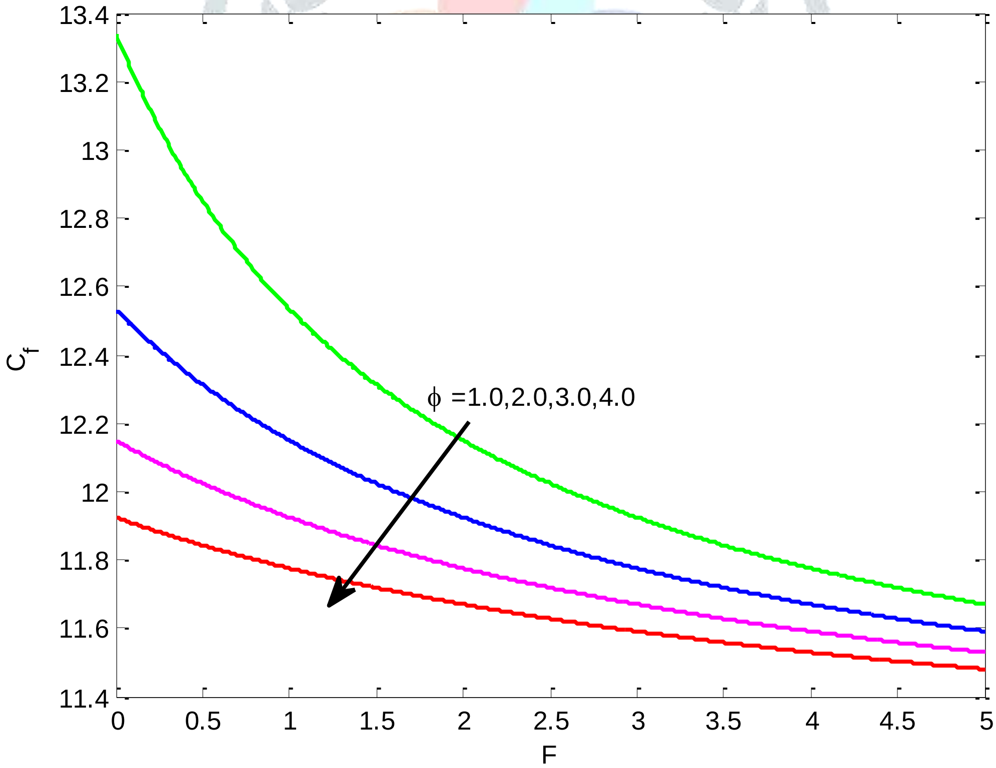

Fig.15. Skin friction coefficient for different values of Heat absorption

Figure.11. illustrates the influence of Grashof number (Gr) on the skin-friction. From this figure it is observed that 'C_f' increases with increase in Gr. Figure.12. represents the effects of modified Grashof number on skin-friction 'C_f'. From this figure it is observed that C_f increases with an increase in Gm. The influences of the rate of Dufour parameter (Du) on the skin-friction 'C_f' are shown in Figure.13. From this figure it is seen that C_f increases with an increase in Du. Skin-friction'C_f' is presented in figures.14 and 15.against radiation parameter (F) with different values of Casson parameter (β) and heat absorption parameter (ϕ). From these figure it is found that the skin-friction decreases with an increase in Casson parameter and heat absorption parameter.

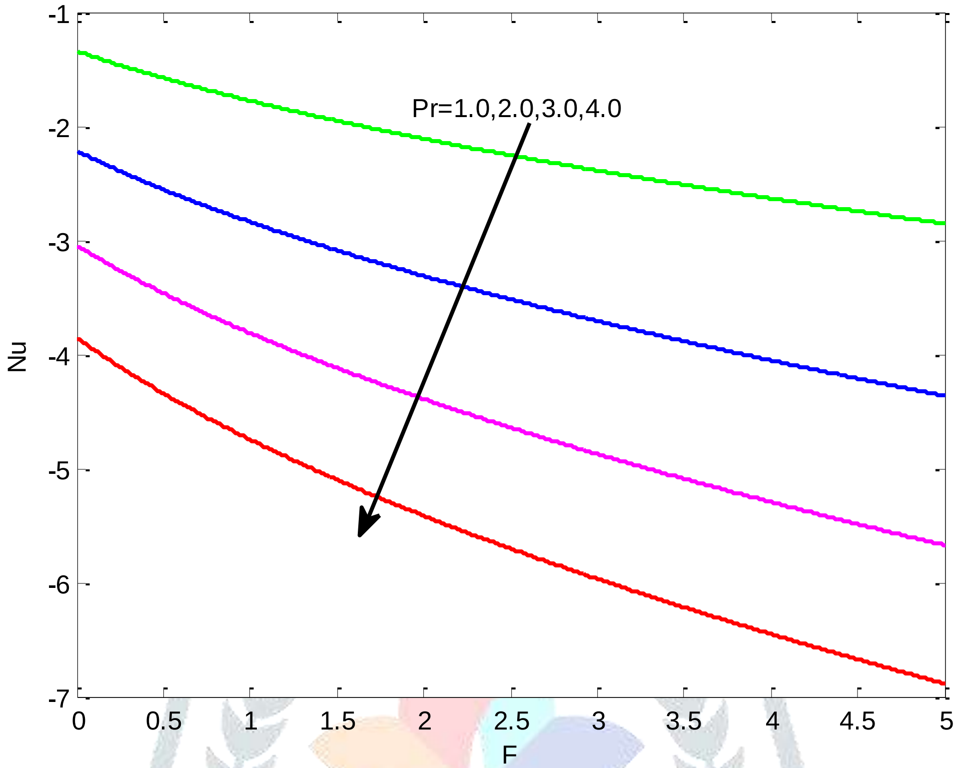

Fig.16. Nusselt number for different values of Prandtl with radiation parameter

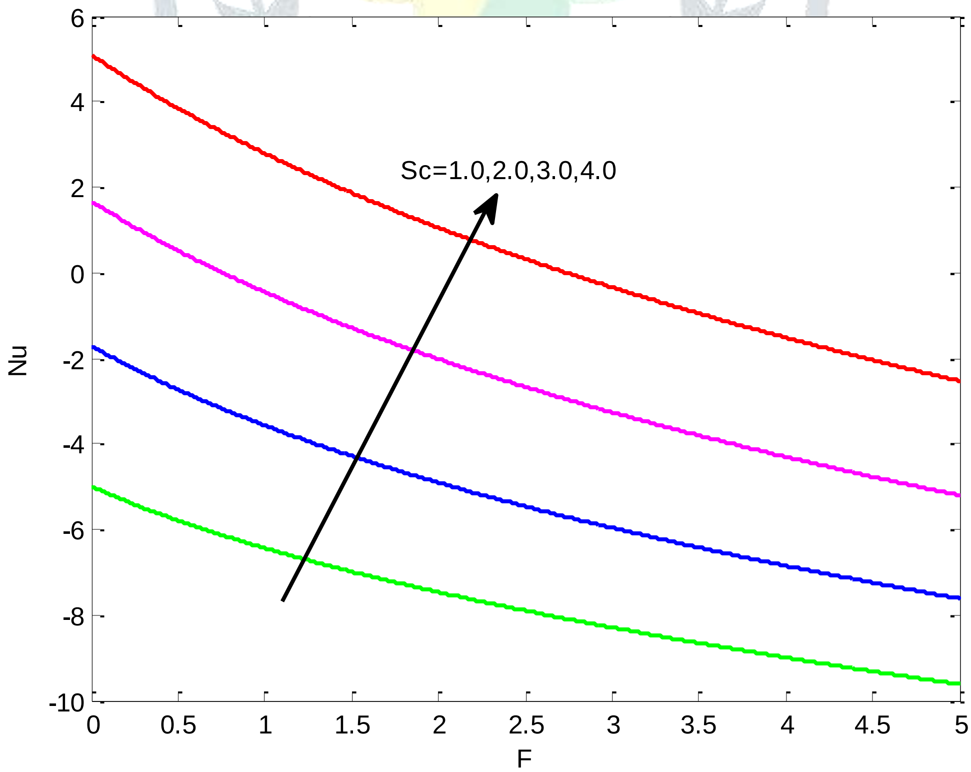

Fig.17. Nusselt number for different values of Schmidt number with radiation parameter

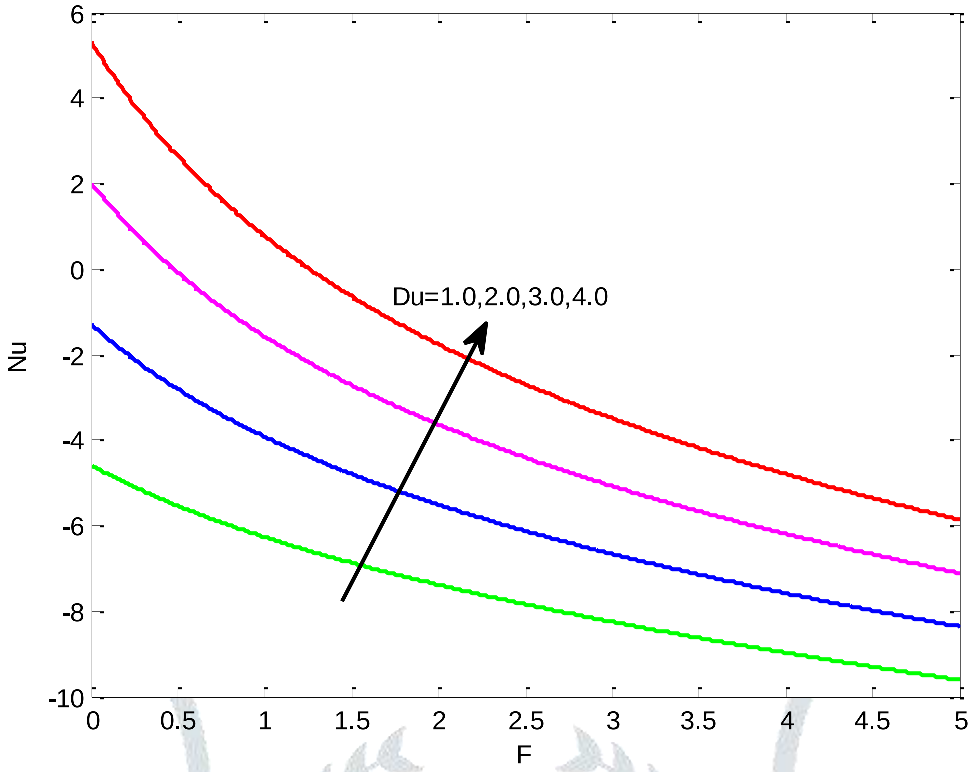

Fig.18. Nusselt number for different values of Dufour with radiation parameter

Figure.16. presented Nusselt number (Nu) against radiation parameter F with different values of Prandtl number ($\Pr$). It is observed that the Nusselt number decreases with increase in Prandtl number ($\Pr$). Nusselt number is studied in Figures.17 and 18.against radiation parameter F with various values of Schmidt number (Sc) and Dufour parameter (Du). From these figure it is observed that Nusselt number increases with an increase the value of Schmidt number and Dufour parameter.

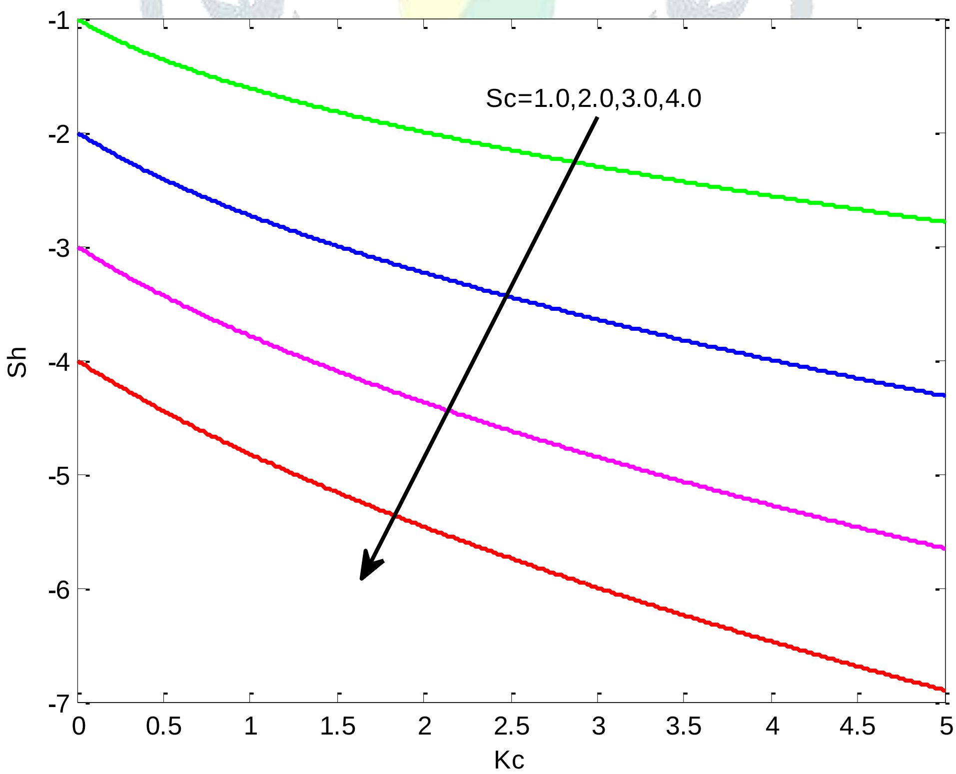

Fig.19. Sherwood number for different values of Schmidt number

From this Figure.19.it is seen that ‘ Sh ’ decreases with increase in Schmidt number (Sc).

V. CONCLUSION

The Dufour effect on unsteady Magnetohydrodynamic flow past a semi-infinite vertical permeable moving plate in the presence of thermal radiation, heat absorption and first order homogeneous chemical reaction are reported here. The following is the summery of the conclusions.

- Velocity distribution 'u' is observed that increases with an increase in Grashof number (Gr), modified Grashof number (Gm) and the Dufour parameter (Du). Whereas it shows reverse effects in the case of heat absorption coefficient (ϕ) and Prandtl number ($\Pr$).
- Temperature distribution 'T' increases with an increase in Schmidt number (Sc) and Dufour parameter (Du), whereas it decreases with an increase in Prandtl number ($\Pr$).
- Concentration distribution 'C' decreases as the chemical reaction parameter (Kc) and Schmidt number (Sc) increase.
- Skin-friction coefficient distribution 'C_f' increases with an increase in Grashof number (Gr), modified Grashof number (Gm) and Dufour parameter (Du), whereas it decreases with an increase in Casson parameter (β) and heat absorption coefficient parameter (ϕ).
- Nusselt number distribution (Nu) increases with an increase in Schmidt number (Sc) and Dufour parameter (Du), whereas it decreases with an increase in Prandtl number ($\Pr$).
- Sherwood number distribution (Sh) is observed that decrease with an increase in Schmidt number (Sc).

LIST OF SYMBOLS

A Suction velocity parameter
B_0 Magnetic induction
C Concentration
C_p Specific heat at constant pressure
C_f Skin friction coefficient
D Mass diffusion coefficient
$e_{b\lambda}$ Plank's function
F Radiation parameter
g Acceleration due to gravity
Gr Grashof number
Gm Modified Grashof number
Kc Chemical reaction parameter
K_λ Absorption parameter
M Magnetic field parameter
N Dimension less material parameter
n Dimension less exponential index
Nu Nusselt number
$\Pr$ Prandtl number
Q_0 Heat absorption parameter
Re_x Local Reynolds number
Sc Schmidt number
Sh Sherwood number
T Temperature
$t^/$ Dimensional time
t Dimensional less time
U_0 Scale of free stream velocity

$u^{/}, v^{/}$ Dimensional velocity components
u, v Velocity components
V_0 Scale of suction velocity
$x^{/}, y^{/}$ Dimensional distance along and perpendicular to the plate respectively
x, y Distance along and perpendicular to the plate respectively

GREEK SYMBOLS

α Thermal diffusivity of the fluid
β_C Coefficient of volumetric concentration expansion
β_T Coefficient of volumetric thermal expansion
ε Scalar constant
χ Dimension less material parameter
η Dimension less normal distance
ϕ Dimension less heat absorption parameter
k Thermal conductivity
σ Electrical conductivity
ρ Density of the fluid
μ Dynamic viscosity
ν Kinematic viscosity
θ Dimensional temperature

SUBSCRIPTS AND SUPERSCRIPT

$/$ Dimensional properties
p Plate
w Wall condition
∞ Free stream condition

VI. REFERENCES

[1] Ramana Murthy, Ch. V. and Chandra Sekhar, K. V. 2011. Analysis of Various Flow Entities on the Flow past a Semi Infinite Moving Vertical Plate with Viscous Dissipation. International Journal of Mathematical Archive, 2(1): 146-153.
[2] Suresh, P. Ramana Murthy, M.V. Kamala, G. and Sreeram Reddy, K. 2017. Behaviour of Casson Fluid Slip Flow Past a Vertically Inclined Plate Filled in Porous Medium Submitted in Magnetic Field: Heat Absorption and Chemical Reaction Effects. International Journal of Engineering and Management Research, 7(4): 27-43.
[3] Chamkha, Ali J. 2004. Unsteady MHD convective heat and mass transfer pasta semi-infinite vertical permeable moving plate with heat absorption. International Journal of Engineering Science, 42: 217–230.
[4] Kishan, N. and Amrutha, P. 2010. Effects of Viscous Dissipation on MHD Flow with Heat and Mass Transfer over a Stretching Surface with Heat Source, Thermal Stratification and Chemical Reaction. Journal of Naval Architecture and Marine Engineering, 7, 11-18.
[5] Joseph, K.M. Ayuba, P. Yusuf, L.H. Mohammed, S.M. and Ayok, I.J. 2015. Chemically Reacting Fluid on Unsteady MHD Oscillatory Slip Flow in a Planer Channel with varying Temperature and Concentration in the Presence of Suction/Injection. International Journal of Scientific Engineering and Applied Science, 1(5): 376-389.
[6] Beg, O. A. Beg, T. A. Bakier A. Y. and Prasad, V. R. 2009. Chemically-Reacting Mixed Convective Heat and Mass Transfer along Inclined and Vertical Plates with Soret and Dufour Effects: Numerical Solutions. Int. J. of Appl. Math and Mech., 5(2): 39-57.
[7] Nadeem Ahmad Sheikh, Farhad Ali, Muhammad Saqib, Ilyas Khan, Syed Aftab Alam Jan, Ali Saleh Alshomrani and Metib Said Alghamdi, 2017. Comparison and analysis of the Atangana–Baleanu and Caputo–Fabrizio fractional derivatives for generalized Casson fluid model with heat generation and chemical reaction. Results in Physics, 7: 789–800.
[8] Kumaran, G. Sandeep, N. and Ali, M.E. 2017. Computational analysis of Magnetohydrodynamic Casson and Maxwell flows over a stretching sheet with cross diffusion. Results in Physics, 7: 147–155.
[9] Imran Ullah, Sharidan Shafie and Ilyas Khan, 2017. Effects of slip condition and Newtonian heating on MHD flow of Casson fluid over a nonlinearly stretching sheet saturated in a porous medium. Journal of King Saud University – Science, 29: 250–259.

[10] Raju, C.S.K. Sandeep, N. Sugunamma, V. Jayachandra Babu, M. and Ramana Reddy, J.V. 2016. Heat and mass transfer in Magnetohydrodynamic Casson fluid over an exponentially permeable stretching surface. Engineering Science and Technology, an International Journal, 19: 45–52.
[11] Ibrahim, S.M. Lorenzini, G. Vijaya Kumar, P. and Raju, C.S.K. 2017. Influence of chemical reaction and heat source on dissipative MHD mixed convection flow of a Casson Nano fluid over a nonlinear permeable stretching sheet. International Journal of Heat and Mass Transfer, 111: 346–355.
[12] Adrian Postelnicu, 2007. Influence of chemical reaction on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects. Heat Mass Transfer, 43:595–602.
[13] Sunita Rani, Y. Ramana Murthy, M.V. Vani Sree, G. and Kamala, G. 2017. Jeffrey Fluid Performance on MHD Convective Flow Past a Semi-Infinite Vertically Inclined Permeable Moving Plate in Presence of Heat and Mass Transfer: a Finite Difference Technique. International Journal of Dynamics of Fluids, 13(2): 173-195.
[14] Srinivas Reddy, C. Kishan Naikoti and Mohammad Mehdi Rashid. 2017. MHD flow and heat transfer characteristics of Williamson Nano fluid over a stretching sheet with variable thickness and variable thermal conductivity. Transactions of A. Razmadze Mathematical Institute, 171:195–211.
[15] Prabhakar Reddy, B. 2015. MHD flow over a vertical moving porous plate with viscous dissipation by considering double diffusive convection in the presence of chemical reaction. Int. J. Adv. Appl. Math. And Mech., 2(4): 73 – 83.
[16] Mohebujjaman, M. Khaleque, Tania. S. and Samad, M.A. MHD Heat Transfer Mixed Convection Flow Along a Vertical Stretching Sheet in Presence of Magnetic Field With Heat Generation. International Journal of Basic & Applied Sciences, 10 (2): 133-142.
[17] Makinde, O.D. Aziz, A. 2010. MHD mixed convection from a vertical plate embedded in a porous medium with a convective boundary condition. International Journal of Thermal Sciences, 49: 1813-1820.
[18] Sumit Gupta, Devendra Kumar and Jagdev Singh. 2018. MHD mixed convective stagnation point flow and heat transfer of an incompressible nanofluid over an inclined stretching sheet with chemical reaction and radiation. International Journal of Heat and Mass Transfer, 118: 378–387.
[19] Jayachandra Babu, M. and Sandeep, N. 2016. MHD non-Newtonian fluid flow over a slandering stretching sheet in the presence of cross-diffusion effects. Alexandria Engineering Journal, 55: 2193–2201.
[20] Mohamed Abd El-Aziz, Aishah S. Yahya. 2017. Perturbation analysis of unsteady boundary layer slip flow and heat transfer of Casson fluid past a vertical permeable plate with Hall current. Applied Mathematics and Computation, 307: 146–164.
[21] Babu, P. R. Rao, J. A. and Sheri, S. 2014. Radiation Effect on MHD Heat and Mass Transfer Flow over a Shrinking Sheet with Mass Suction. Journal of Applied Fluid Mechanics, 7(4): 641-650.