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Mathematics

EFFECT OF CHEMICAL REACTION PIECES ON MHD FREE CONVECTIVE FLOW OF NANO FLUID OVER AN EXPONENTIALLY ACCELERATED INCLINED PLATE EMBEDDED IN A POROUS MEDIUM

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ABSTRACT Effect of chemical reaction pieces on MHD free convective flow of fluid over an exponentially accelerated inclined plate embedded in the porous medium is discussed. The differential equations are solved utilizing Laplace Transformation Technique. The influences of the various parameters on the flow field, skin friction, and rate of heat transfer, rate of mass transfer, heat field, and mass concentration field are vividly discussed through graphs and tables.

KEYWORDS : MHD, Free convection, Heat Transfer, Chemical reaction, Exponential acceleration, Mass Transfer, Nano Fluid and Porous medium.

1. INTRODUCTION:

The phenomenon of magnetohydromagnetic free convective flow of fluids over an inclined plate embedded in a porous medium in the presence of heat and mass transfer has drawn the attention of most number of investigators due to its wide applications in many engineering problems such as MHD Generators, Plasma studies, thermonuclear reactors, oil explorations, purification of crude oil, pump, paper industries, radio propagation through the ionosphere, space propulsions, cure of diseases, Geothermal energy extractions and in the control boundary layer of aerodynamics. Both temperature difference and concentration difference along with different geophysical situations play an important role in the above flow, which is a common theory of stellar structure. Also, remarkable effects are detected on the solar surface. Similarly, mass transfer plays a important role in, burning spray drying, leaching, vaporization of the ocean and abolition of a meteorite, etc. The magnetic effect on free convection flow is important in liquid metals like liquid sodium, mercury, etc., and ionized gases. To discourse such applications which are closely associated with magneto-chemistry needs knowledge of the equation of state and transfer properties completely such as diffusion, shear stress, thermal conduction, electrical conduction, etc. Some of these properties are influenced by the presence of chemical reactions, external magnetic fields, and heat sources. Kafousias and Raptis [1] have studied "the mass transfer and free convection effects on the flow past an accelerated vertical infinite plate with variable suction or injection". Mohapatra and Senapati [2] have analyzed "magnetohydrodynamic free convection flow with mass transfer past a vertical plate". Singh [6] has studied the effect of mass transfer on MHD free convection flow of a viscous fluid through a vertical plate. Senapati et. al. [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. Again, Senapati et. al. [10] have studied the effects of chemical reaction on MHD unsteady free convective Walter's memory flow with constant suction and heat sink. Jha et. al. [3] have examined the free convection and mass transfer about an infinite vertical plate moving impulsively in its plane.

In the present era, a large number of investigations are continued on nanofluids. Nanofluid is a mixture of the base fluid and nanoparticles of base metals (Al, Cu), oxides (Al_2O_3, TiO_2), carbides (SiC), etc. Nanofluid contains nanoparticles of nanometer-sized within the length scale of 1-100 nm diameters and 5% volume fraction of nanoparticles. The base fluid is typically a conductive liquid, for instance, $C_2H_6O_2, H_2O$, and engine oil. Nanofluids with or without the presence of magnetic fields have numerous applications in the industries. Since materials of nanometer size have unique chemical and physical properties concerning sundry utilizations of Nanofluid, the cooling applications of nanofluid, incorporate silicon mirror cooling, electronic cooling, vehicle cooling, transformer cooling, and so on. Nanofluids have been appeared to increase the thermal conductivity and convective heat transfer performance of the base liquids. Due to the increasing importance of nanofluids, several literatures on convective heat transport in nanofluid problems are developed. These fluids are suspended in designing the colloidal system of nanoparticles in the base fluid. The hypothesis of nanofluid is first presented by Choi and has been a field of dynamic research area for about two decades. Choi has proposed the infusion of nano-size particles into regular fluids, for example, water and oil. Choi et. al. [4] has demonstrated experimentally that the injection of nanoparticles enhances the thermal conductivity of the fluid. This conclusion has opened the best approach to utilize these new fluids in chemical engineering, mechanical designing, medicines, and many other fields. Again, Choi et. al. [5] have studied anomalous thermal conductivity enhancement in nanotube suspensions. Venkataramanaiah et. al. [12] have been clarified the Nanoparticle effect on MHD boundary layer flow of Williamson fluid over a stretching sheet. Ramya et. al. [11] have been researched the steady two-dimensional flow of a viscous nanofluid of MHD flow for the boundary layer flow. Abbasi et. al. [8] have studied the influence of heat and mass flux conditions in the hydromagnetic flow of Jeffery Nanofluid. Shehzad et. al. [7] have studied MHD mixed convective peristaltic motion of Nanofluid with Joule heating and thermophoresis effects. Zubair et. al. [13] have discussed the heat and mass transfer analysis of MHD Nanofluid flow with radiative heat effects in the presence of spherical Au-Metallic

Nanoparticles.

In this problem, we try to investigate the effects of chemical reaction on MHD free convective flow of Nanofluid over an exponentially accelerated inclined plate embedded in the porous medium.

FORMULATION OF PROBLEM:

Let us consider the unsteady free convection flow of an incompressible, electrically conducting viscous Nanofluid past an infinite inclined plate embedded in a porous medium with the presence of heat source and chemical reaction. The X' - axis is taken along the plate makes an angle α with vertical and Y' - axis is taken normal to the plate. A magnetic field of uniform strength B_0 acts normal to the plate. Initially, we assume that the plate and fluid are in the constant temperature T'_∞ and of mass concentration C'_∞. At time $t' > 0$, the plate is given a sudden jerk making exponential movement having velocity $u' = U_0 e^{At'}$ and temperature of the plate and concentration level are also raised linearly with time and same parameter $A = \frac{U_0^2}{\nu_f}$. It is assumed that the fluid has constant properties and the variation in density and mass concentration is considered only in body force terms. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations:

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

$$\frac{\partial T'}{\partial t'} = \frac{k_{nf}}{(\rho C_p)_{nf}}\frac{\partial^2 T'}{\partial y'^2} - S'(T' - T'_\infty) \quad (2)$$

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

with the following boundary conditions

$$\left.\begin{array}{l} t \le 0: \; u = 0, T' = T'_\infty, \quad C' = C'_\infty \\ t > 0: \left| \begin{array}{ll} u' = U_0 e^{At'}, T' = T'_\infty + (T'_p - T'_\infty)At', \; C' = C'_\infty + (C'_p - C'_\infty)At' & at \;\; y = 0 \\ u' = 0, \quad T' = T'_\infty, \quad C' = C'_\infty & as\; y \to \infty \end{array}\right. \end{array}\right\} \quad (4)$$

where μ_{nf} is the dynamic viscosity, k_{nf} is the thermal diffusivity, ρ_{nf} is the effective density, $(\rho C_p)_{nf}$ is the heat capacity, $(\beta)_{nf}$ $is\ the$ coefficient of volumetric expansion of heat and $(\beta_c)_{nf}$is the coefficient of volumetric expansion of the mass of nano-fluid and are defined by

$$\mu_{nf} = \frac{\mu_f}{(1-\phi)^{2.5}}, \quad \rho_{nf} = (1-\phi)\rho_f + \phi\rho_s, \quad (\rho C_p)_{nf} = (1-\phi)(\rho C_p)_f + \phi(\rho C_p)_s,$$

$$k_{nf} = \left[\frac{k_s + 2k_f - 2\phi(k_f - k_s)}{k_s + 2k_f + 2\phi(k_f - k_s)}\right] k_f, \; (\beta)_{nf} = (1-\phi)(\beta)_f + \phi(\beta)_s, (\beta_c)_{nf} = (1-\phi)(\beta_c)_f + \phi(\beta_c)_s$$

Also, K' is the permeability coefficient, σ is the electrical conductivity of the fluid, g is the acceleration due to gravity and ϕ is the Volumatic fraction of nano-fluid, S is the source Parameter.

Let us introduce the non-dimensional quantities:

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

Where D is the mass diffusion, Gr is the Grashof number, Gm is the modified Grashof number, K is the permeability of the porous medium, M is the magnetic parameter, Sc is the Schmidt number, Pr is the Prandtl number and R is the chemical reaction parameter.

Applying equation (5) in equations (1) to (3) with boundary conditions (4), we get

$$\phi_1 \frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + \phi_2 Gr\theta cos\alpha + \phi_3 GmCcos\alpha - \phi_0 Mu - \frac{u}{K} \quad (6)$$

$$Pr\frac{\partial \theta}{\partial t} = \phi_4 \frac{\partial^2 \theta}{\partial y^2} - PrS\theta \quad (7)$$

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

with boundary conditions

$$\left.\begin{array}{l} t \le 0: u = 0, \; \theta = 0, \; C = 0 \qquad for\; y = 0 \\ t > 0: \left| \begin{array}{ll} u = e^t, \; \theta = t, \quad C = t & for\; y = 0 \\ u = 0, \; \theta \to 0, \quad C \to 0 & for\; y \to \infty \end{array}\right. \end{array}\right\} \quad (9)$$

3. METHOD OF SOLUTION:

We solve the governing equations in an exact form by using Laplace Transforms. Taking Laplace transform of equations (6) to (8) with boundary condition (9), we have

$$\frac{d^2\bar{u}}{dy^2} - \left(\phi_0 + M + \frac{1}{K}\right)\bar{u} = -\phi_2 Gr\, Cos\,\alpha\,\bar{\theta} - \phi_3 Gm\, Cos\,\alpha\,\bar{C} \tag{10}$$

$$\phi_4 \frac{d^2\bar{\theta}}{dy^2} - Pr(S+s)\bar{\theta} = 0 \tag{11}$$

$$\frac{d^2\bar{C}}{dy^2} - Sc(R+s)\bar{C} = 0 \tag{12}$$

with the following boundary conditions

$$\left.\begin{array}{ll} \bar{u} = \frac{1}{s-1},\ \bar{\theta} = \frac{1}{s^2},\ \bar{C} = \frac{1}{s^2} & \text{at } y = 0 \\ \bar{u} = 0,\ \bar{\theta} = 0,\ \bar{C} = 0 & \text{as } y \to \infty \end{array}\right\} \tag{13}$$

By solving equations (10) to (12) using the boundary conditions (13), we get

$$\bar{u} = \left(\frac{1}{s-1} + \frac{a_1}{s-b_1} + \frac{a_2}{s-b_2}\right) e^{-\sqrt{(M_1+s)}y} + \frac{a_1}{s-b_1} e^{-\sqrt{\left(\frac{Pr}{\phi_4}(S+s)\right)}y} + \frac{a_2}{s-b_2} e^{-\sqrt{(Sc(R+s))}\,y} \tag{14}$$

$$\bar{\theta} = \frac{e^{-\sqrt{\left(\frac{Pr}{\phi_4}(S+s)\right)}y}}{s^2} \tag{15}$$

$$\bar{C} = \frac{e^{-\sqrt{(Sc(R+s))}\,y}}{s^2} \tag{16}$$

By solving the equations (14) to (16) using inverse Laplace transform, we get

$$\begin{aligned} u = {} & \frac{1}{2}\left(e^{t-2\eta\sqrt{t(M_1+1)}}.erfc\left(\eta - \sqrt{t(M_1+1)}\right) + e^{t+2\eta\sqrt{t(M_1+1)}}.erfc\left(\eta + \sqrt{t(M_1+1)}\right)\right) \\ & -\frac{a_1}{2}\left[\left(e^{tb_1-2\eta\sqrt{t(M_1+b_1)}}.erfc(\eta - \sqrt{t(M_1+b_1)}\right) + \left(e^{tb_1+2\eta\sqrt{t(M_1+b_1)}}.erfc(\eta + \sqrt{t(M_1+b_1)}\right)\right] \\ & -\frac{a_2}{2}\left[\left(e^{tb_2-2\eta\sqrt{t(M_1+b_2)}}.erfc(\eta - \sqrt{t(M_1+b_2)}\right) + \left(e^{tb_2+2\eta\sqrt{t(M_1+b_2)}}.erfc(\eta + \sqrt{t(M_1+b_2)}\right)\right] \\ & +\frac{a_1}{2}\left[\left(e^{tb_1-2\eta\sqrt{\frac{Pr}{\phi_4}t(S+b_1)}}.erfc\left(\frac{Pr}{\phi_4}\eta - \sqrt{t(S+b_1)}\right)\right) + \left(e^{tb_1+2\eta\sqrt{\frac{Pr}{\phi_4}t(S+b_1)}}.erfc\left(\frac{Pr}{\phi_4}\eta + \sqrt{t(S+b_1)}\right)\right)\right] \\ & +\frac{a_2}{2}\left[\left(e^{tb_2-2\eta\sqrt{tSc(R+b_2)}}.erfc(\eta - \sqrt{t(R+b_2)}\right) + \left(e^{tb_2+2\eta\sqrt{tSc(R+b_2)}}.erfc(\eta + \sqrt{t(R+b_2)}\right)\right] \end{aligned} \tag{17}$$

$$\theta = \left(\frac{t}{2} - \frac{\eta}{2}\sqrt{\frac{tPr}{S\phi_4}}\right)\left(e^{-2\eta\sqrt{St\frac{Pr}{\phi_4}}}.erfc\left(\eta\sqrt{\frac{Pr}{\phi_4}} - \sqrt{tS}\right)\right) + \left(\frac{t}{2} + \frac{\eta}{2}\sqrt{\frac{tPr}{S\phi_4}}\right)\left(e^{2\eta\sqrt{St\frac{Pr}{\phi_4}}}.erfc\left(\eta\sqrt{\frac{Pr}{\phi_4}} + \sqrt{tS}\right)\right) \tag{18}$$

$$C = \left(\frac{t}{2} - \frac{\eta}{2}\sqrt{\frac{tSc}{R}}\right)\left(e^{-2\eta\sqrt{RtSc}}.erfc\left(\eta\sqrt{Sc} - \sqrt{tR}\right)\right) + \left(\frac{t}{2} + \frac{\eta}{2}\sqrt{\frac{tSc}{R}}\right)\left(e^{2\eta\sqrt{RtSc}}.erfc\left(\eta\sqrt{Sc} + \sqrt{tR}\right)\right) \tag{19}$$

The non-dimensional heat transfer(Nu) is given by

$$Nu = -\left(\frac{\partial\theta}{\partial\eta}\right)_{\eta=0} = -\frac{1}{2}\left(\sqrt{\frac{tPr}{S\phi_4}} + 4\sqrt{St\frac{Pr}{\phi_4}}\right)\left(erfc(\sqrt{tS}) - erfc(-\sqrt{tS})\right) - \frac{2t}{\sqrt{\pi}}e^{-St}\sqrt{\frac{Pr}{\phi_4}} \tag{20}$$

The non-dimensional rate of mass transfer(Sh) is given by

$$Sh = -\left(\frac{\partial C}{\partial\eta}\right)_{\eta=0} = -\frac{1}{2}\left(\sqrt{\frac{tSc}{R}} + 4\sqrt{RtSc}\right)\left(erfc(\sqrt{tR}) - erfc(-\sqrt{tR})\right) - \frac{2t}{\sqrt{\pi}}e^{-Rt}\sqrt{Sc} \tag{21}$$

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

$$\begin{aligned} \tau = \left(\frac{\partial u}{\partial\eta}\right)_{\eta=0} = {} & t\sqrt{(M_1+1)}e^t\left(erfc(-\sqrt{t(M_1+1)}) - erfc(\sqrt{t(M_1+1)})\right) + \frac{2}{\sqrt{\pi}}e^{-tM_1} \\ & +a_1\left[\sqrt{t(M_1+b_1)}\,e^{tb_1}\left(erfc\left(\sqrt{t(M_1+b_1)}\right) - erfc\left(-\sqrt{t(M_1+b_1)}\right)\right) - \frac{2}{\sqrt{\pi}}e^{-tM_1}\right] \\ & +a_2\left[\sqrt{t(M_1+b_2)}\,e^{tb_2}\left(erfc\left(\sqrt{t(M_1+b_2)}\right) - erfc\left(-\sqrt{t(M_1+b_2)}\right)\right) - \frac{2}{\sqrt{\pi}}e^{-tM_1}\right] \\ & +a_1\left[\frac{2}{\sqrt{\pi}}\frac{Pr}{\phi_4}e^{-tS} + \sqrt{\frac{Prt(S+b_1)}{\phi_4}}e^{tb_1}\left(erfc\left(-\sqrt{t(S+b_1)}\right) - erfc\left(\sqrt{t(S+b_1)}\right)\right)\right] \\ & +a_2\left[\frac{2}{\sqrt{\pi}}Sce^{-tR} + \sqrt{Sct(R+b_2)}e^{tb_2}\left(erfc\left(-\sqrt{t(R+b_2)}\right) - erfc\left(\sqrt{t(R+b_2)}\right)\right)\right] \end{aligned} \tag{22}$$

where $\phi_0 = (1-\phi)^{2.5}, \phi_1 = (1-\phi)^{2.5}\left((1-\phi) + \phi\frac{\rho_s}{\rho_f}\right)$ $\phi_2 = \phi_1\left((1-\phi) + \phi\frac{\beta_s}{\beta_f}\right)$

$$\phi_3 = \phi_1\left((1-\phi)+\phi\frac{(\beta_c)_s}{(\beta_c)_f}\right), M_1 = \phi_0 M + \frac{1}{K}, a_1 = -\frac{\phi_4\phi_2 GrCos\alpha}{Pr-\phi_4}, a_2 = -\frac{\phi_3 GrCos\alpha}{Sc-1}$$

$$b_1 = \frac{M_1\phi_4 - SPr}{Pr-\phi_4}, b_2 = \frac{M_1 - ScR}{Sc-1}, \quad \phi_4 = \left(\frac{k_s+2k_f-2\phi(k_f-k_s)}{k_s+2k_f+2\phi(k_f-k_s)}\right)\left(\frac{1}{(1-\phi)+\phi\frac{(\rho C_p)_s}{(\rho C_p)_f}}\right)$$

4. RESULT AND DISCUSSION:

In this paper, the effects of chemical reaction on MHD free convective flow of Nanofluid over an inclined plate embedded in a porous medium which is accelerated exponential with heat and mass transfer in the presence of heat source has been analyzed. The effects of the parameters Gr, Gm, M, K, α, t, Pr, S, R, and Sc on flow characteristics have been studied and shown through plotted graphs and tables. To have physical correlations, we choose suitable values of flow parameters. The graphs of velocities, heat, and mass concentration are taken concerning η, and the values of Skin friction, Nusselt number, and Sherwood Number with different values of flow parameters are shown in tables.

Velocity profiles: The velocity profiles are depicted in Figs 1-5. Figure (1) shows the effect of the parameters K and M on velocity profile at any point of the fluid when Pr = 2, Sc = 2, S = 2, R = 2, Gr = 2, Gm = 2, t = 0.2, and $\alpha = \frac{\pi}{6}$. It is noticed that the velocity decreases with the increase of magnetic parameter (M), whereas increases with the increase of permeability of porous medium (K)

Figure-(2) shows the effect of the parameters Pr and Sc on velocity profile at any point of the fluid when M = 2, K = 2, S = 2, R = 2, Gr = 2, Gm = 2, t = 0.2 and $\alpha = \frac{\pi}{6}$. It is noticed that the velocity increases with the increase of Schmidt number (Sc), whereas decreases with the increase of Prandtl number (Pr).

Figure-(3) shows the effects of the parameters S and R on velocity profile at any point of the fluid when M = 2, K = 2, Pr = 2, Sc = 2, Gr = 2, Gm = 2, t = 0.2 and $\alpha = \frac{\pi}{6}$. It is noticed that the velocity increases with the decrease of the Source parameter (S) and increases with the increase of the chemical parameter (R).

Figure-(4) shows the effects of parameters Gr and Gm on velocity profile at any point of the fluid when M = 2, K = 2, Pr = 2, Sc = 2, R = 2, S = 2, t = 0.2 and $\alpha = \frac{\pi}{6}$. It is noticed that the velocity increases with the increase of Grashof number (Gr) and decreases with the increase of Modified Grashof number (Gm).

Figure-(5) shows the effects of parameters α and t on velocity profile at any point of the fluid when M = 2, K = 2, Pr = 2, Sc = 2, Gr = 2, Gm = 2, S = 2, and R = 2. It is noticed that the velocity decreases with the increase of angle of inclination with vertical (α), whereas initially increases and then decreases with the increase of Time (t).

Heat profile: The Heat profiles are depicted in Fig. (6). Figure-(6) shows the effects of the parameters S, Pr, and t on Heat profile at any point of the fluid in the absence of other parameters. It is noticed that the temperature falls with the increase of Prandtl number (Pr) and Source parameter (S), whereas rises with the increase of Time (t).

Mass concentration profile: The mass concentration profiles are depicted in Fig.-(7). Figure-(7) shows the effects of the parameters Sc, R, and t on mass concentration profile at any point of the fluid in the absence of other parameters. It is noticed that the mass concentration decreases with the increase of Schmidt number (Sc) and chemical parameter (R), whereas increases with the increase of Time (t).

Nusselt Number (Nu): The value of the Nusselt number is depicted in the table-(1), which illustrates the effect of parameters Pr, S, and t in the absence of other parameters. It is noticed that the absolute value of the Nusselt number at plate increases with the increase of Prandtl number (Pr), Source parameter (S), and Time (t).

Sherwood Number (Sh): Table – (2) shows the effect of the parameters R, Sc, and t on values of the Sherwood number. It is observed that the absolute value of Sherwood Number (Sh) increases with the increase of Time (t), Chemical reaction parameter (R), and Schmidt number (Sc).

Skin friction(τ): The value of Skin friction is depicted in Table-(3), which illustrates the effects of the parameters R, S, Pr, Gr, Gm, M, K, Sc, t, and α on Skin friction at the plate. It is noticed that the absolute value of Skin friction at the plate decreases with increases of permeability of porous medium(K), Chemical reaction parameter(R), Grashof number(Gr), and Schmidt number (Sc), whereas increases with the increase of magnetic parameter (M), Source parameter (S), Prandtl number (Pr), angle of inclination (α) and Time (t).

Table-1 for Nusselt number at the plate:

Sl.No	S	Pr	t	Nusselt Number
01	2	2	0.1	0.6523

02	2	2	0.2	1.0343
03	2	2	0.3	1.3442
04	2	4	0.1	0.7524
05	2	6	0.1	0.8161
06	4	2	0.1	1.1221
07	6	2	0.1	1.4804

Table-2 for Sherwood Number at the plate:

Sl.No	R	Sc	t	Sherwood number
01	2	2	0.2	2.3174
02	2	2	0.3	3.3194
03	2	2	0.4	4.2333
04	4	2	0.2	4.1256
05	6	2	0.2	5.5756
06	2	4	0.2	3.2772
07	2	6	0.2	4.0138

Table-3 for Skin friction at the plate:

Sl.No.	R	Sc	S	Pr	Gr	M	K	Gm	t	α	Skin friction
01	2	2	2	2	2	2	2	2	0.2	$\pi/6$	1.2723
02	2	2	2	2	2	2	2	2	0.3	$\pi/6$	3.1646
03	2	2	2	2	2	2	2	2	0.4	$\pi/6$	5.2831
04	2	2	1.5	2	2	2	2	2	0.2	$\pi/6$	1.1797
05	2	2	1	2	2	2	2	2	0.2	$\pi/6$	1.0770
06	1.5	2	2	2	2	2	2	2	0.2	$\pi/6$	1.6239
07	1	2	2	2	2	2	2	2	0.2	$\pi/6$	2.1192
08	2	2	2	2	3	2	2	2	0.2	$\pi/6$	0.7478
09	2	2	2	2	4	2	2	2	0.2	$\pi/6$	0.2232
10	2	2	2	3	2	2	2	2	0.2	$\pi/6$	1.2687
11	2	2	2	4	2	2	2	2	0.2	$\pi/6$	1.2664
12	2	3	2	2	2	2	2	2	0.2	$\pi/6$	0.2039
13	2	4	2	2	2	2	2	2	0.2	$\pi/6$	-0.1244
14	2	2	2	2	2	2	2	2	0.2	$\pi/4$	1.2925
15	2	2	2	2	2	2	2	2	0.2	$\pi/3$	1.3187
16	2	2	2	2	2	3	2	2	0.2	$\pi/6$	2.9188
17	2	2	2	2	2	4	2	2	0.2	$\pi/6$	4.8961
18	2	2	2	2	2	2	3	2	0.2	$\pi/6$	1.0244
19	2	2	2	2	2	2	4	2	0.2	$\pi/6$	0.9029

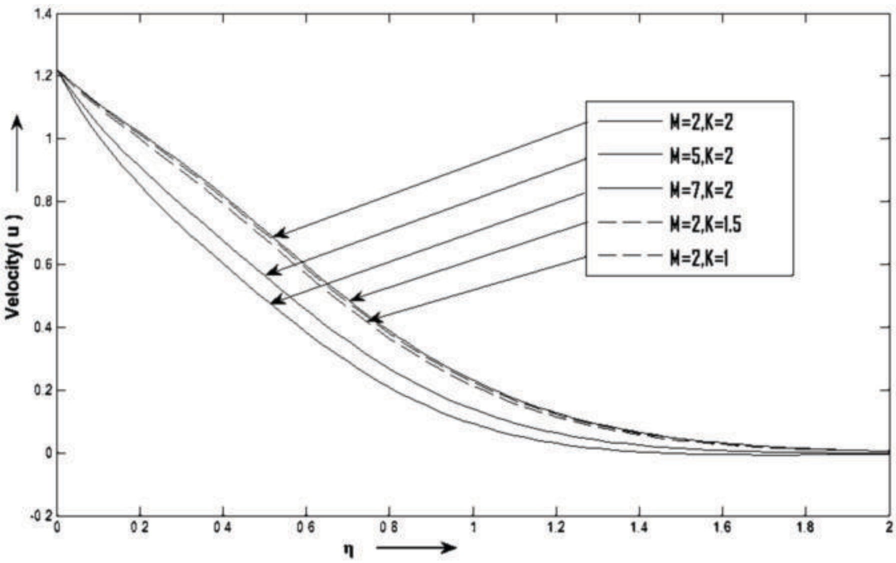

Fig-(1): Effects of M and K on Velocity profile, when Pr = 2, Sc = 2, S = 2, R = 2, Gr = 2, Gm = 2, t = 0.2 and = $\frac{\pi}{6}$.

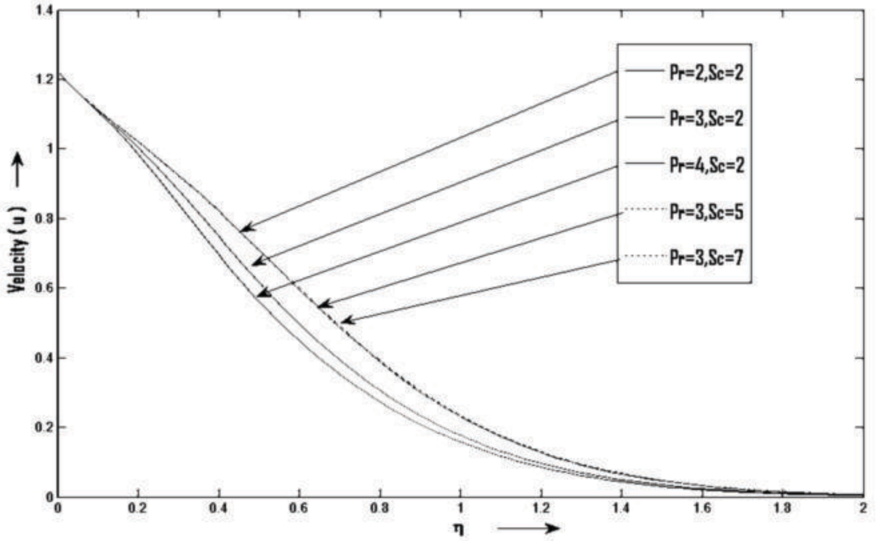

Fig-(2): Effects of Pr and Sc on Velocity profile, when M = 2, K = 2, S = 2, R = 2, Gr = 2, Gm = 2 t = 0.2 and $\alpha = \frac{\pi}{6}$.

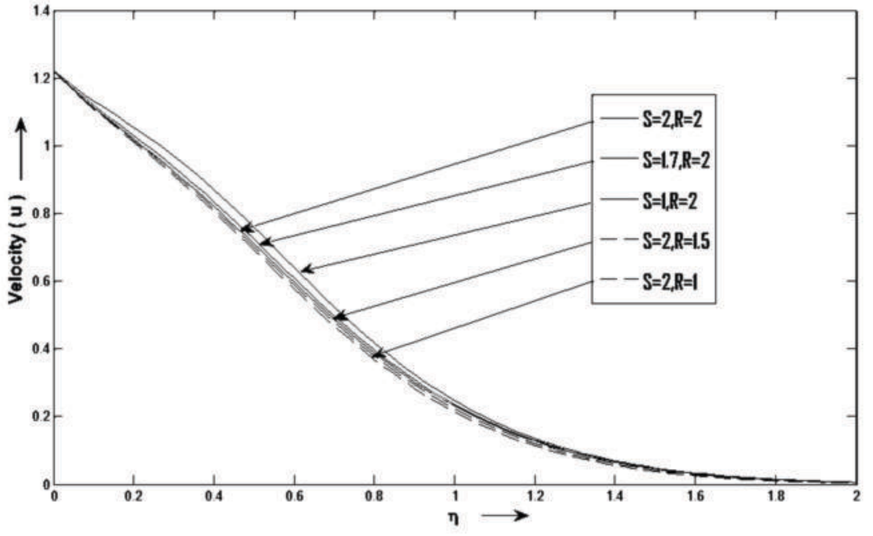

Fig-(3): Effect of S and R on Velocity profile, When M = 2, K = 2, Pr = 2, Sc = 2, Gr = 2, Gm = 2, t = 0.2 and $\alpha = \frac{\pi}{6}$.

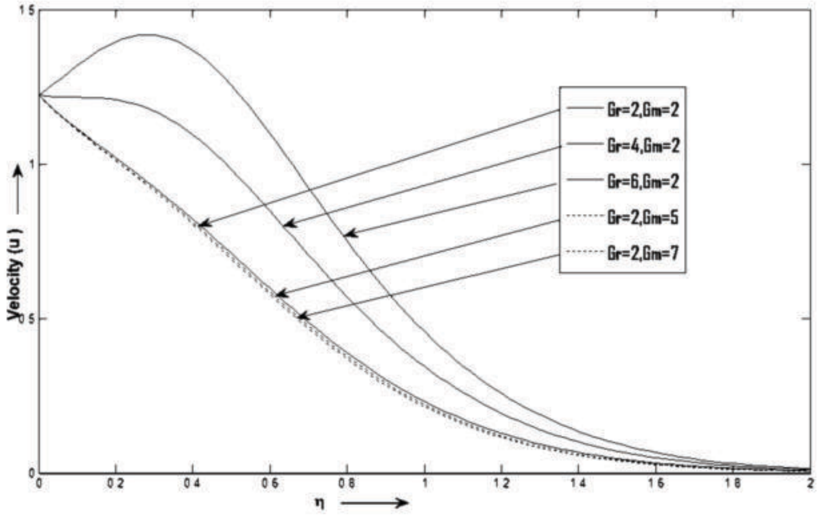

Fig-(4): Effects of Gr and Gm on Velocity profile, when M=2, K=2, Pr=2, Sc=2 R = 2, S = 2, t=0.2 and $\alpha = \frac{\pi}{6}$.

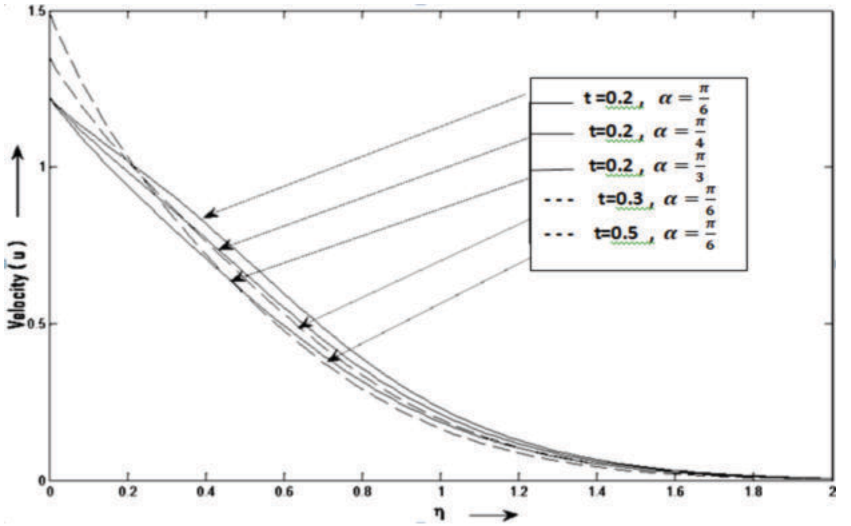

Fig-(5): Effects of t and α on Velocity profile, when M = 2, K=2, Pr=2, Sc=2, Gr=2, Gm=2, S = 2 and R =2.

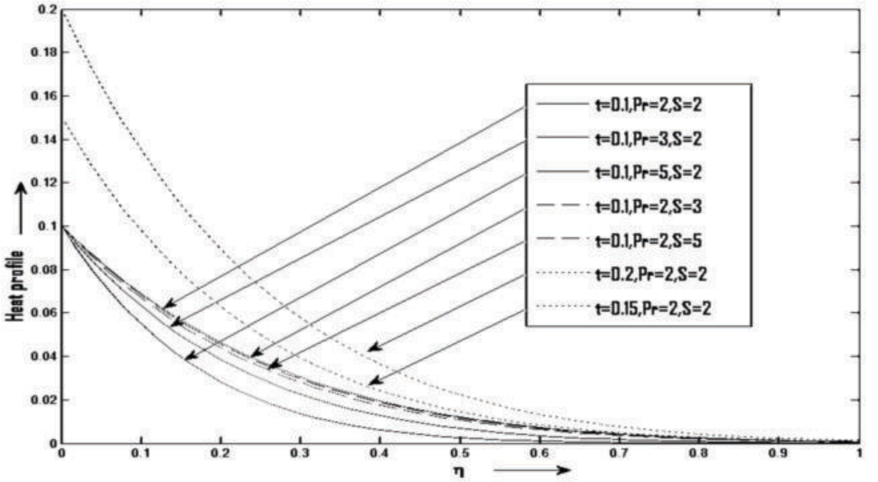

Fig-(6): Effects of t, S, and Pr on Heat profile, when other parameters are absent.

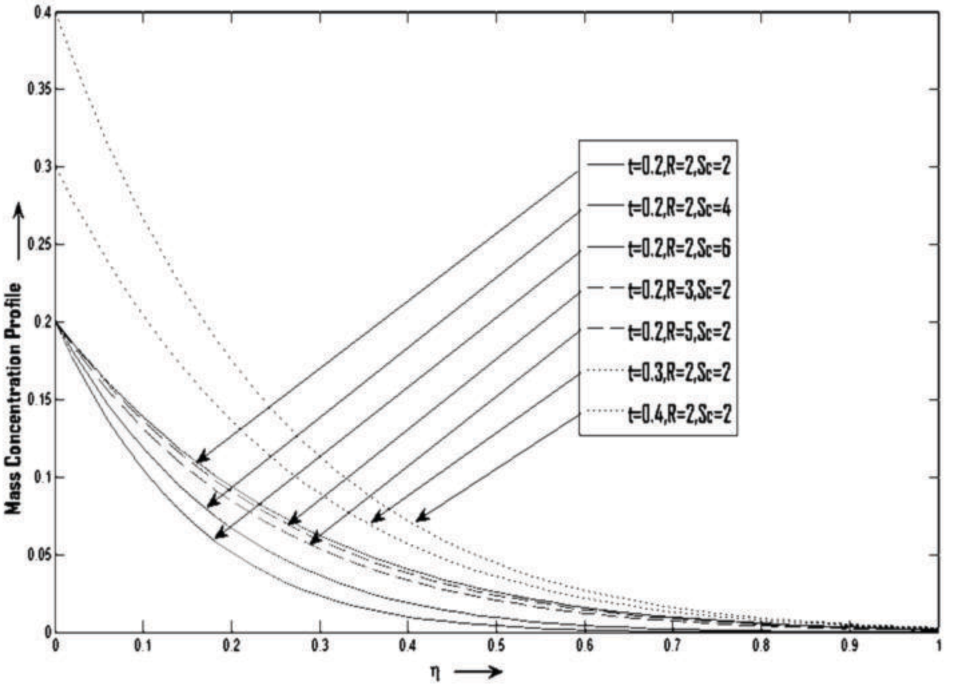

Fig-(7): Effects of t, R, and Sc in Mass concentration profile, when other parameters are absent.

CONCLUSIONS

The following results are obtained in the effect of chemical reaction on MHD free convective flow of Nanofluid over an exponential accelerated inclined plate embedded in a porous medium with heat and mass transfer in the presence of heat source.

(a)The velocity increases with the increase in K, S, Sc, R, Gr, and α, but decreases with the increase of M, Pr, Gm, and t, which indicates that the increase of the size of the pore, heat source, species concentration and angle of inclination allows the flow of nanofluid and velocity to slow down due to the increase of Lorenz force.

(b) Heat rises with the enhancing of the value of S and Pr.

(c) Mass concentration increases with the increase of R and Sc.

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