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EFFECT OF CHEMICAL REACTION ON MHD FREE CONVECTION FLOW PAST AN EXPONENTIALLY ACCELERATE POROUS PLATE IN THE SLIP FLOW REGIME WITH POROUS MEDIUM

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ABSTRACT

Effect of chemical reaction on MHD free convection flow past an exponentially accelerate porous plate in the slip flow regime with porous medium has been studied. The dimensionless governing equations are solved using Series solution technique .The velocity near the plate with slip flow regime is assumed to vary with respect to time. The influences of the various parameters on the flow field, skin friction, rate of heat transfer, rate of mass transfer and Temperature field are extensively discussed from graphs.

KEYWORDS: MHD, Free convection, Heat Transfer, Slip flow Regime, Chemical reaction, exponential acceleration, Mass transfer and Porous medium.

INTRODUCTION

Coupled heat and mass transfer by natural convection in a fluid –saturated porous medium has attracted considerable attention in the last few years due to many important engineering and geophysical applications. It occurs not only due to temperature difference, but also due to concentration difference as well as different geophysical situations. Its application in many process industries like extrusion of plastic in the manufacture of Rayon and Nylon, purification of crude oil, pulp, paper industries, Radio propagation through the ionosphere. The phenomenon of mass transfer is a common theory of stellar structure. Also observable effects are detected on the solar surface. The flow through porous media has become an important topic because of the recovery of crude oil from pores of reservoir rocks .From the primitive year's mass transfer plays an impotent role in vaporization of ocean, burning of pool of oil, spray drying, leaching and abolition of a meteorite

MHD plays an important role in power generation, space propulsions, cure of diseases, control of thermonuclear reactor, boundary layer control in field of aerodynamics .In past few years several simple flow problems associated with classical hydrodynamics have received new attention within the more general context of hydrodynamics. Convection in porous medium has applications in geothermal energy recovery, oil extraction and thermal energy storage. The effect of magnetic field on free convection flow is important in liquid–metals and ionized gases. To study such applications which are closely associated with magneto-chemistry requires a complete understanding of the equation of state and transfer properties such as diffusion, the shear stress, thermal conduction, electrical conduction etc. Some of these properties will undoubtedly be influenced by the presence of external magnetic field and chemical reaction. Kafousias and Raptis [1] have studied the mass transfer effect of unsteady free convection flow of an incompressible viscous fluid past an infinite vertical accelerated porous plate. Mohapatra and Senapati [2] have been analyzed magneto hydrodynamic free convection flow with mass transfer past a vertical plate. Chamkha, A.J. [3] have studied MHD-free convection from a vertical plate embedded in a thermally stratified porous medium with Hall effects. Rahman and Mulolani [4] have discussed Convective- Diffusive Transport chemical reaction in Natural convection Flows. Singh [5] have studied the effect of mass transfer on MHD free convection Flow of a viscous fluid through a vertical channel. Muthucumaraswamy and Ganesan [6] have analyzed natural convection on a moving isothermal vertical plate with chemical. Senapati et. al.[7] have discussed the magnetic effect on mass and heat transfer of a hydrodynamic flow past a vertical oscillating plate in presence of chemical reaction. Senapati et. al.[8,9] have studied the effect of chemical reaction on MHD unsteady free convection flow through a porous medium bounded by a linearly accelerated vertical plate, also Effects of chemical reaction on MHD unsteady free convective walter's memory flow with constant suction and heat sink. Das et.al.[10] have investigated the unsteady hydromagnetic convective flow past an infinite vertical flat plate in a porous medium .Effects of chemical reaction on free convection MHD flow through porous medium bounded by vertical plate with slip flow region is studied by Senapati et .al.[11]

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In this problem, we try to investigate the Effect of chemical reaction on MHD free convection flow past an exponentially accelerate porous plate in the slip flow regime with porous medium.

FORMULATION OF PROBLEM

Consider the unsteady free convection two-dimensional flow of an incompressible, electrically conducting viscous fluid along an infinite oscillating porous plate in the slip flow regime with porous medium. The X' –axis is taken along the plate in the upward direction growing in the direction of motion and Y' –axis is taken normal to the plate. Assume that the fluid has constant properties and the variation in density and mass concentration is considered only in the body force term. A magnetic field of uniform strength B_0 acts normal to the plate. Initially we assume that the plate and fluid are in the same temperature and concentration at all points. At time t'>0, the plate starts oscillating in its own plane with frequency and temperature of the plate and concentration level are also raised linearly with time. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations:

$$\frac{\partial u'}{\partial t'} = \nu \frac{\partial^2 u'}{\partial y'^2} - \frac{\nu}{K'} u' - \frac{\sigma B_0^2 u'}{\rho} + g\beta(T' - T'_\infty) + g\beta_c(C' - C'_\infty) \quad (1)$$

$$\rho C_p \frac{\partial T'}{\partial t'} = k \frac{\partial^2 T'}{\partial y'^2} \quad (2)$$

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y^2} - R'(C' - C'_\infty) \quad (3)$$

where ν is the kinematic viscosity, k is the thermal diffusivity, K' is the permeability coefficient, β is the volumetric coefficient of expansion for heat transfer, ρ is the density , σ is the electrical conductivity of the fluid , g is the acceleration due to gravity , T' is the temperature, T'_∞ is the temperature of the fluid far away from the plate.

Now the first order velocity slip boundary conditions of the problem when the plate executes linear harmonic oscillations in its own plane are given by

$$\left.\begin{array}{l} t' \le 0, u' = 0, T' = T'_\infty, C' = C'_\infty \ \ for\ all\ y' \\ t' > 0, u' = U_0 exp(i\omega' t') + L_1 \frac{\partial u'}{\partial y'}, T' = T'_\infty + (T'_w - T'_\infty)At', \\ \qquad C' = C'_\infty + (C'_w - C'_\infty)At' \ \ at\ y' = 0 \\ t' > 0, u' = 0, T' \to T'_\infty, C' \to C'_\infty \ \ \text{as}\ \ y' \to \infty \end{array}\right\} \quad (4)$$

where $A = \frac{U_0^2}{\upsilon}$,$L_1 = \left(\frac{2-m}{m}\right) L$, $L = \mu\left(\frac{\pi}{2P\rho}\right)^{\frac{1}{2}}$ and L is mean free path and m is maxwell 's reflexion coeficients.

Let us introduce the dimensionless quantities

$$\left.\begin{array}{l} u = \frac{u'}{U_0}, t = \frac{t' U_0^2}{\upsilon}, y = \frac{y' U_0}{\upsilon}, \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, \omega = \frac{\upsilon \omega'}{U_0^2} \\ Gr = \frac{g\beta\upsilon(T'_w - T'_\infty)}{U_0^3}, Gm = \frac{g\beta_C\upsilon(C'_w - C'_\infty)}{U_0^3}, Pr = \frac{\mu C_p}{k}, Sc = \frac{\upsilon}{D}, M = \frac{\sigma \upsilon B_0^2}{\rho U_0^2} \\ K = \frac{U_0^2 K'}{\upsilon^2}, R = \frac{R' U_0^2}{\upsilon}, h = \frac{U_0 L_1}{\upsilon} \end{array}\right\} \quad (5)$$

where D is the mass diffusion, Gr is Grashof number, Gm is modified Grashof number ,K is permeability of porous medium, M is magnetic parameter ,Sc is Schmidt number, Pr is Prandtl number, β is thermal expansion co-efficient , β_C concentration expansion co-efficient, $B_0 = \mu_e H_0$, ω is the frequency of oscillation ,R is chemical reaction parameter and h is rarefaction parameter.

Substituting equation (5) in the equations (1), (2) & (3), we have

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC - \left(M + \frac{1}{K}\right)u \tag{6}$$

$$Pr\frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\partial y^2} \tag{7}$$

$$Sc\frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial y^2} - RScC \tag{8}$$

With boundary conditions

$$\left.\begin{array}{ll} t \le 0, & u = 0,\ \theta = 0,\ C = 0 \ for\ y = 0 \\ t > 0, & u = \exp(i\omega t) + h\frac{\partial u}{\partial y},\ \theta = t,\ C = t \quad \text{for } y = 0 \\ & u = 0,\ \theta \to 0,\ C \to 0 \quad \text{for } y \to \infty \end{array}\right\} \tag{9}$$

METHOD OF SOLUTION

For solving equations (6) - (8) with boundary condition (9), we assume the following for the velocity, temperature and concentration of flow of the flow field.

$$\begin{array}{l} u = u_0 + u_1 e^{i\omega t} \\ \theta = \theta_0 + \theta_1 e^{i\omega t} \\ C = C_0 + C_1 e^{i\omega t} \end{array} \tag{10}$$

and substitute in equations (6) to (9) then , we get,

$$u_0'' - \left(M + \frac{1}{K}\right)u_0 = -Gr\theta_0 - GmC_0 \tag{11}$$

$$u_1'' - \left(M + \frac{1}{K} + i\omega\right)u_1 = -Gr\theta_1 - GmC_1 \tag{12}$$

$$\theta_0'' = 0 \tag{13}$$

$$\theta_1'' - iPr\omega\theta_1 = 0 \tag{14}$$

$$C_0'' - RScC_0 = 0 \tag{15}$$

$$C_1'' - (R + i\omega)ScC_1 = 0 \tag{16}$$

With the following boundary conditions

$$\begin{array}{l} u_0 = h\frac{\partial u_0}{\partial y}, u_1 = 1 + h\frac{\partial u_1}{\partial y}, \theta_0 = t, \theta_1 = 0, C_0 = t, C_1 = 0 \ \ at \ \ y = 0 \\ u_0 = 0, u_1 = 0, \theta_0 = 0, \theta_1 = 0, C_0 = 0, C_1 = 0 \ \ as \ \ y \to \infty \end{array} \tag{17}$$

By solving (11)-(16) using boundary conditions (17) ,we get

$$u = (B_{11}e^{-A_{12}y} + B_{12}) + (B_{13}e^{-A_{13}y})e^{i\omega t} \tag{18}$$

$$\theta = t \tag{19}$$

$$C = te^{-A_{11}y} \tag{21}$$

The dimensional rate of heat transfer /Shearing stress,

$$\mathrm{Nu} = -\left(\frac{\partial \theta}{\partial y}\right)_{\eta=0} = 0 \tag{22}$$

The dimensionless rate of mass transfer,

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{\eta=0} = tA_{11} \tag{23}$$

The non-dimensional Skin friction at the plate is given by

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$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = -(A_{12}B_{11} + A_{13}B_{13}e^{i\omega t}) \quad (24)$$

where $A_{11} = \sqrt{R\,Sc}, A_{12} = \sqrt{M + \frac{1}{K}},\ A_{13} = \sqrt{M + i\omega + \frac{1}{K}}$

$$B_{11} = \frac{-(G_r + G_m)t}{\left(M + \frac{1}{K}\right)(1 + hA_{12})}, B_{12} = \frac{(G_r + G_m)}{\left(M + \frac{1}{K}\right)}, B_{13} = \frac{1}{1 + hA_{13}}$$

RESULTS AND DISCUSSION

In this paper we have studied the effect of chemical reaction on MHD free convection flow past an exponentially accelerate porous plate in the slip flow regime with porous medium. The effect of the parameters Gr, Gm, M, K, R, Sc, Pr, ω and h on flow characteristics have been studied and shown by means of graphs and tables. In order to have physical correlations, we choose suitable values of flow parameters. The graphs of velocities, heat and mass concentration are taken w.r.t. y and the values of Shearing stress and Sherwood Number are shown in the table for different values of flow parameters.

Velocity profiles: The velocity profiles are depicted in Figs 1-4. Figure-(1) shows the effect of the parameters M and K on velocity at any point of the fluid, when Sc=0.22,R=2,Gr=2 ,h=0.5, t=1 and w=1 It is noticed that the velocity increases with the increase of permeability parameter porous medium (K), whereas decreases with the increase of magnetic parameter(M),physically ,it is justified because the application of transverse magnetic field always results in a restive type force called Lorentz force which is similar to drag force and tends to resist the fluid motion ,finally reducing the velocity. Also by increasing the permeability parameter, drag force decreases and hence velocity increases.

Figure-(2) shows the effect of the parameters R and Gr on velocity at any point of the fluid, when Sc=0.22,M=2,K=2 ,h=0.5, t=1 and w=1. It is noticed that the velocity increases with the increase of Grashoff number (Gr) and reaction parameter (R).Actually, the thermal Grashof number signifies the relative impotence of buoyancy force to the viscous hydrodynamic force. Increase of Grashof Number (Gr) indicates small viscous effects in the momentum equation and consequently, causes increase in the velocity profiles.

Figure-(3) shows the effect of the parameters h and ω on velocity at any point of the fluid, when Sc=0.22,R=2,M=2,K=2 ,h=0.5, t=1 and w=1.It is noticed that the velocity increases with the increase of ω frequency of oscillation(ω) and rarefaction parameter(h).

Figure-(4) shows the effect of the parameters Sc on velocity at any point of the fluid, when R=2,M=2,K=2 ,h=0.5, t=1 and ω =1..It is noticed that the velocity increases with the increase of Schmidt number(Sc) .

Mass concentration profile: The mass concentration profiles is depicted in Figs 5 . Figure-(5) shows the effect of R,Sc and t on Mass concentration profile in the absence of other parameters .It is noticed that the mass concentration decreases in the increase of Schmidt number(Sc) and reaction parameter (R), whereas increases in the increase of time (t).

Table-(1) shows the effects of different parameters on Shearing stress .It is noticed that shearing stress increases in the increase of Grashoff number (Gr), permeability parameter porous medium (K) Magnetic parameter (M) ,Chemical reaction parameter (R), oscillation (ω) and Schmidt number (Sc).

Table-(2) shows the effects of different parameters on Sherwood Number .It is noticed that Sherwood Number increases in the increase of Chemical reaction parameter (R) and Schmidt number (Sc).

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Table-(1) Effect of different parameters on Shearing stress

R	K	M	Sc	Gm	w	Shearing Stress
2						3.7143
3						3.8736
4						4.0079
	3					3.7291
	4					3.7399
		3				3.7167
		4				3.7859
			.3			3.8332
			0.6			4.1761
				3		3.8915
				4		4.0687
					1.1	4.1130
					1.2	4.5659

Table-(2) Effect of R and Sc on Sherwood Number

R	2	3	4	2	2
Sc	0.22	0.22	0.22	0.3	0.6
Sherwood Number	0.6633	0.8124	0.9381	0.7796	1.0954

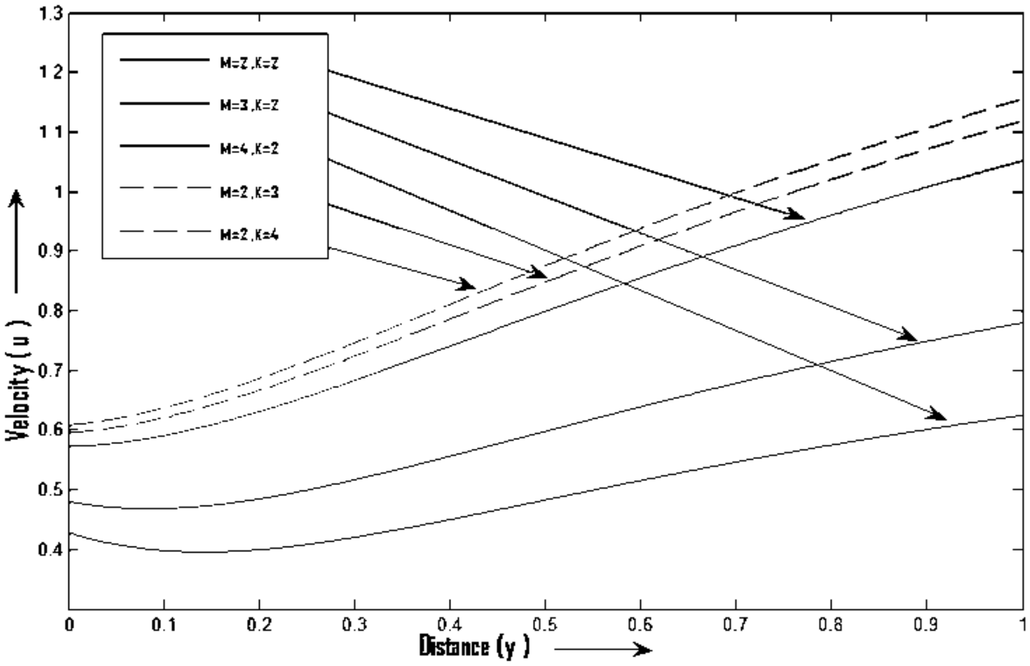

Fig-(1) Effect of M and K on velocity profile when Sc=0.22,R=2,Gr=2 ,h=0.5, t=1 and w=1.

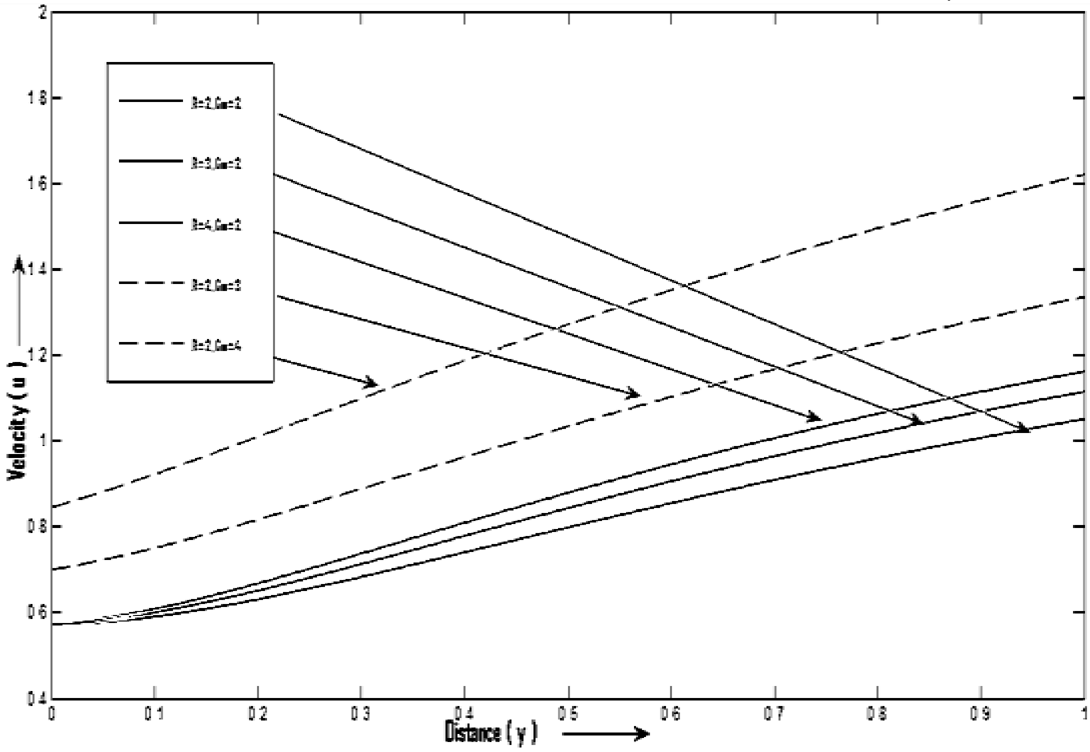

Fig-(2) Effect of R and Gr on velocity profile when Sc=0.22, M=2,K=2 ,h=0.5, t=1 and w=1.

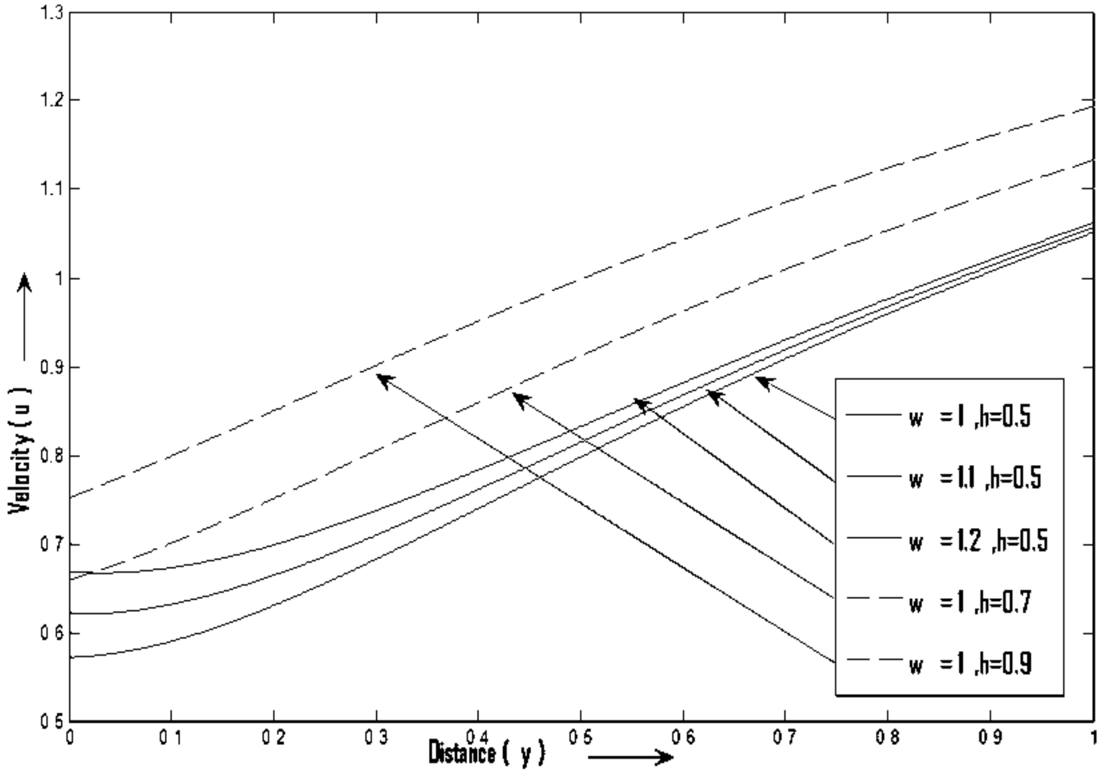

Fig-(3) Effect of w and h on velocity profile when Sc=0.22,R=2,M=2,K=2 ,h=0.5, t=1 and w=1.

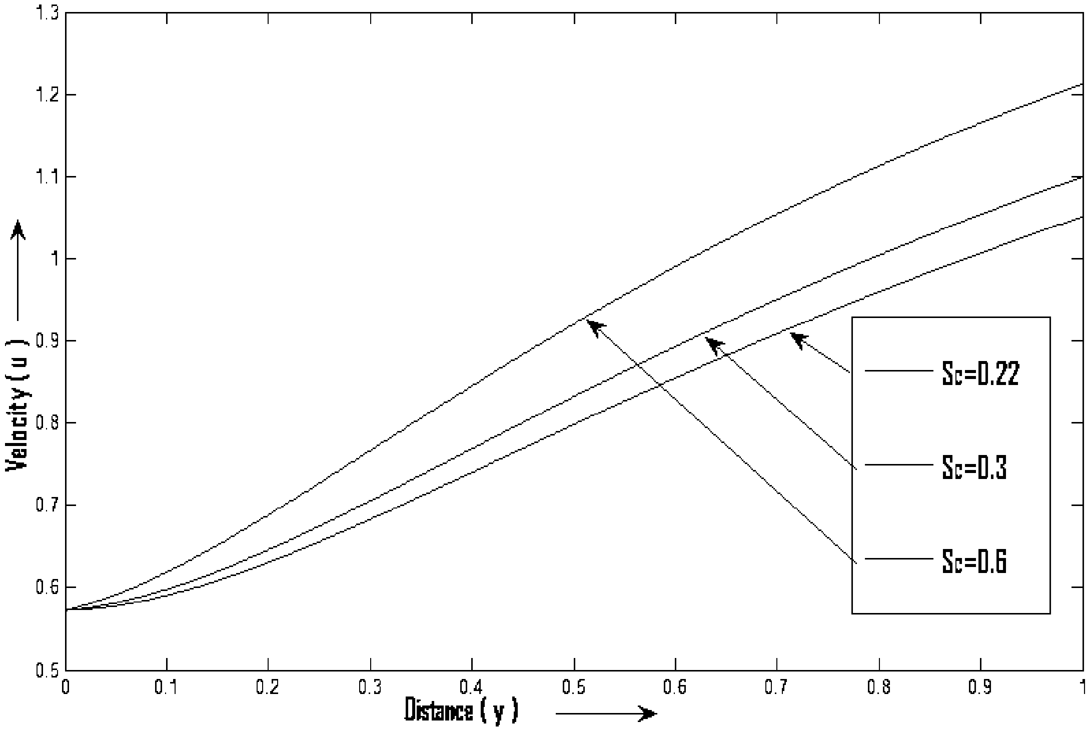

Fig-(4) Effect of Sc on velocity profile, when R=2,M=2,K=2 ,h=0.5, t=1 and w=1.

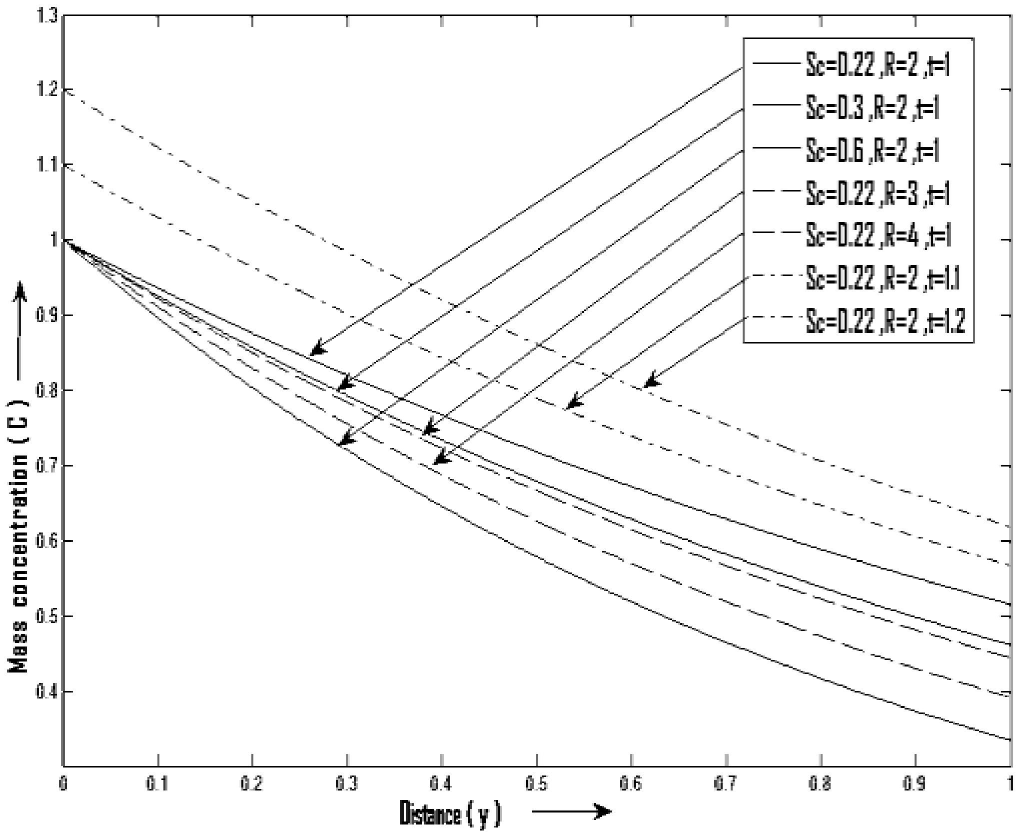

Fig-(4) Effect of R,Sc and t on Mass concentration profile in the absence of other parameters.

CONCLUSION

In this study of Effect of chemical reaction on MHD free convection flow past an exponentially accelerate porous plate in the slip flow regime with porous medium, the following points are set out:

i. Permeability parameter porous medium (K) and magnetic parameter (M) both action are opposite to each other. Velocity increases for the increase of K, Sc,R,Gr, h and ω whereas decrease in the increase of M.
ii. Mass concentration increases in the increase of Sc,R and t.
iii. The value of Sherwood Number and shearing stress near the plate increases with the increase of all parameter involved in the flow field.

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