Chemical Reaction and its Influence on MHD Flow on Continuously Moving Vertical Surface with Uniform Heat and Mass Flux

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Abstract: Present study is concerned the influence of chemical reaction on Magneto Hydro Dynamics (MHD) flow on continuously moving vertical surface with uniform heat and mass flux taking into account the homogeneous chemical reaction of 1st order. The expressions for velocity, temperature, concentration and skin friction are obtained. The effects of various parameters are discussed with the help of graphs and table.

Keywords: MHD; Heat and mass flux, Chemical reaction parameter, Homogeneous reaction.

1. Introduction

The study of heat and mass transfer to chemically reacting MHD free convection on a moving vertical plate has received a growing interest during the last decays,its importance are in several engineering, industrial, geophysical and astrophysical application, such as polymer production, manufacturing of ceramic, packed-bed, catalytic reactors, food processing, cooling of nuclear reactors, enhanced oil recovery, underground energy transport, high speed plasma wind and stellar systems.

The problem of steady and unsteady of combined heat and mass by free convection along an infinite and semi-infinite vertical plate with and without chemical reaction has studied extensively. Angerasa [1], studied combined heat and mass transfer by natural convection with opposing buoyancy effects in a fluid saturated porous medium. Henkes and Hoogendoorn [2], discussed natural convection boundary layer flow along a heated vertical plate in a stratified environment. Ganeshan and Loganathan [3], observed the heat and mass flux effects on a moving vertical cylinder with chemically reactive species diffusion. Muthucumarswamy and Ganeshan [4] studied natural convection on a moving isothermal vertical plate with chemical. Rahman and Mulolani [5] discussed convective diffusive transport chemical reaction in natural convection flows. Jadon et. al.[6] determined heat transfer in MHD free convection flow over an infinite vertical plate through porous medium with time dependent suction. Ahamai and Manvi [7] studied equation of motion for viscous flow through a rigid porous medium. Koriko [8] observed approximate solutions of a higher order MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption which obtained result from quadratic reaction. Jadon and yadav [9] provide the effect of chemical reaction on MHD free convective flow of viscous fluid through porous medium bounded by an oscillating porous plate in slip flow regime. Readdy et. al. [10] studied heat and mass transfer effects on MHD flow of continuously moving vertical surface with uniform heat and mass flux. Ramana and Kumar [11] determined chemical reaction effects on MHD free convective flow past an inclined plate. Reddy [12], the present study investigates the natural convection MHD flow of fluid beyond an oscillating vertical plate in a rotating system. Selimefendigil and Öztop [13] studied magnetic field effects on free convective nano fluid flow in a cavity. The concept of mixed convection in fluid flow problems has attracted many researchers due to its importance in many engineering applications such as food processing, microelectronic devices, cooling of electronic devices and, nuclear reactors. Selimefendigil and. Öztop [14] considered mixed convection MHD flow of nanofluid with different physical conditions Waqas et al. [15] studied mixed convection MHD flow due to the nonlinear stretched sheet. Currently, many researchers have scrutinized the influence of thermal radiation on the heat transport features of fluids across stretched surfaces. The heat transfer process has many applications in solar power technology, and photochemical reactors, etc.

The aim of present study is to investigate numerically the influence of chemical reaction on MHD flow on continuously moving vertical surface with uniform heat and mass flux taking into account the homogeneous chemical reaction of first order. The boundary layer equations governing the problem under consideration are solved and the effect of magnetic field and chemical reaction on the velocity, concentration and skin friction are presented and discussed graphically.

2. Formulation of the Problem

Let us consider the steady, two-dimensional, laminar, incompressible flow of a viscous fluid on a continuously moving vertical surface in the presence of a uniform magnetic field. The homogeneous chemical reaction of first order, uniform heat and mass flux effects, issuing a slot and moving with uniform velocity is u_w in a fluid at the rest. A uniform magnetic field B_0 acts along y-axis. The temperature and concentration levels near the surface are raised uniformly. The induced magnetic field, viscous dissipation assumed to be neglected. Now under the usual Boussinesq's approximation of the flow field is governed by the following equations.

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{2.1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}+g\beta(T'-T'_\infty)+g\beta^*(C'-C'_\infty)-\frac{\sigma B_0^2 u}{\rho} \tag{2.2}$$

$$\rho c_p\left(u\frac{\partial T'}{\partial x}+v\frac{\partial T'}{\partial y}\right)=k\frac{\partial^2 T'}{\partial y^2} \tag{2.3}$$

$$u\frac{\partial C'}{\partial x}+v\frac{\partial C'}{\partial y}=D\frac{\partial^2 C'}{\partial y^2}-K_l C' \tag{2.4}$$

The initial and boundary conditions are:

$$u=u_w, v=v_0=cnst<0, \frac{\partial T'}{\partial y}=-\frac{q}{k}, \frac{\partial C'}{\partial y}=-\frac{j''}{D} \quad at\ y=0 \tag{2.5}$$

$$u\to 0,\ T'\to T'_\infty,\ C'\to C'_\infty \qquad at\ y\to\infty$$

We now introduce the following non-dimensional quantities:

$$Y=\frac{yv_0}{\upsilon},\ U=\frac{u}{u_w},\ \theta=\frac{T'-T'_\infty}{\left(\frac{q\upsilon}{kv_0}\right)},\ \phi=\frac{C'-C'_\infty}{\left(\frac{j''\upsilon}{kv_0}\right)},\ Gr=\frac{g\beta\upsilon\left(\frac{q\upsilon}{kv_0}\right)}{u_w v_0^2}, \tag{2.6}$$

$$Gc=\frac{g\beta^*\upsilon\left(\frac{j''\upsilon}{kv_0}\right)}{u_w v_0^2},\ Pr=\frac{\mu c_p}{k},\ Sc=\frac{\upsilon}{D},\ M=\frac{\sigma B_0^2\upsilon}{\rho v_0^1},\ K_l=\frac{\gamma v_0^2}{\upsilon}$$

In view of Equation (2.6), the governing Equations (2.2) -(2.4) reduce to the following non-dimensional from:

$$\frac{d^2U}{dY^2}+\frac{dU}{dy}+Gr\theta+Gc\phi-MU=0 \tag{2.7}$$

$$\frac{d^2\theta}{dY^2}+Pr\frac{d\theta}{dY}=0 \tag{2.8}$$

$$\frac{d^2\phi}{dY^2}+Sc\frac{d\phi}{dY}-Sc\gamma\phi=0 \tag{2.9}$$

The corresponding initial and boundary conditions in non-dimensional form are:

$$U=1,\ \frac{\partial\theta}{\partial Y}=-1,\ \frac{\partial\phi}{\partial Y}=-1 \quad at\ \ y=0$$

$$U\to 0,\ \theta\to 0,\ \phi\to 0 \qquad at\ y\to\infty \tag{2.10}$$

Where

Gr: Thermal Grashof number (Grashof number for heat transfer)

Gc: Solutal Grashof number (Grashof number of mass transfer),

M: magnetic parameter (Hartmann number),
Pr: Prandtl number
Sc: Schmidt number
γ: Chemical reaction parameter, etc.

3. Solution of the Problem

Solving Equations (2.7) -(2.9) with boundary conditions (2.10), we get,

$$U = (1 + A_3 + A_4)e^{-A_2 Y} - A_3 e^{-Pr\,Y} - A_4 e^{-A_1 Y} \quad (3.1)$$

$$\theta = \frac{1}{Pr} e^{-Pr\,Y} \quad (3.2)$$

$$\phi = \frac{1}{A_1} e^{-A_1 Y} \quad (3.3)$$

Where $A_1 = \dfrac{\left(Sc + \sqrt{Sc^2 + 4Sc\gamma}\right)}{2}$

$$A_2 = \frac{\left(1 + \sqrt{1 + 4M}\right)}{2}$$

$$A_3 = \frac{Gr}{Pr\left(Pr^2 - Pr - M\right)}$$

$$A_4 = \frac{Gc}{A_1\left(A_1^2 - A_1 - M\right)}$$

The skin-friction is given as:

$$\tau = -\left(\frac{dU}{dY}\right)_{Y=0} = A_2(1 + A_3 + A_4) - Pr\,A_3 - A_4 A_1$$

The velocity distribution equation, the mass diffusion equation and skin-friction equation can be adjusted to meet these circumstances if one takes

(i) $\gamma > 0$ for the destructive reaction,

(ii) $\gamma = 0$ for no reaction and

(iii) $\gamma < 0$ for the generative reaction.

4. Results and Discussion:

The velocity distribution of boundary layer flow for destructive reaction is plotted against y in **figure-1** $\mathrm{Pr} = 0.71, \mathrm{Sc} = 4, \mathrm{Gr} = 2, \mathrm{Gc} = 2, \gamma = 2$ for different values of Hartman number M and it is observed that the fluid velocity decreases due to increasing Hartmann number M.

The velocity distribution of boundary layer flow for generative reaction is plotted against y in **figure-2** $\mathrm{Pr} = 0.71, \mathrm{Sc} = 4, \mathrm{Gr} = 2, \mathrm{Gc} = 2, \gamma = -0.5$ for different values of Hartman number M and it is observed that the fluid velocity decreases due to increasing Hartmann number M.

The velocity distribution of boundary layer flow is plotted against y in **figure-3** for $\mathrm{Pr} = 0.71, \mathrm{Sc} = 2, \mathrm{Gr} = 2, \mathrm{Gc} = 2, M = 1$ and different values of chemical reaction parameter γ and it is observed that the fluid velocity decreases due to destructive reaction of chemical and it increases due to generative reaction of chemical.

The concentration distribution of boundary layer flow for destructive reaction is plotted against y in **figure-4** $\mathrm{Pr} = 0.71, \mathrm{M} = 2, \mathrm{Gr} = 2, \mathrm{Gc} = 2, \gamma = 2$ for different values of Schmidt number Sc and it is observed that the concentration of fluid decreases due to increasing Schmidt number Sc.

The concentration distribution of boundary layer flow for generative reaction is plotted against y in **figure-5** $\mathrm{Pr} = 0.71, \mathrm{M} = 2, \mathrm{Gr} = 2, \mathrm{Gc} = 2, \gamma = -0.5$ for different values of Schmidt number Sc and it is observed that the concentration of fluid decreases due to increasing Schmidt number Sc.

The concentration distribution of boundary layer flow is plotted against y in **figure-6** for $\mathrm{Pr} = 0.71, \mathrm{Sc} = 2, \mathrm{Gr} = 2, \mathrm{Gc} = 2, M = 1$ and different values of chemical reaction parameter γ and it is observed that the concentration distribution decreases due to Destructive reaction of chemical and it increases due to generative reaction of chemical.

The temperature distribution of boundary layer flow is plotted against y in **figure-7** for $\Pr = 0.71, Sc = 4, Gr = 2, Gc = 2, \gamma = 2$ and different values of Prandtl, number Pr and it is observed that the fluid temperature decreases due to increasing Prandtl number Pr.

In table-1, the skin friction co-efficient of boundary layer flow are tabulated for different value of Schmidt number Sc and chemical reaction parameter γ and it is observed that the skin friction increases due to increasing Schmidt number Sc, it is also observed that skin friction decreases due to generative reaction of chemical and it increases due to Destructive reaction of chemical.

Figure-1: Velocity for destructive chemical reaction on different value of M

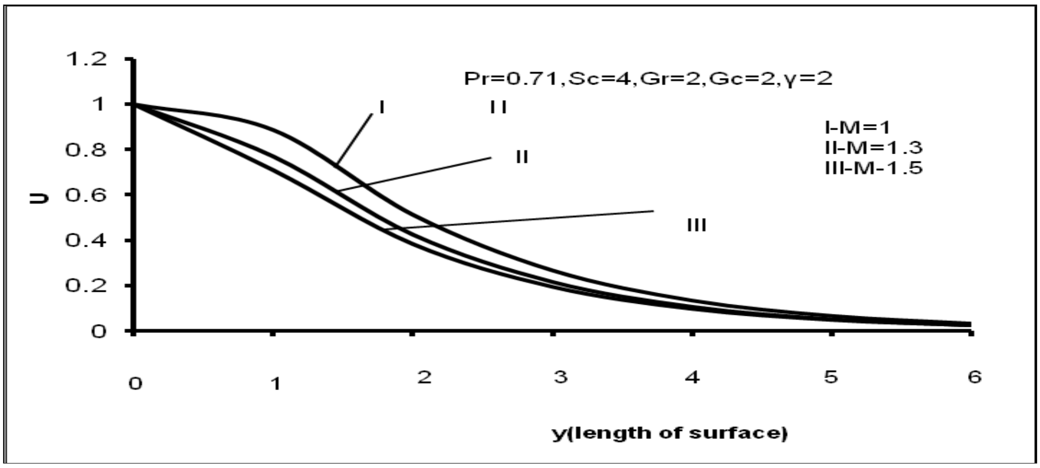

Figure-2: Velocity for generative chemical reaction on different value of M

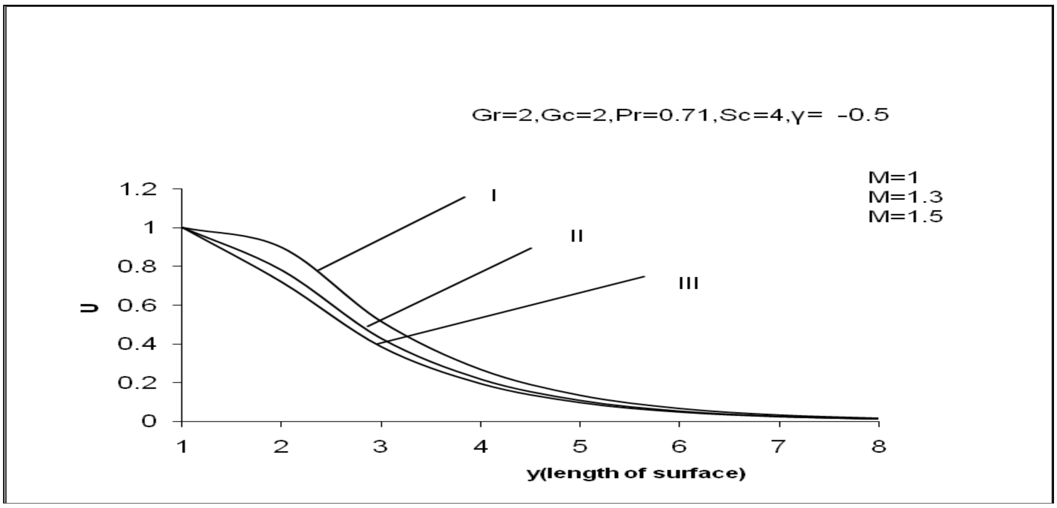

Figure-3: Velocity for different value of chemical reaction parameter γ

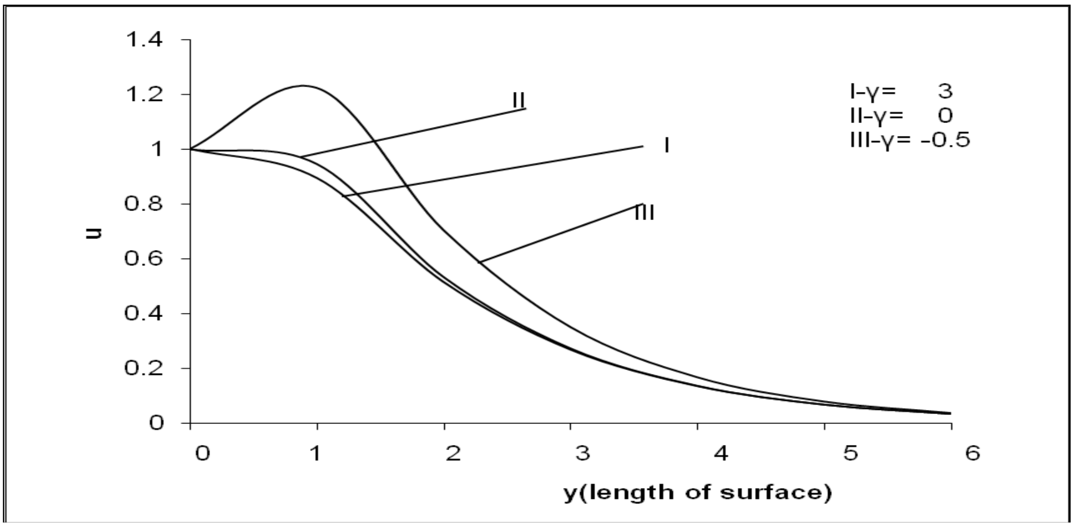

Figure –4: Concentration for destructive chemical reaction on different value of Sc.

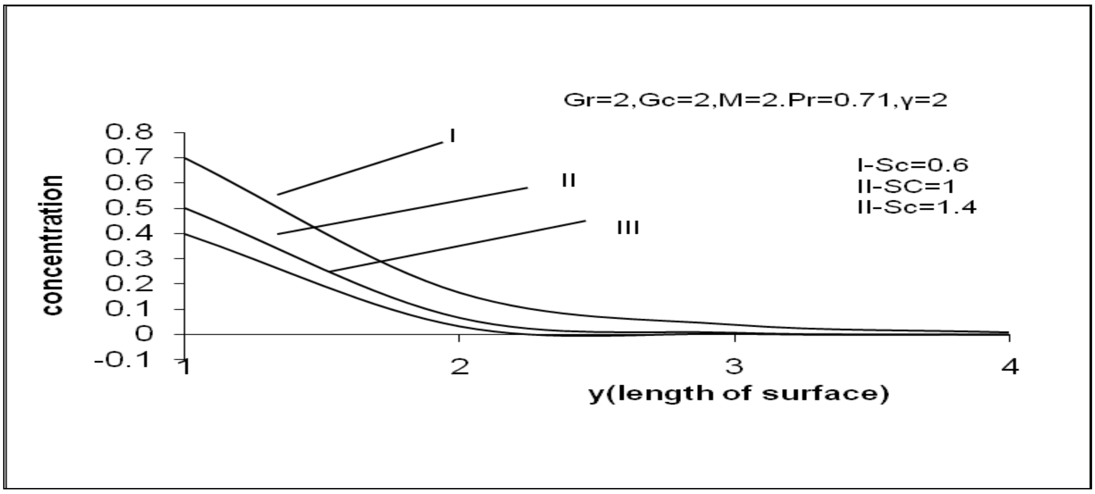

Figure- 5: Concentration for generative chemical reaction on different value of Sc .

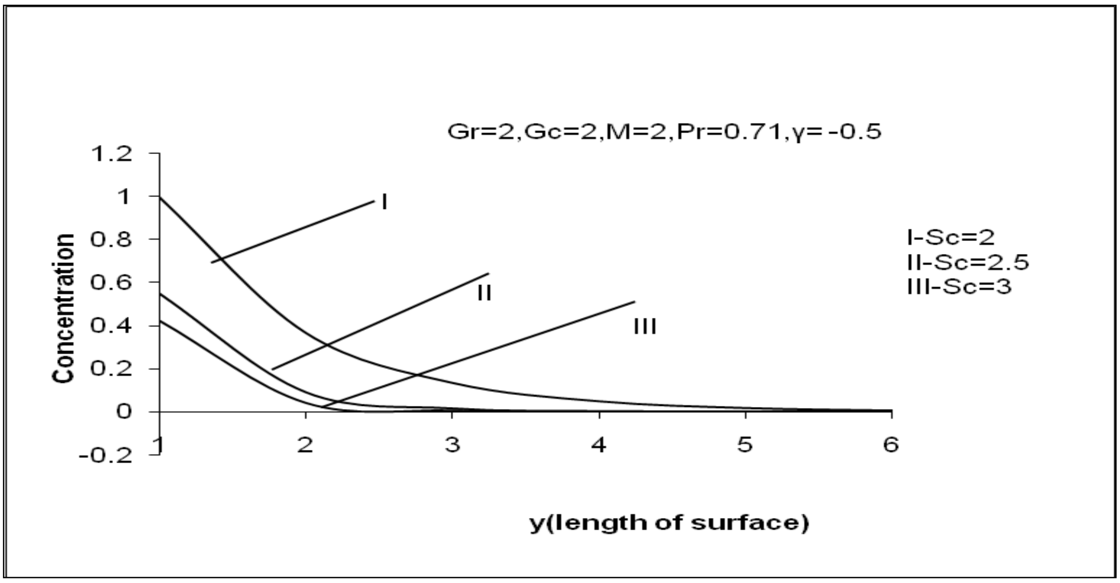

Figure-6: Concentration for different value of chemical reaction parameter γ

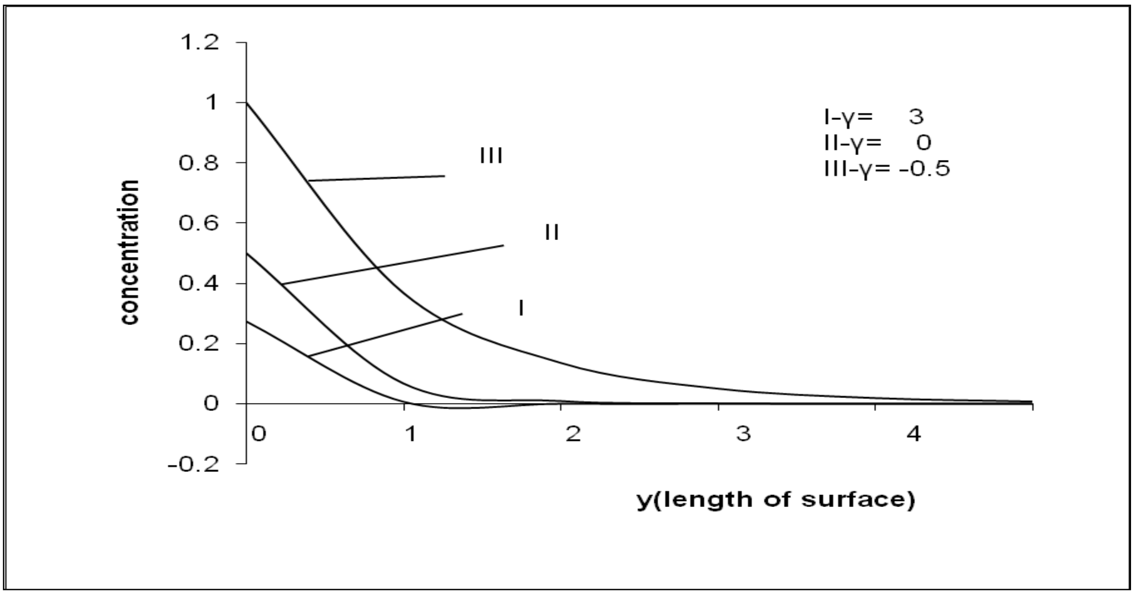

Figure –7: Temperature for different value of *P*r.

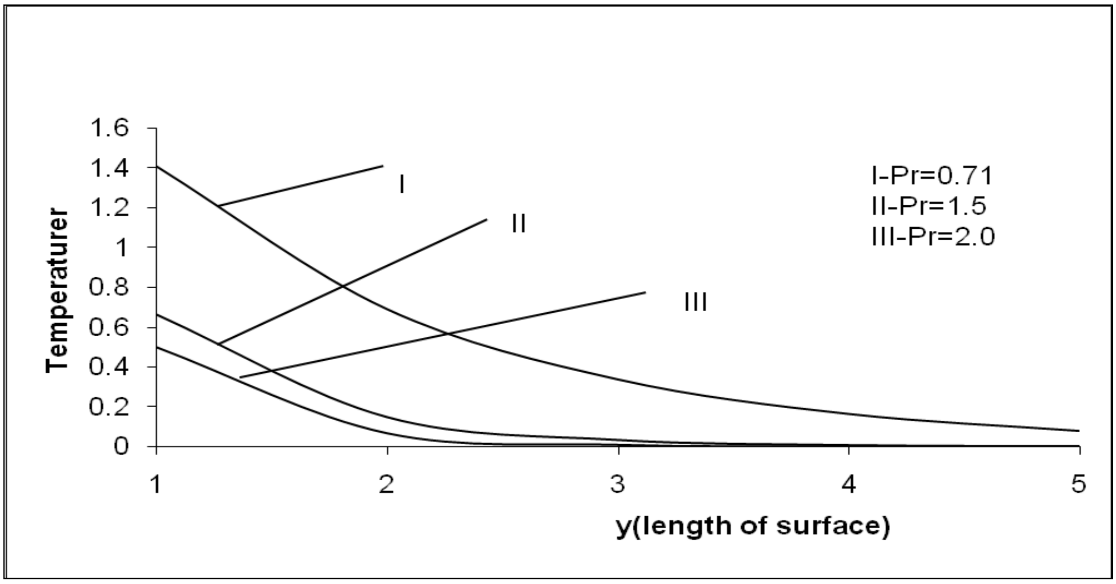

Table.1: Skin friction co-efficient of boundary layer flow with different value of Schmidt number Sc and chemical reaction parameter γ

Schmidt number Sc	Chemical reaction parameter γ	Skin friction τ
2	3	0.234606
2.5	3	0.263449
3	3	0.282306
3	0	0.186023
3	-0.5	0.101562

5. Conclusion:

Present study is concerned the influence of chemical reaction on MHD flow on continuously moving vertical surface with uniform heat and mass flux taking into account the homogeneous chemical reaction of 1st order. The expressions for velocity, temperature, concentration and skin friction are obtained. The effects of various parameters are discussed with the help of graphs and tables. The fundamental parameters found to affect the problem under consideration are the chemical reaction parameter and magnetic field parameter. It is found that, the fluid velocity for both destructive and generative reaction decreased due to increasing Hartmann number M, the fluid velocity decreased due to Destructive reaction of chemical and it increased due to generative reaction of chemical. The concentration for both destructive and generative reaction decreased due to increasing Schmidt number Sc, the concentration decreased due to Destructive reaction of chemical and it increased due to generative reaction of chemical. The fluid temperature decreased due to increasing Prandtl number Pr. The skin friction increased due to increasing Schmidt number Sc, it is also observed that skin friction decreased due to generative reaction of chemical and it increased due to Destructive reaction of chemical.

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