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ORIGINAL ARTICLE

Chemical reaction and radiation effects on unsteady MHD free convection flow in a porous medium past an infinite inclined isothermal plate

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ABSTRACT – The effect of chemical reaction on unsteady magentohydrodynamic (MHD) free convection flow in a porous medium past an infinite inclined plate has been investigated. Laplace transform technique is the method to solve the solutions for velocity, temperature and concentration fields. The analytical expressions for non-dimensional skin friction, Nusselt number and Sherwood number has been presented. The influence of various embedded parameter on velocity, temperature and concentration such as chemical reaction parameter, magnetic field and radiation has been discussed in detail. The effects of involved parameters have been discussed and the numerical results are presented graphically.

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chemical reaction;
radiation;
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INTRODUCTION

The study of MHD free convection flow problems has attracted many researchers to study about it due to their demand of application in the field such as chemical engineering, solar physics and aeronautics. Free convection flow is usually encountered in cooling of nuclear reactors or in the study of the structure of stars and planets. Thus, Alim et al. [1] attracted to study one of the MHD field which they studied about the effect of MHD natural convection flow along a vertical flat plate with Joule heating and heat conduction. This work transformed the governing boundary layer equations into a non-dimensional form and resulting nonlinear system of partial different equations are then solved numerically by using the implicit finite difference method with Keller box scheme.

(MHD) free convection flows have significant important applications in the field of planetary magneto-sphere, aeronautics and chemical engineering. Many researchers have great attention to the problems of MHD free convection flows with heat and mass transfer through various domains with various domains with various boundary conditions. Ahmad et al. [2] have studied about magnetic field influence on unsteady free convection flow of a second grade fluid near an infinite vertical flat plate with ramped wall temperature embedded in a porous medium. They have stated that the magnitude of velocity and skin friction in case of ramped temperature is quite less than the isothermal temperature. Investigation shows there are two cases that obtained from this work which second grade fluid in the absence of magnetic field and porous medium and Newtonian fluid in the presence of magnetic field that performing the same motion. Siddique et al. [3] take an opportunity to investigate about the unsteady free cpnvection flow, with heat and mass transfer of an electrically conducting viscoelastic fluid, through a porous medium of variable permeability. This study focusing on the half space of flow domain, bounded by a vertical porous plate with the constant heat flux, constant concentration and a rectilinear translation in its plane with constant velocity. The effect of chemical reaction in the fluid flow over a stretching sheet was then continued by Mjankwi et al. [4] where they have studied about the unsteady MHD flow of nanofluid with variable fluid properties over an inclined stretching sheet in the presence of thermal radiation and chemical reaction.

Influence of chemical reaction with heat source under the study of convective flow with heat and mass transfer has become plays an important role in many areas of science and engineering. Chemical reaction effect actually produce qualitative changes to the rate of heat transfer depending on the differentiation of concentration. Rout et al. [5] are motivated to research the influence of chemical reaction and the combined effects of internal heat generation and a convective boundary condition on the laminar boundary layer MHD heat and mass transfer flow over a moving vertical flat plate. They decided to put the lower surface of the plate is in contact with a hot fluid while the stream of cold fluid flows over the upper surface with heat source and chemical reaction. All the analysis has been solved numerically by Runge-Kutta fourth-order integration scheme in association with shooting method. Huge applications in water and air pollutions has using knowledge from the combined free and forced convection flow of an incompressible viscous fluid with simultaneous heat and mass transfer past a vertical plate under the influence of a chemical reaction. Thus, Kumar et al. [6] has analysed the effects of chemical reaction on MHD mixed convection with the stagnation point flow towards a vertical plate embedded in a porous medium with radiation and internal heat generation. The enhanced thermal properties of nanofluids was reported by Nandkeolyar et al. [7]. They was studied about the combined effects of homogenous and

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heterogeneous chemical reactions and heat absorption on the fully developed MHD Newtonian nanofluid flow past a linearly stretching sheet. Sharma et al. [8] are motivated to investigate the influence of chemical reaction and radiation on unsteady MHD free convection flow and mass transfer of a viscous incompressible electrically conducting fluid past a heated vertical porous plate in a porous medium with viscous dissipation effect in the presence of heat source, oscillating free stream and transverse magnetic field.

Recently, MHD heat and mass transfer from different geometry embedded in a porous medium are one of interest for engineering and geographical applications. Hence, Swain et al. [9] has made an attempt to study the MHD flow of a viscous incompressible electrically conducting fluid flow past an exponentially stretching sheet through a porous medium in the presence of transverse magnetic field and thermal radiation in the presence of uniform heat source/sink. Raju et al. [10] are studied about a steady MHD forced convective flow of a flow of viscous fluid of finite depth in a saturated porous medium over a fixed horizontal channel with thermally insulated and impermeable bottom wall in the presence of viscous dissipation and joule heating. Ismail et al. [11] are motivated to study about unsteady MHD free convection flows in a porous medium past an infinite inclined plate with ramped wall temperature with MHD and radiation effects.

Knowledge of radiation heat transfer becomes very important to the industry especially for designing the equipment due to the processes occur at high temperature. the knowledge of radiation caught an attention to Hady et al. [12] to study about flow and heat transfer characteristics of a viscous nanofluid over a nonlinearly stretching sheet in the presence of thermal radiation, included in the energy equation and variable wall temperature. Rani et al. [13] have studied about radiation and mass transfer effects on MHD flow through porous medium past and exponentially accelerated inclined plate with variable temperature.

In recent years, knowledge of radiation heat transfer becomes very important to the industry especially for designing the equipment due to the processes occur at high temperature. Investigation about the radiation effects were continued by Balla et al. [14] where they made a numerical analysis study about the unsteady natural convection flow of viscous, incompressible, Newtonian fluid past an impulsively started semi-infinite vertical plate with variable temperature and mass diffusion under the influence of applied magnetic field, first order chemical reaction, radiation and viscous dissipation. Yao et al. [15]has made an interesting study where they studied about the forced convective heat transfer due to a non-Newtonian fluid flowing past a flat plate using a modified power-law viscosity model.

Motivated by the previous work, the aim of the present work is to study the chemical reaction effects on unsteady MHD free convection flow past an infinite inclined isothermal plate with ramped wall temperature. The problem has not been studied before despite its application in many engineering processes. The governing partial differential equations are transform to ordinary differential equations in such way that the system found the Reynolds number and Peclet's number in the energy equation. The exact solution is obtained by using Laplace transform technique for velocity, temperature and concentration fields. All the solutions obtained from the derivation satisfy all the imposed initial boundary conditions.

DESCRIPTION OF THE PROBLEM

Consider the unsteady MHD free convection flow of an incompressible viscous, electrically conducting heat fluid near an infinite inclined plate embedded in a saturated porous medium. We introduced a coordinate system plate with x *-axis along to the plate with an inclination angle ϕ to the vertical plate, the y *-plane. A uniform transverse magnetic field of strength B_0 is applied with the assumption of the plate to be electrically conducting. The chemical reaction effect are taken into account. Initially, at time $t^* \leq 0$, the plate and the fluid are at rest with the same temperature T_∞^* and concentration C_∞^*. At time $t^* > t_0$, both plate of temperature and concentration is raised to constant temperature T_w^* and constant concentration C_w^* while when $t^* > 0$, both plate of temperature and concentration are approaching to zero. The flow is assumed laminar and the effects of the convective and pressure gradient terms in the momentum, energy and concentration equations are neglected. As a result of the boundary layer approximations, the physical variables become functions of the time t^* and the space y^* only. The free convective flow past an inclined plate are under Boussinesq approximation, governed by the equations

$$\frac{\partial u^*}{\partial t^*} = v\frac{\partial^2 u^*}{\partial y^{*2}} - \frac{\sigma B_0^2}{\rho}u^* - \frac{v}{K^*}u^* + g\beta_T \cos\phi(T^* - T_\infty^*) + g\beta_C \cos\phi(C^* - C_\infty^*) \tag{1}$$

$$\frac{\partial T^*}{\partial t^*} = \frac{k}{\rho c_p}\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial y} \tag{2}$$

$$\frac{\partial C^*}{\partial t^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} - K_r(C^* - C_\infty^*) \tag{3}$$

with the following appropriate boundary conditions:

$$\begin{array}{llll} u^* = 0, & T^* = T_\infty^*, & C^* = C_\infty^* & \text{for } y^* \geq 0 \text{ and } t^* \leq 0 \\ u^* = 0, & T^* = T_w^*, & C^* = C_w^* & \text{for } y^* = 0 \text{ and } t^* > t_0 \\ u^* \to 0, & T^* \to 0, & C^* \to 0 & \text{for } y^* \to \infty \text{ and } t^* > 0 \end{array} \tag{4}$$

where u^*, T^*, C^* represent velocity, temperature and concentration respectively, ν is kinematic viscosity, σ is the electrical conductivity ρ is the fluid density, $K^* > 0$ is the permeability of the porous medium, β_T and β_C are the thermal expansion and concentration expansion, k is the thermal conductivity , c_p is the specific heat, q_r is the radiative heat flux, D is the mass diffusion and K_r is the chemical reaction parameter. According to the governing equations, temperature of the plates, T_∞^* and T_w^*, is assumed to produced radiative heat flux term and simplified by using Rosseland approximation is given by

$$\frac{\partial q_r}{\partial y} = -\frac{4\sigma^*}{3K^*}\frac{\partial T^{*4}}{\partial y^*} \tag{5}$$

where σ^* is Stefan-Boltzmann constant and K^* is the mean absorption coefficient. We assume that the temperature differences within the flow are sufficiently small such that T^{*4} may be expressed as a linear function of the temperature. Using Taylor series by expanding T^{*4} about T_∞^* and neglecting higher-order terms, thus

$$T^{*4} \cong 4T_\infty^* T - 3T_\infty^4 \tag{6}$$

Then, Rosseland approximation become,

$$\frac{\partial q_r}{\partial y} = -\frac{16\sigma^*}{3K^*}\frac{\partial^2 T^{*4}}{\partial y^{*2}} \tag{7}$$

Introducing the dimensionless variable as follow:

$$y = \frac{y^*}{L},\ t = \frac{t^*(vg)^{1/3}}{L},\ u = \frac{u^*}{(vg)^{1/3}},\ T = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*},\ C = \frac{C^* - C_\infty^*}{C_w^* - C_\infty^*}. \tag{8}$$

Using dimensionless variables in equation (8), equations (1), (2) and (3) can be expressed as:

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} - Mu - \frac{u}{K} + GrT\cos\phi + GcC\cos\phi \tag{9}$$

$$\frac{\partial T}{\partial t} = \frac{(1+R)}{Pe}\frac{\partial^2 T}{\partial y^2} \tag{10}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Pe_c}\frac{\partial^2 C}{\partial y^2} - KrC \tag{11}$$

where

$$\begin{gathered} M = \frac{\sigma B_0^2 L^2}{\rho v},\ K = \frac{K^*}{L^2},\ Gr = \frac{g^{1/3}\beta_T(T_w^* - T_\infty^*)L}{v^{2/3}},\ Gc = \frac{g^{1/3}\beta_C(C_w^* - C_\infty^*)L}{v^{2/3}}, \\ R = \frac{16\alpha\sigma^* T_\infty^* L^2}{k},\ Pe = \operatorname{Re}\Pr,\ Pe_c = \operatorname{Re}Sc. \end{gathered} \tag{12}$$

Here, M is magnetic parameter known as Hartmann number, K is the porosity parameter, Gr is the thermal Grasof number, Gc is the mass Grasof number, R is radiation parameter Pe known as Peclet's number of mass transfer, Pe_c

is known as Peclet's number of concentration, Re is Reynold number, Pr is Prandtl number and Sc is Schmidt number. According to the above non-dimensionalisation process, the characteristic length can be defined as:

$$L=\frac{v^{2/3}}{g^{1/3}} \tag{13}$$

The dimensionless initial and boundary conditions given by Equation 4 now become:

$$\begin{aligned} &u=0\,, \quad T=0\,, \quad C=0 \quad \text{for } y\geq 0 \text{ and } t\leq 0 \\ &u=0\,, \quad T=1\,, \quad C=1 \quad \text{for } y=0 \text{ and } t\geq 0 \\ &u\to 0\,, \quad T\to 0\,, \quad C\to 0 \quad \text{for } y\to\infty \text{ and } t>0 \end{aligned} \tag{14}$$

SOLUTION OF THE PROBLEM

The energy and concentration equations is uncoupled from the momentum. Hence, the temperature variable $T(y,t)$ and concentration variable $C(y,t)$ can be solved where the solution $u(y,t)$ can be achieved. In order to solve the equations, we are apply inverse Laplace transform to Equation (9), (10) and (11) with respect to t with the present of dimensionless variables in Equation (12) and solving the result from different equations, we obtained:

$$\overline{T}=\frac{1}{s}e^{-y\sqrt{\frac{s(Pe_m)}{1+R}}} \tag{15}$$

$$\overline{C}=\frac{1}{s}e^{-y\sqrt{Pe_c(Kr+s)}} \tag{16}$$

$$\begin{aligned} \overline{u}=a_1\left[\frac{1}{a_2(s-a_2)}-\frac{1}{a_2 s}\right]e^{-y\sqrt{\frac{s(\mathrm{Re}\,\mathrm{Pr})}{(1+R)}}}+a_3\left[\frac{1}{a_4(s-a_4)}-\frac{1}{a_4 s}\right]e^{-y\sqrt{(Kr+s)\mathrm{Re}\,Sc}} \\ a_1\left[\frac{1}{a_2(s-a_2)}-\frac{1}{a_2 s}\right]e^{-y\sqrt{\lambda+s}}-a_3\left[\frac{1}{a_4(s-a_4)}-\frac{1}{a_4 s}\right]e^{-y\sqrt{\lambda+s}} \end{aligned} \tag{17}$$

where

$$a_1=\frac{-Gr\cos\phi}{(\frac{Pe}{1+R}-1)},\quad a_2=\frac{\lambda(1+R)}{Pe-1},\quad a_3=\frac{-Gc\cos\phi}{(1-\mathrm{Re}\,Sc)}. \tag{18}$$

The exact solution for the temperature, concentration and velocity are obtained from equations (15), (16) and (17) by using inverse Laplace transform. These solution are:

$$T=erfc(\frac{y}{2}\sqrt{\frac{\theta}{t}}) \tag{19}$$

$$C=\frac{1}{2}\left[\begin{aligned} &e^{y\sqrt{\mathrm{Re}\,ScKr}}erfc(\frac{y}{2}\sqrt{\frac{\mathrm{Re}\,Sc}{t}})+\sqrt{Krt} \\ &+e^{-y\sqrt{\mathrm{Re}\,ScKr}}erfc(\frac{y}{2}\sqrt{\frac{\mathrm{Re}\,Sc}{t}}-\sqrt{Krt}\,) \end{aligned}\right] \tag{20}$$

$$u=u_1+u_2+u_3-u_4+u_5+u_6+u_7-u_8, \tag{21}$$

where

$$u_1(y,t)=\frac{a_1e^{a_2t}}{2a_2}\left[e^{y\sqrt{\theta a_2}}erfc(\frac{y}{2}\sqrt{\frac{\theta}{t}}+\sqrt{a_2t})+e^{-y\sqrt{\theta a_2}}erfc(\frac{y}{2}\sqrt{\frac{\theta}{t}}-\sqrt{a_2t})\right]$$

$$u_2(y,t)=\frac{a_1}{a_2}erfc(\frac{y}{2}\sqrt{\frac{\mathrm{Pr}}{t}})$$

$$u_3(y,t)=\frac{a_3e^{a_4t}}{2a_4}\left[e^{y\sqrt{Pe_m(Kr+a_4)}}erfc(\frac{y}{2}\sqrt{\frac{Pe_m}{t}}+\sqrt{(Kr+a_4)t})+e^{-y\sqrt{Pe_m(Kr+a_4)}}erfc(\frac{y}{2}\sqrt{\frac{Pe_m}{t}}-\sqrt{(Kr+a_4)t})\right]$$

$$u_4(y,t)=\frac{a_3}{2a_4}\left[e^{y\sqrt{Pe_mKr}}erfc(\frac{y}{2}\sqrt{\frac{Pe_m}{t}}+\sqrt{Krt})+e^{-y\sqrt{Pe_mKr}}erfc(\frac{y}{2}\sqrt{\frac{Pe_m}{t}}-\sqrt{Krt})\right]$$

$$u_5(y,t)=\frac{a_1e^{a_2t}}{2a_2}\left[e^{y\sqrt{\lambda+a_4)}}erfc(\frac{y}{2\sqrt{t}}+\sqrt{(\lambda+a_2)t})+e^{-y\sqrt{\lambda+a_2}}erfc(-\frac{y}{2\sqrt{t}}-\sqrt{(\lambda+a_2)t})\right]$$

$$u_6(y,t)=\frac{a_1}{2a_2}\left[e^{y\sqrt{\lambda)}}erfc(\frac{y}{2\sqrt{t}}+\sqrt{\lambda t})+e^{-y\sqrt{\lambda}}erfc(\frac{y}{2\sqrt{t}}-\sqrt{\lambda t})\right]$$

$$u_7(y,t)=\frac{a_3e^{a_4t}}{2a_4}\left[e^{y\sqrt{\lambda+a_4)}}erfc(\frac{y}{2\sqrt{t}}+\sqrt{(\lambda+a_4)t})+e^{-y\sqrt{\lambda+a_4)}}erfc(-\frac{y}{2\sqrt{t}}-\sqrt{(\lambda+a_4)t})\right]$$

$$u_8(y,t)=\frac{a_3}{2a_4}\left[e^{y\sqrt{\lambda}}erfc(\frac{y}{2\sqrt{t}}+\sqrt{\lambda t})+e^{-y\sqrt{\lambda}}erfc(\frac{y}{2\sqrt{t}}-\sqrt{\lambda t})\right]$$

$erfc(x)$ being the complimentary error function defined by $erfc(x)=1-erf(x)$, where $erf(x)\frac{2}{\sqrt{n}}\int_0^x e^{-\eta^2}d\eta$.

SKIN FRICTION, NUSSELT NUMBER AND SHERWOOD NUMBER

The expression of Nusselt number:

$$Nu=\frac{\sqrt{\frac{Pe}{\pi(1+R)}}}{\sqrt{t}} \tag{22}$$

The expression of Sherwood number:

$$Sh=\frac{e^{-Krt}\sqrt{Pe}}{\sqrt{\pi t}}-\sqrt{KrPe}Erf(\sqrt{Krt}) \tag{23}$$

The expression of skin-friction:

$$\begin{aligned}\tau = K\cos\phi[&(\frac{Gr(-1+\Pr\mathrm{Re}\sqrt{(\frac{1}{K}+M)t}Erf[\sqrt{\frac{1}{K}}+M\sqrt{t}}{(1+KM)(1+R-\Pr\mathrm{Re})\sqrt{t}})+\\ &\frac{\begin{aligned}&(e^{\frac{(1+KM)(1+R)t}{K(-1+\Pr\mathrm{Re})}}Gr(-1+\Pr\mathrm{Re})(\sqrt{\frac{(1+KM)\Pr\mathrm{Re}}{K(-1+\Pr\mathrm{Re})}}\\ &Erf[\sqrt{\frac{(1+KM)(R+\Pr\mathrm{Re})t}{K(-1+\Pr\mathrm{Re})}}]-\sqrt{\frac{(1+KM)(R+\Pr\mathrm{Re})t}{K(-1+\Pr\mathrm{Re})}}\\ &Erf[\sqrt{\frac{(1+KM)(R+\Pr\mathrm{Re})t}{K(-1+\Pr\mathrm{Re})}}])\end{aligned}}{((1+KM)(1+R-\Pr\mathrm{Re}))})\\ &\frac{\begin{aligned}&(-2Gc\sqrt{Kr\Pr\mathrm{Re}}Erf[\sqrt{Krt}]+2e^{\frac{(1+KM-KKr\mathrm{Re}Sc)t}{K(-1+\mathrm{Re}Sc)}}Gc\sqrt{\frac{(1-KKr+KM)\Pr\mathrm{Re}}{K(-1+\mathrm{Re}Sc)}}\\ &Erf[\sqrt{\frac{t-KKrt+KMt}{-K+K\mathrm{Re}Sc}}])\end{aligned}}{(1+K(M-Kr\mathrm{Re}Sc))}\end{aligned} \tag{24}$$

The numerical values of skin friction, Nusselt number and Sherwood number are presented in Table 1, Table 2 and Table 3 From Table 1, it is observe that skin-friction had an increment with the increasing of ϕ, M, t and $\Pr$ values whereas skin-friction decreased with the increasing of K, R, Gr, Gc, Kr and Sc values.We can see from Table 2, Nusselt number is increasing with the increasing value of Pe, whereas Nusselt number decreases with increasing of R and t values. On the other hand, Table 3 shows the numerical result of Sherwood number where we can see that Sherwood number is increase when t value is increase. Conversely, the decreasing of Sherwood number is caused by the increasing of Pe_c and Kr values.

GRAPHICAL RESULTS AND DISCUSSION

The effect of chemical reaction on unsteady MHD free convection flow in a porous medium past an infinite inclined plate has been investigate. The influence of various embedded parameter on velocity, temperature and concentration such as chemical reaction parameter, magnetic field and radiation has been analysed.

Figure 1 display the influence of magnetic parameter M on velocity profile. It is observed that the velocity decreased with increasing the values of magnetic parameter. The application of transverse magnetic field will resulting a resistive type of force named Lorentz force. Basically, Lorentz force tends to resist the fluid flow, thus velocity is reduced.

The profiles for velocity at various chemical reaction parameter Kr are shown in Figure 2. We observed that the velocity profiles is increase with an increasing of chemical reaction parameter. The effect of hydrodynamic and the concentration is boundary layer become thin as the chemical reaction parameter increase.

The temperature profiles for different value of Pe are shown in Figure 3. It is observed that the temperature decreased with an increasing of Pe and we can see the uniform temperature distribution across the thermal boundary layer. This may be explained by the fact when lower value Peclet number are equivalent to increasing thermal conductivity. In addition, Peclet number is defined as the fluid motion ratio of heat transfer by thermal conduction. Therefore, heat is able to diffuse away from the heated surface more rapidly with greater value of Peclet number.

Figure 4 shows the concentration profiles at various value of Peclet's number of concentration, Pe_c. The trend of distribution shows the decreasing of concentration profile with an increasing of Pe_c number. In fact, Pe_c number is defined as the ratio of kinematic viscosity towards mass diffusivity.

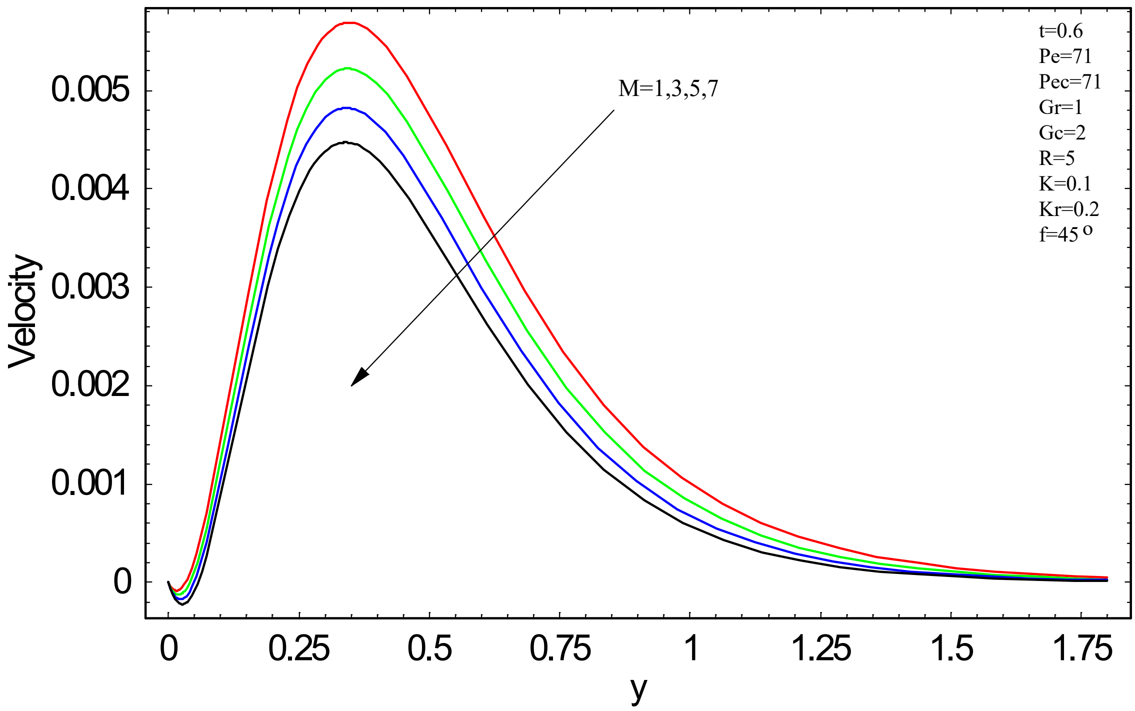

Figure 1. The influence of magnetic field on velocity profiles.

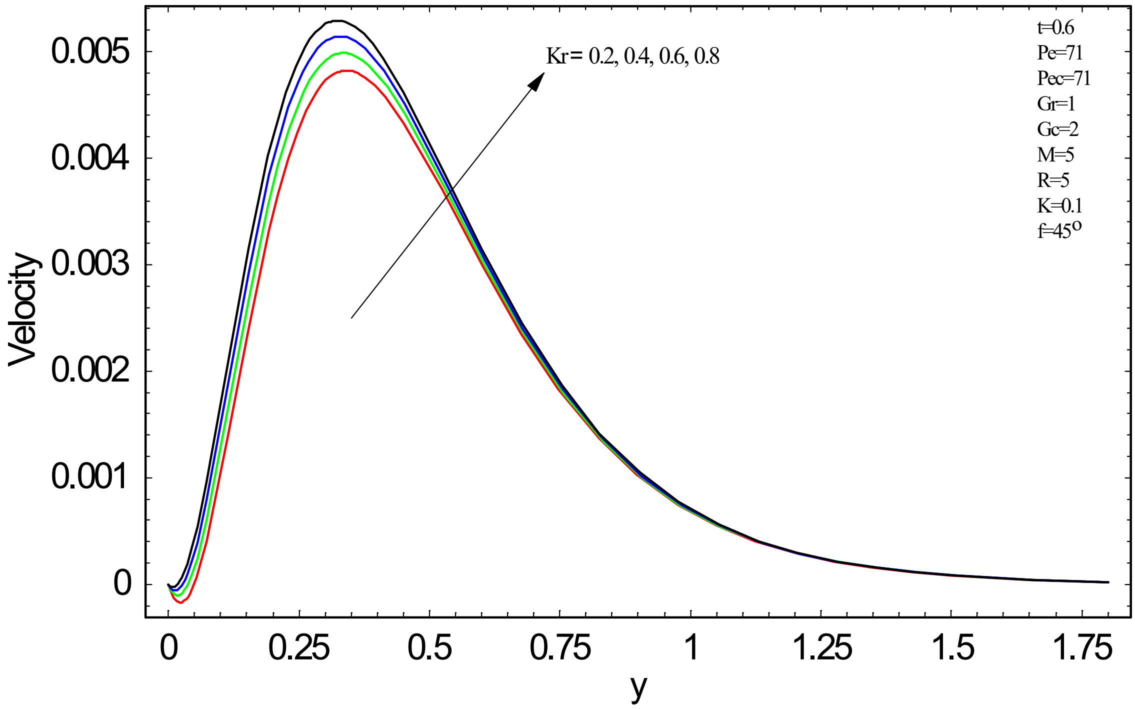

Figure 2. The influence of chemical reaction on velocity profiles.

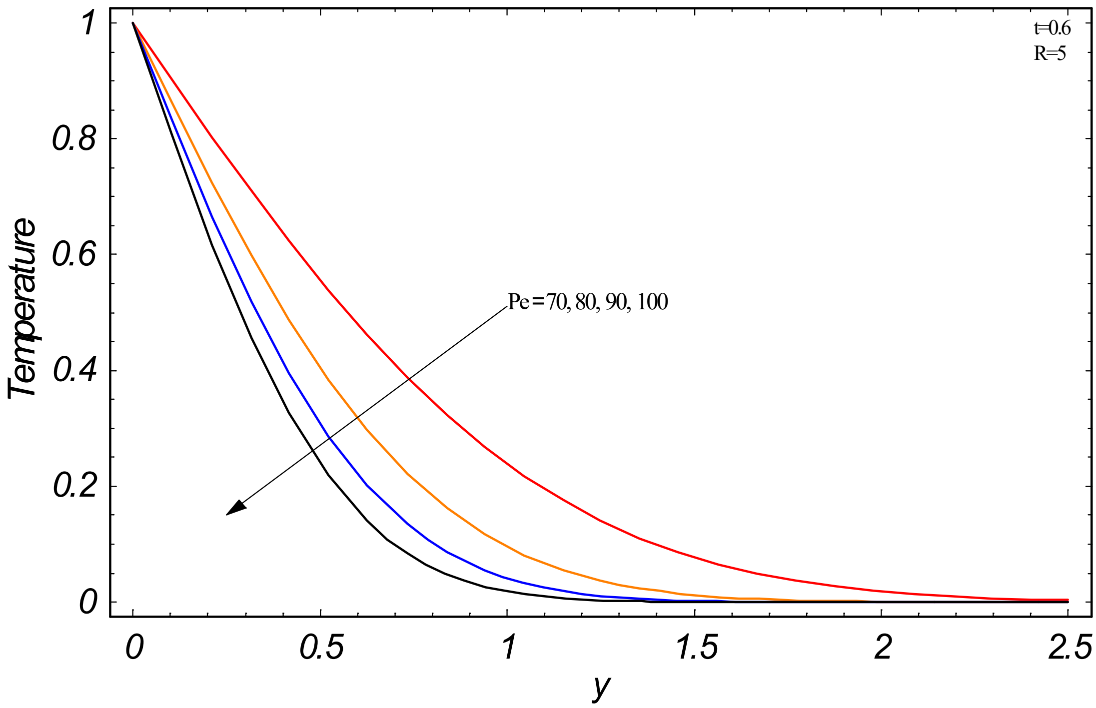

Figure 3. The influence of Peclet's number of mass on temperature profiles.

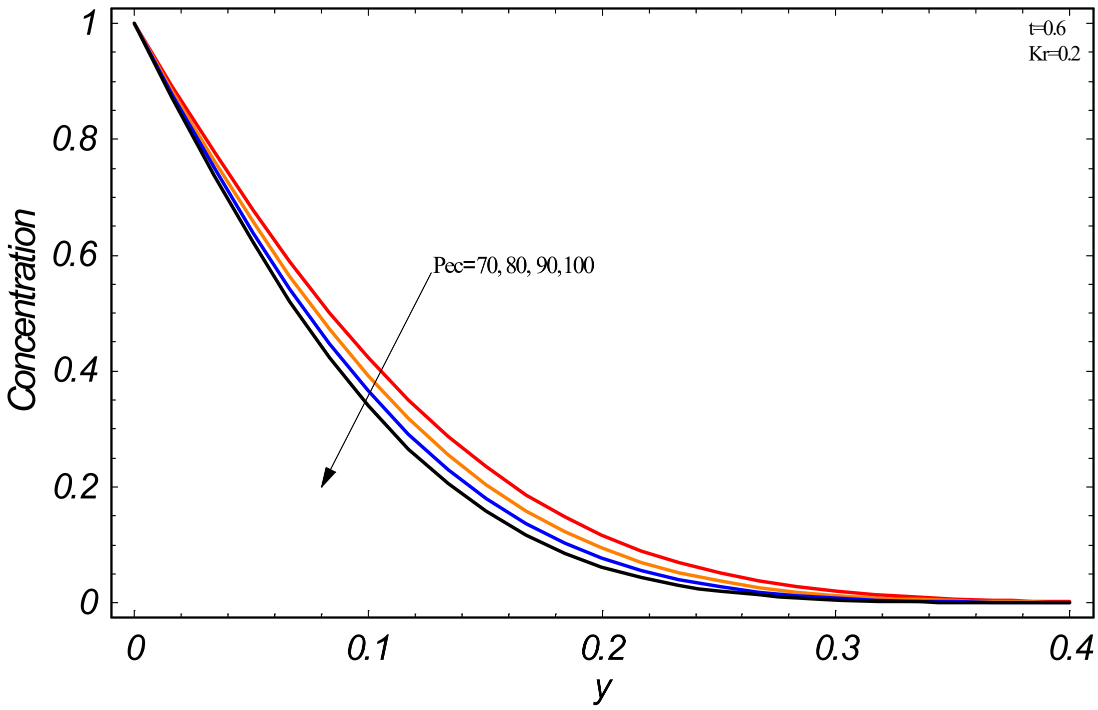

Figure 4. The influence of Peclet's number of concentration on concentration profiles.

Table 1. Nusselt number.

Pe	R	t	Nu
70	3	0.1	7.46353
80	3	0.1	7.97885
80	4	0.1	7.1365
80	4	0.2	5.04627

Table 2. Sherwood number.

Pe_c	Kr	t	Sh
70	0.2	0.1	-0.15225
80	0.2	0.1	-16.2758
80	0.5	0.1	-16.749
80	0.5	0.2	-12.3937

Table 3. Skin-Friction

ϕ	K	M	t	R	Gr	Gc	Pr	Re	Kr	Sc	τ
15	0.3	1	0.1	3	1	1	0.7	100	0.2	0.7	-0.0146799
30	0.3	1	0.1	3	1	1	0.7	100	0.2	0.7	0.00298069
30	0.4	1	0.1	3	1	1	0.7	100	0.2	0.7	0.00291725
30	0.4	3	0.1	3	1	1	0.7	100	0.2	0.7	0.00306771
30	0.4	3	0.2	3	1	1	0.7	100	0.2	0.7	0.0047529
30	0.4	3	0.2	4	1	1	0.7	100	0.2	0.7	0.00355464
30	0.4	3	0.2	4	2	1	0.7	100	0.2	0.7	-0.0117088
30	0.4	3	0.2	4	2	1.2	0.7	100	0.2	0.7	-0.0079452
30	0.4	3	0.2	4	2	1.2	0.8	100	0.2	0.7	-0.0049367
30	0.4	3	0.2	4	2	1.2	0.8	100	0.4	0.7	-0.0052630
30	0.4	3	0.2	4	2	1.2	0.8	100	0.4	0.8	-0.0083029

Effect of inclination angle, permeability parameter, magnetic field parameter, time, radiation, thermal Grashof number, concentration Grashof number, Prandtl number, Reynolds number, chemical reaction parameter and Schmidt number on skin-friction, Nusselt number and Sherwoof number are presented in tables.

The numerical values of skin friction, Nusselt number and Sherwood number are presented in Table 1, Table 2 and Table 3. From Table 1, it is observe that skin-friction had an increment with the increasing of ϕ, M, t and $\Pr$ values whereas skin-friction decreased with the increasing of K, R, Gr, Gc, Kr and Sc values.

We can see from Table 2, Nusselt number is increasing with the increasing value of Pe, whereas Nusselt number decreases with increasing of R and t values. On the other hand, Table 3 shows the numerical result of Sherwood number where we can see that Sherwood number is increase when t value is increase. Conversely, the decreasing of Sherwood number is caused by the increasing of Pe_c and Kr values.

CONCLUSION

The effect of chemical reaction on unsteady magentohydrodynamic (MHD) free convection flow in a porous medium past an infinite inclined plate has been investigate. The governing equation are solve analytically by using Laplace transform technique. The result of various parameter embedded on velocity, temeparture and concentration are plotted graphically whereas skin-friction, Nusselt number and Sherwood number are shown in tables. These are the following conclusion made:

1) The velocity decreased with increasing the values of magnetic parameter. The application of transverse magnetic field will resulting a resistive type of force named Lorentz force.
2) The velocity profiles increase with an increasing of chemical reaction parameter.
3) It is observed that the temperature decreased with an increasing of Pe.
4) The decreasing of concentration profile is due to the increasing value of Schmidt number.
5) Skin-friction had an increment with the increasing of ϕ, M, t and $\Pr$ values whereas skin-friction decreased with the increasing of K, R, Gr, Gc, Kr and Sc values.
6) Nusselt number is increasing with the increasing value of Pe, whereas Nusselt number decreases with increasing of R and t values.
7) Sherwood number is increase when t value is increase. Conversely, the decreasing of Sherwood number is caused by the increasing of Pe_c and Kr values.

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