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RESEARCH ARTICLE

SLIP EFFECT ON MHD OSCILLATORY FLOW OF FLUID IN A POROUS MEDIUM WITH HEAT AND MASS TRANSFER AND CHEMICAL REACTION

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ABSTRACT

The slip effect on MHD oscillatory flow of fluid in a porous channel with heat and mass transfer and chemical reaction has been studied. The temperature prescribed at plates is uniform and asymmetric. A closed form analytical method is employed to solve the momentum and energy equations. The skin frictions, the Nusselt numbers and Sherwood numbers are evaluated using perturbation technique. The effects of various dimensionless parameters on velocity and temperature profiles are considered and discussed in details through graphs and tables. It is found that, the velocity u increases with decrease in Gr, Gc, and increase in Re, Sc and K_c. The velocity also increases with decrease in Ha and ω. It is also observed that the temperature θ decreases with increase in $N, Re,$ and ω. Increase in Schmidt number Sc, chemical parameter K_c and frequency of oscillation ω increase the species concentration or the concentration boundary layer thickness of the flow field.

INTRODUCTION

The slip effect on MHD oscillatory flow of fluid in a porous channel with heat and mass transfer and chemical reaction has applications in the fields of engineering, geophysics, agriculture etc. These applications are geothermal reservoirs, thermal insulation, oil recovery, cooling of nuclear reactor. Many chemical engineering processes like polymer extrusion processes involve cooling of a molten liquid being stretched into a cooling system. In this cooling system, better electromagnetic properties are normally used as cooling liquid as their flow can be regulated by external magnetic fields in order to improve the quality of the final product. Oscillatory flow is a periodic flow that oscillates around a zero value. Oscillatory flow is always important for it has many practical applications for example in the aerodynamics of helicopter rotor or in fluttering airfoil and also in a variety of bio – engineering problems.

Flows through porous media are frequently used in filtering gasses, liquid and drying of bulk materials. This also play an important role in human body particularly the breathing and discharge of excretes through porous skin. In the field of agricultural engineering, porous media heat transfer plays an important role in germination of seed. A chemical reaction in this paper involves in the breaking of bonds in the reactive substances and formulation of bonds to form different products. Several researches have studied and have related literatures on the slip effect on unsteady MHD oscillatory flow of fluid in a porous channel with heat and mass transfer and chemical reaction.

Das et al (2012) analyzed the effect radiative heat and mass transfer on unsteady natural convection coquette flow of a viscous incompressible fluid through a porous medium in the slip flow regime in the presence of suction and radiative source.
The Effect of slip condition on unsteady MHD oscillatory flow in a channel filled with porous medium in the presence of transverse magnetic field and radiative heat and mass transfer is studied by Nityananda Senapati and Rajendra Kumar Dhal (2013). Makinde and Mhone (2005) investigated the combine effect of transvers magnetic field and radiative transfer to unsteady flow of a conducting optically thin fluid through a channel filled with saturated porous medium and non – uniform walls temperature. Aruna Kumari B. et al (2012) studied the slip effects on MHD oscillatory flow of Jeffrey fluid in a channel with heat transfer.

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Radiation and heat transfer effects on a MHD non – Newtonian unsteadyflow in a porous medium with slip conditions are investigated by Gbadeyan and Dada (2013). The fluid is assumed not to absorb its own emitted radiation but that of the boundaries. Sekhar et al (2012) studied the unsteady MHD mixed convective oscillatory flow of an electrically conducting optically thin fluid flow though a panar channel filled with saturated porous medium. The effect of buoyancy, heat source, thermal radiation and chemical reaction are taken into account embedded with slip boundary condition, varying temperature and concentration. The combine effect of a transverse magnetic field and rdiative heat transfer to unsteady flow of a conducting optically third order fluid through a channel filled with saturated porous medium and non – uniform temperature is investigated by Hala Kahtanhamdi and Ahmed M. Abdulhadi (2012).

An analysis of first order homogeneous chemical reaction and heat source on MHD oscillatory flow of visco – elastic fluid through a channel filled with saturated porous medium are reported by Devika et al (2013). Gital and Abdulhameed (2013) studied mixed convection flow for unsteady oscillatory MHD second grade fluid in a porous channel with heat generation. It is assumed that the walls of the channel are porous so that the injection/suction may take place. Umavathi et al (2009) studied the problem of unsteady oscillatory flow and heat transfer in a horizontal composite porous medium. The flow is modeled using the Darcy – Brinkman equation. This present paper studied the slip the slip effect on MHD oscillatory flow of fluid in a porous medium with heat and mass transfer and chemical reaction. The temperatures prescribed at the plates are uniform and asymmetric.

Problem formulation

Consider the flow of a conducting optically thin fluid in a channel filled with saturated porous medium under the influence of an externally applied homogeneous magnetic and radiative heat transfer as shown in figure 1 below

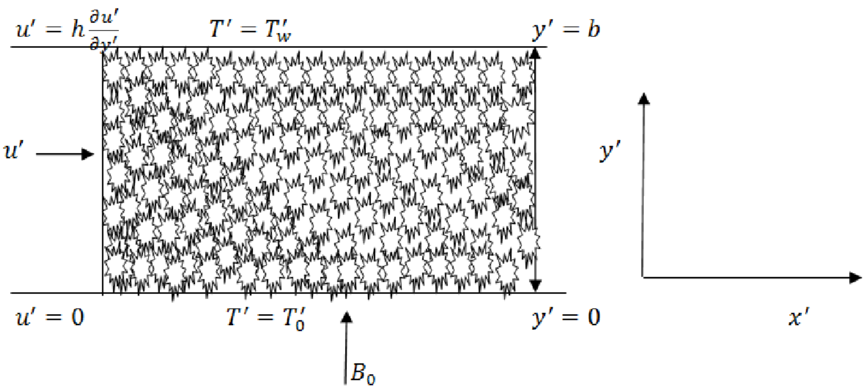

Figure 1. Configuration of the system.

Assumed that the fluid is electrically conductivity and the electromagnetic force produced is very small. Take a Cartesian coordinate system (x', y') where y' is the distance measured in the normal section. Then, assuming a Boussinesq approximation, the equations governing the motion are given as

$$\frac{\partial u'}{\partial t'} = -\frac{1}{\rho}\frac{\partial p}{\partial x'} + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\nu u'}{K} - \frac{\sigma B_0 u'}{\rho} + g\beta(T' - T'_0) + g\beta'(C' - C'_0) \qquad (1)$$

$$\frac{\partial T'}{\partial t'} = \frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho c_p}\frac{\partial q}{\partial y'} \qquad (2)$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} - K'_c(C' - C'_0) \qquad (3)$$

The q in (2) is the radiative heat flux. It is given by

$$\frac{\partial q}{\partial y'} = 4\alpha^2(T'_0 - T'_w) \qquad (4)$$

Where, u' is the axial velocity, T' is the fluid temperature, ρ is the fluid density, B_0 is the magnetic field strength, σ is the conductivity of the fluid, g is the acceleration due to gravity, ν is the kinematic viscosity, β is the coefficient of volume expansion due to temperature, β' is the coefficient of volume expansion due to species concentration, c_p is the specific heat at constant pressure, k is the thermal conductivity, K is the permeability coefficient of the porous medium, D is the mass diffusion coefficient and K_c is the chemical reaction parameter.
The boundary conditions are given by

$$u' = h'\frac{\partial u'}{\partial y'}, \quad T' = T'_w, \quad C' = C'_w \quad at\ y' = b,$$

$$u' = 0, \quad T' = T'_0, \quad C' = C'_0 \quad at\ y' = 0, \quad (5)$$

In order to write the governing equations and the relevant boundary conditions in non – dimensional form, the following dimensionless quantities are introduced

$$x = \frac{x'}{b}, \quad y = \frac{y'}{b}, \quad u = \frac{u'}{U_0}, \quad \theta = \frac{T' - T'_0}{T'_w - T'_0}, \quad t = \frac{t'U_0}{b}, \quad Ha^2 = \frac{\sigma b^2 B_0^2}{\rho v}, \quad Gr = \frac{g\beta(T'_w - T'_0)b}{vU_0},$$
$$Re = \frac{\rho h U_0}{\mu}, \quad Pe = \frac{\rho b U_0 c_p}{k}, \quad N^2 = \frac{4\alpha^2 b^2}{k}, K_c = \frac{K'_c v}{U_0}, Sc = \frac{U}{D}, Gc = \frac{g\beta'(C'_w - C'_0)}{vU_0}, p = \frac{bp'}{\rho v U_0},$$
$$Da = \frac{K}{b^2}, h = \frac{h'}{b}, C = \frac{C - C'_0}{C'_w - C'_0} \quad (6)$$

Where Gr is Grash of number for heat transfer, Gc is Grash of number for mass transfer, Ha is Hartman number, Sc is Schmidt number, Pe is Peclet number, Da is Darcy number, N is radiation parameter, U_0 is the flow mean velocity, b is rare factor parameter and Re is Reynolds number.

The momentum equation (1), the energy equation (2) and the species concentration equation (3) now become

$$Re\frac{\partial u}{\partial t} = -\frac{\partial p}{\partial x} - \frac{\partial^2 u}{\partial y^2} - (S^2 + Ha^2)u + Gr\theta + GcC \quad (7)$$

$$Pe\frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\partial y^2} + N^2\theta \quad (8)$$

$$Sc\frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial y^2} - K_c ScC \quad (9)$$

The relevant boundary conditions in dimensionless form are

$$u = h\frac{\partial u}{\partial y}, \quad \theta = 1, \quad C = 1 \quad at\ \ y = 1,$$

$$u = 0, \quad \theta = 0, \quad C = 0 \quad at\ \ y = 0 \quad (10)$$

Solution of the Problem

To solve equations (7) – (9) subject to the boundary conditions (10) for purely oscillatory flow, let

$$-\frac{\partial p}{\partial x} = \lambda e^{i\omega t} \quad (11)$$

$$u(y,t) = u_0(y)e^{i\omega t} \quad (12)$$

$$\theta(y,t) = \theta_0(y)e^{i\omega t} \quad (13)$$

$$C(y,t) = C_0(y)e^{i\omega t} \quad (14)$$

Where λ is a constant u_0, θ_0 *and* C_0 are the mean flows of velocity, temperature and species concentration respectively. Substituting equations (11) – (14) into equations (7) – (9), we obtain the following

$$u_0''(y) - Bu_0(y) = -\lambda - Gr\theta_0(y) - GcC_0(y) \quad (15)$$

Where, $A = S^2 + Ha^2$ and $B = A + i\omega Re$

$$\theta_0''(y) - E\theta_0(y) = 0 \quad (16)$$

Where, $E = N^2 - i\omega Pe$

$$C_0''(y) - FC_0(y) = 0 \quad (17)$$

Where, $F = K_c Sc + i\omega Sc$

By solving equations (15) – (17) we obtain the following

$$u_0(y) = c_1 e^{\sqrt{B}y} + c_2 e^{-\sqrt{B}y} + k_1 + k_2 e^{\sqrt{E}y} + k_3 e^{-\sqrt{E}y} + k_4 e^{\sqrt{F}y} + k_5 e^{\sqrt{F}y} \quad (18)$$

Where, $k_1 = \frac{-\lambda}{B}$

$$L = \frac{1}{2sinh\sqrt{E}}$$

$$W = \frac{1}{2sinh\sqrt{F}}$$

$$k_2 = \frac{-GrL}{E-B}$$

$$k_3 = \frac{GrL}{E-B}$$

$$k_4 = \frac{-GcW}{F-B}$$

$$k_5 = \frac{GcW}{F-B}$$

$$k_6 = k_1 + k_2 + k_3 + k_4 + k_5$$

$$k_7 = \sqrt{E}k_2 e^{\sqrt{E}} - \sqrt{E}k_3 e^{-\sqrt{E}} + \sqrt{F}k_4 e^{\sqrt{F}} - \sqrt{F}k_5 e^{-\sqrt{F}}$$

$$k_8 = \sqrt{E}k_2 e^{\sqrt{E}} + \sqrt{E}k_3 e^{-\sqrt{E}} + \sqrt{F}k_4 e^{\sqrt{F}} + \sqrt{F}k_5 e^{-\sqrt{F}}$$

$$c_1 = \frac{k_2\left(\sqrt{B}he^{\sqrt{B}} - e^{-\sqrt{B}}\right) - hk_7 + k_8}{-2\sqrt{B}hcosh\sqrt{B} + 2cosh\sqrt{B}} - k_6$$

$$c_2 = \frac{k_2\left(\sqrt{B}he^{\sqrt{B}} - e^{-\sqrt{B}}\right) - hk_7 + k_8}{-2\sqrt{B}hcosh\sqrt{B} + 2cosh\sqrt{B}}$$

$$\theta_0(y) = \frac{sinh\sqrt{E}y}{sinh\sqrt{E}} \quad (19)$$

$$C_0(y) = \frac{sinh\sqrt{F}y}{sinh\sqrt{F}} \quad (20)$$

Therefore, the solution of velocity, temperature and species concentration are

$$u(y,t) = \left(c_1 e^{\sqrt{B}y} + c_2 e^{-\sqrt{B}y} + k_1 + k_2 e^{\sqrt{E}y} + k_3 e^{-\sqrt{E}y} + k_4 e^{\sqrt{F}y} + k_5 e^{\sqrt{F}y}\right) e^{i\omega t} \quad (21)$$

$$\theta(y,t) = \left(\frac{sinh\sqrt{E}y}{sinh\sqrt{E}}\right) e^{i\omega t} \quad (22)$$

$$C(y,t) = \left(\frac{sinh\sqrt{F}y}{sinh\sqrt{F}}\right) e^{i\omega t} \quad (23)$$

Skin Friction τ

The skin friction τ is given by

$$\tau = -\mu \frac{du'}{dy'} \qquad (24)$$

Here, we considered two skin frictions τ_0 and τ_1 at $y = 0$ and $y = 1$ for lower and upper plate respectively.
And in view of equation (6), equation (24) becomes

$$\tau_0 = -\frac{\rho U^2}{Re}\frac{du}{dy} = \frac{du}{dy}\Big|_{y=0} \qquad (25)$$

$$\tau_0 = \left(c_1\sqrt{B} - c_2\sqrt{B} + \sqrt{E}k_2 - \sqrt{E}k_3 + \sqrt{F}k_4 - \sqrt{F}k_5\right)e^{i\omega t} \qquad (26)$$

Skin friction at the upper plate

$$\tau_1 = \left(c_1\sqrt{B}e^{\sqrt{B}} - c_2\sqrt{B}e^{-\sqrt{B}} + \sqrt{E}k_2e^{\sqrt{E}} - \sqrt{E}k_3e^{-\sqrt{E}} + \sqrt{F}k_4e^{\sqrt{F}} - \sqrt{F}k_5e^{\sqrt{F}}\right)e^{i\omega t} \qquad (27)$$

The Nusselt Number Nu

This is the rate of heat transfer across the channel.

We also consider the Nusselt numbers namely Nu_0 and Nu_1 at the lower and upper wall of the channel i.e. at $y = 0$ and $y = 1$ respectively.

The Nusselt number at the lower wall of the channel is

$$Nu_0 = \frac{d\theta}{dy}\Big|_{y=0} = \frac{\sqrt{E}}{sinh\sqrt{E}}e^{i\omega t} \qquad (28)$$

The Nusselt number at the upper wall of the channel is

$$Nu_1 = \frac{\sqrt{E}cosh\sqrt{E}}{sinh\sqrt{E}}e^{i\omega t} \qquad (29)$$

Sherwood number Sh

This is the coefficient of chemical reaction, that is, the rate of mass transfer across the channel. We also consider the Sherwood numbers namely Sh_0 and Sh_1 at the lower and upper wall of the channel boundaries i.e. at $y = 0$ and $y = 1$ respectively.

The Sherwood number at the lower wall of the channel is

$$Sh_0 = \frac{dC}{dy}\Big|_{y=0} = \frac{\sqrt{F}}{sinh\sqrt{F}}e^{i\omega t} \qquad (30)$$

The Sherwood number at the upper wall of the channel is

$$Sh_1 = \frac{dC}{dy}\Big|_{y=0} = \frac{\sqrt{F}cos\sqrt{F}}{sinh\sqrt{F}}e^{i\omega t} \qquad (31)$$

Analysis and Discussion of Result

To study the slip effect on MHD oscillatory flow of fluid in a porous channel with heat and mass transfer and chemical reaction, the velocity u, temperature θ and the species concentration C profiles are depicted graphically against y for different values of different parameters; rarefaction parameter h , Grash of numbers Gr, Gc, Hartman number Ha, Reynolds number Re, radiation parameter N, Schmidt number Sc, chemical reaction parameter K_c, frequency of oscillation ω, and Peclet number Pe. The graphs are plotted using MATLAB where only the real parts of the equations were considered. All the parameters are assigned a constant value except the one being varied.

The values used here are $h = 1, Gc = 1, Gr = 1, Re = 1, Ha = 1, N = 1, Sc = 1, Sc = 1, Pe = 1, \omega = 1, K_c = 1$ and $t = 0.5$ Figure 2 shows the effect of Grashof number due to heat transfer Gr on velocity u. It is observed that as Gr increases, the velocity decreases. To this effect, at higher Grashof number Gr the flow at the boundary is turbulent while at lower Gr the flow at the boundary is laminar. Figure 3 shows the effect of Grashof number due to mass transfer Gc on velocity u. It is observed that as Gc increases, the velocity decreases. To this effect, at higher Grashof number Gc the flow at the boundary is turbulent while at lower Gr the flow at the boundary is laminar. The effect of the radiation parameter N on velocity u is depicted in figure 4. It is observed that the velocity u decreases as the radiation parameter N increases. Figure 5 depicts the effect of Hartman number Ha on velocity u. It is shown that the velocity u decreases with increase in Ha. This shows the effect of magnetic field on the fluid flow and this effect suppresses the turbulence flow of the fluid. Physically, when magnetic field is applied to any fluid, the apparent viscosity of the fluid increases to the point of becoming visco elastic solid. It is of great interest to note that yield stress of the fluid can be controlled very accurately through variation of the magnetic field intensity. The result is that the ability of the fluid to transmit force can be controlled with the help of electromagnet which give rise to many possible control – based applications, including MHD power generation, electromagnetic casting of metals, MHD ion propulsion etc.

The effect of Reynolds number Re on velocity u is shown in figure 6. It is shown that the velocity u increases with increasing Re. Figure 7 illustrates the effect of frequency of oscillation ω on velocity u. It is observed that the velocity u decreases with increase in the frequency of oscillation ω. Figure 8 demonstrate the effect of Schmidt number Sc on velocity u. It shows that the velocity increases with increase in Sc. Figure 9 illustrates the effect of chemical reaction parameter K_c on velocity u.it is observed that as the chemical reaction parameter increases, the velocity decreases. The lines of the graphs in figure 2 to figure 9, converge at the points $y = 0$, this is simply because the point is lower boundary conditions for the velocity u. The expression for u must satisfied the conditions. The temperature field suffers a major change in magnitude due to the variation of radiation parameter N, Peclet number Pe and the frequency of oscillation ω. The effects of these parameters on the temperature field are discussed in figures 10 – 12. Both the parameters retard the magnitude of temperature field at all points. Figure 10 depicts the effect of radiation parameter N on temperature θ. It is found out the temperature decreases with increase in N.

The effect of Peclet number Pe on temperature θ is shown in figure 11. It is observed that the temperature θ decreases with increase in Pe. Figure 12 reveals the effect of frequency of oscillation ω on temperature θ. It shows that the temperature θ decreases with increase in ω. The presence of foreign mass in the flow field greatly affects the species concentration of the flow field. The factors or parameters responsible for this variations are Schmidt number Sc, chemical reaction parameter K_c, frequency of oscillation ω. The effect of Schmidt number Sc on species concentration C is shown in figure 13. It is shown that the species concentration C decreases with increase in Sc. Figure 14 reveals the effect of chemical reaction K_c on species concentration C. It is observed that increase in K_c decreases the species concentration C. The effect of frequency of oscillation ω on species concentration C is depicted in figure 15. It shows that the species concentration C decreases with increase in ω. Tables 1, 2 and 3 respectively show the numerical values of skin frictions (τ_0 and τ_1), Nusselt numbers (Nu_0 and Nu_1) and Sherwood numbers (Sh_0 and Sh_1). These numerical values are obtained by means of MATLAB for different values of time t. It is shown in figure 1 that the skin friction τ_0 increases with increase in time t while τ_1 increases as time t increases. Table 2 shows that both Nu_0 and Nu_1 decreases as time t increase. Table 3 shows that both the Sh_0 and Sh_1 decreases with increase in time t.

Table 1. Variation of skin friction τ_0 and τ_1 with different values of time t

t	τ_0	τ_1
0.0	−23.1421	−60.1574
0.1	−21.3705	−60.0945
0.2	−19.3854	−60.0335
0.3	−17.2066	−59.9750
0.4	−14.8558	−59.9196
0.5	−12.3567	−59.8677
0.6	−9.7340	−59.8201
0.7	−7.0141	−59.7770
0.8	−4.2241	−59.7389
0.9	−1.3920	−59.7063
1.0	1.4541	−59.6795

Table 2. Variation of Nusselt numbers Nu_0 and Nu_1 with different values of time t

t	Nu_0	Nu_1
0.0	0.8437	1.3216
0.1	0.8301	1.3358
0.2	0.8082	1.3366
0.3	0.7782	1.3242
0.4	0.7405	1.2984
0.5	0.6953	1.2598
0.6	0.6932	1.2085
0.7	0.5847	1.1451
0.8	0.5203	1.0704
0.9	0.4508	0.9849
1.0	0.3767	0.8895

Table 3. Variation of Sherwood number Sh_0 and Sh_1 with different values of time t

t	Sh_0	Sh_1
0.0	0.8467	1.3299
0.1	0.8457	1.2940
0.2	0.8452	1.2451
0.3	0.8383	1.1839
0.4	0.8220	1.1108
0.5	0.7974	1.0266
0.6	0.7650	0.9321
0.7	0.7248	0.8283
0.8	0.6775	0.7163
0.9	0.6233	0.5971
1.0	0.5630	0.4719

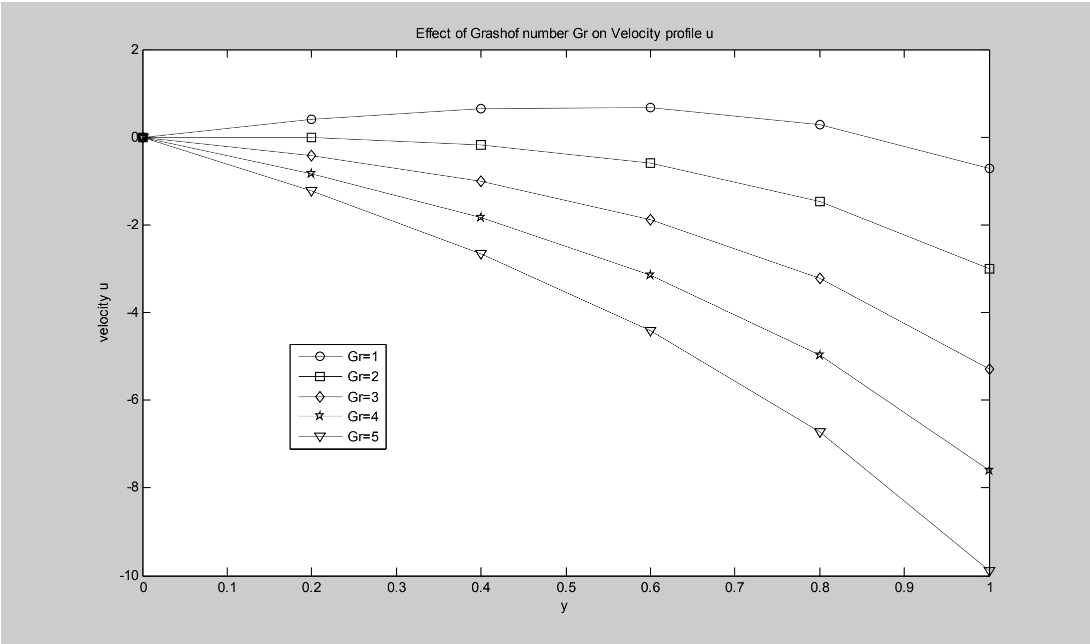

Figure 2. Effect of Grashof Number Gr on Velocity u
with $h = 1, Gc = 1, Re = 1, Ha = 1, N = 1, Sc = 1, Sc = 1, Pe = 1, \omega = 1, K_c = 1$ and $t = 0.5$

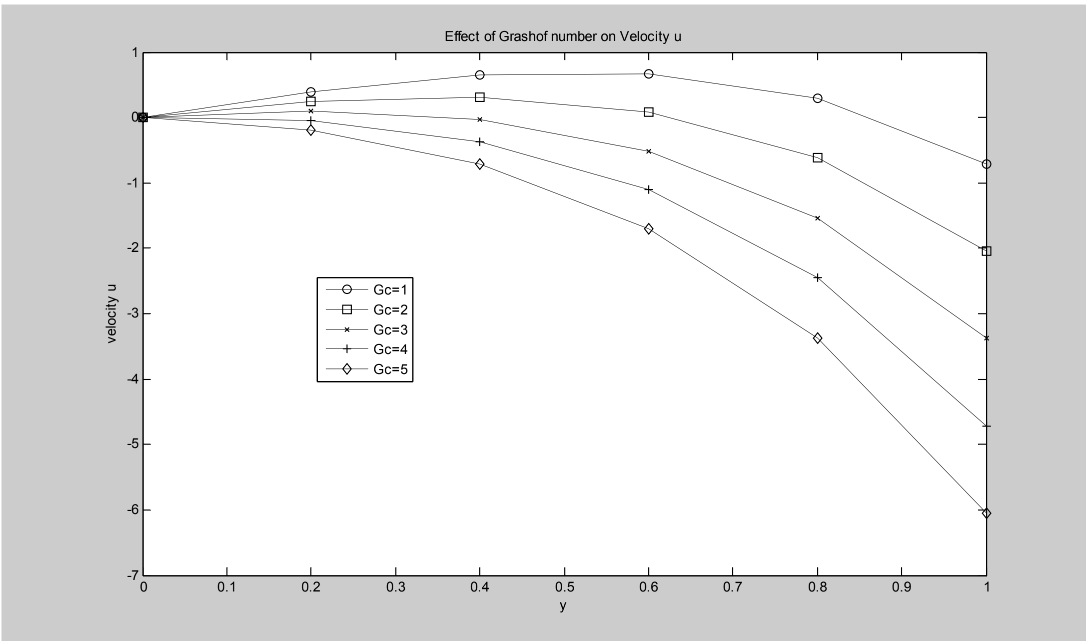

Figure 3. Effect of Grashof number due to mass transfer Gc on velocity u with
$h = 1, Gr = 1, Re = 1, Ha = 1, N = 1, Sc = 1, Sc = 1, Pe = 1, \omega = 1, K_c = 1$ and $t = 0.5$

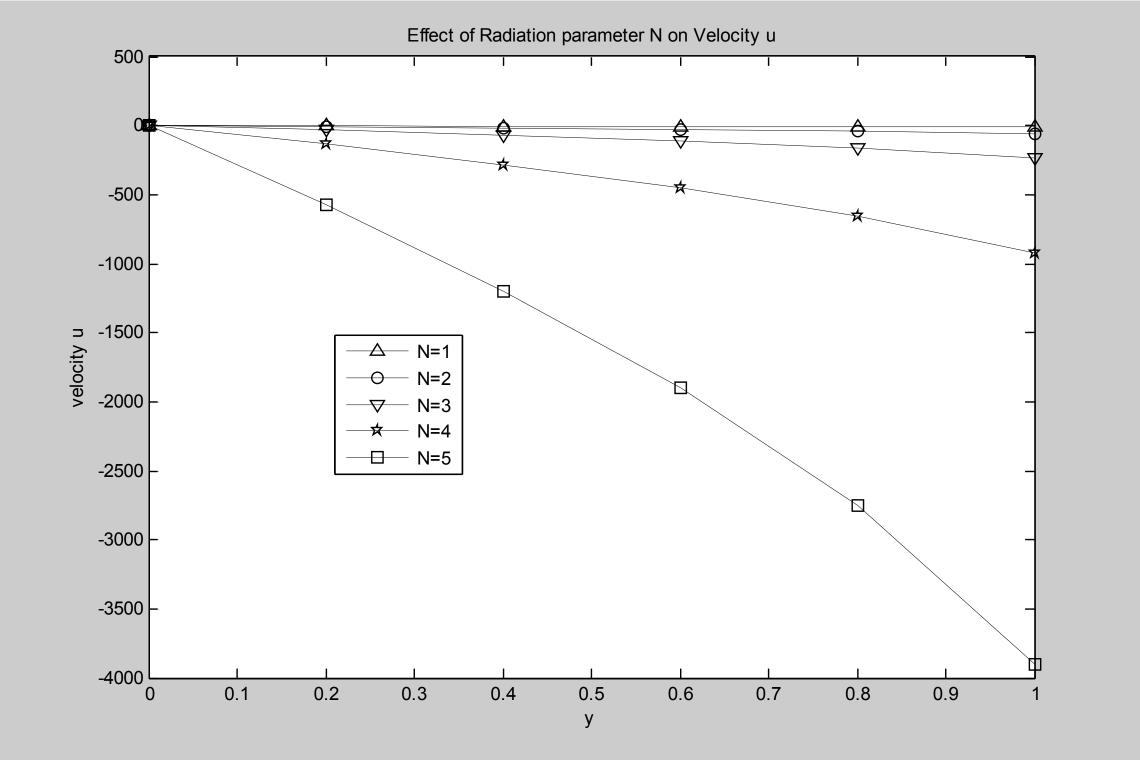

Figure 4. Effect of Radiation parameter N on velocity u with
$h = 1, Gr = 1, Gc = 1, Re = 1, Ha = 1, Sc = 1, Pe = 1, \omega = 1, K_c = 1$ and $t = 0.5$

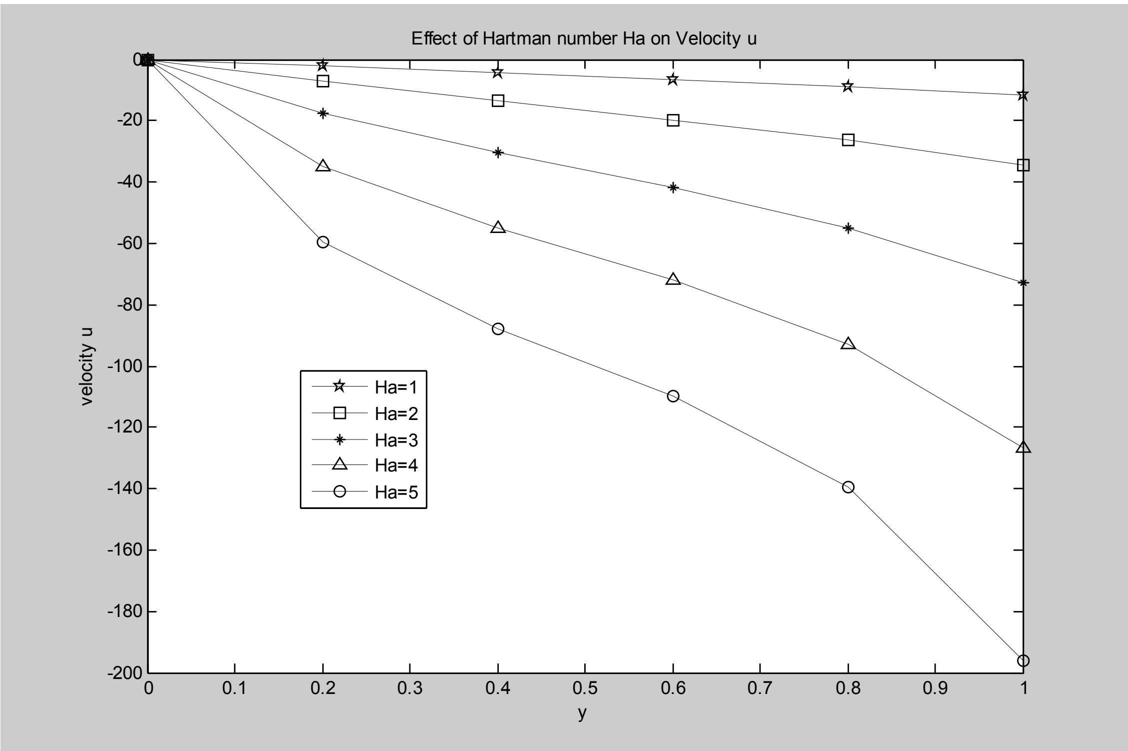

Figure 5. Effect of Hartman number Ha on velocity u with
$h = 1, Gr = 1, Gc = 1, Re = 1, N = 1, Sc = 1, Pe = 1, \omega = 1, K_c = 1$ and $t = 0.5$

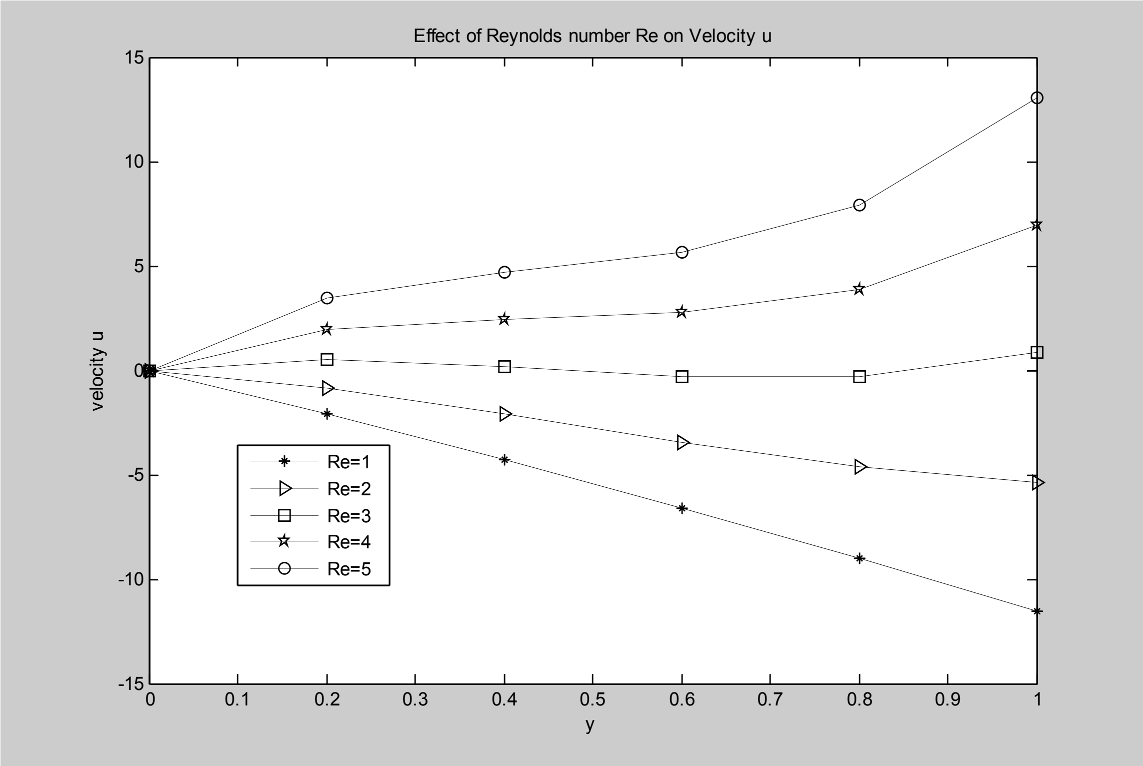

Figure 6. Effect of Reynolds number Re on velocity u with
$h = 1, Gr = 1, Gc = 1, Ha = 1, N = 1, Sc = 1, Pe = 1, \omega = 1, K_c = 1$ and $t = 0.5$

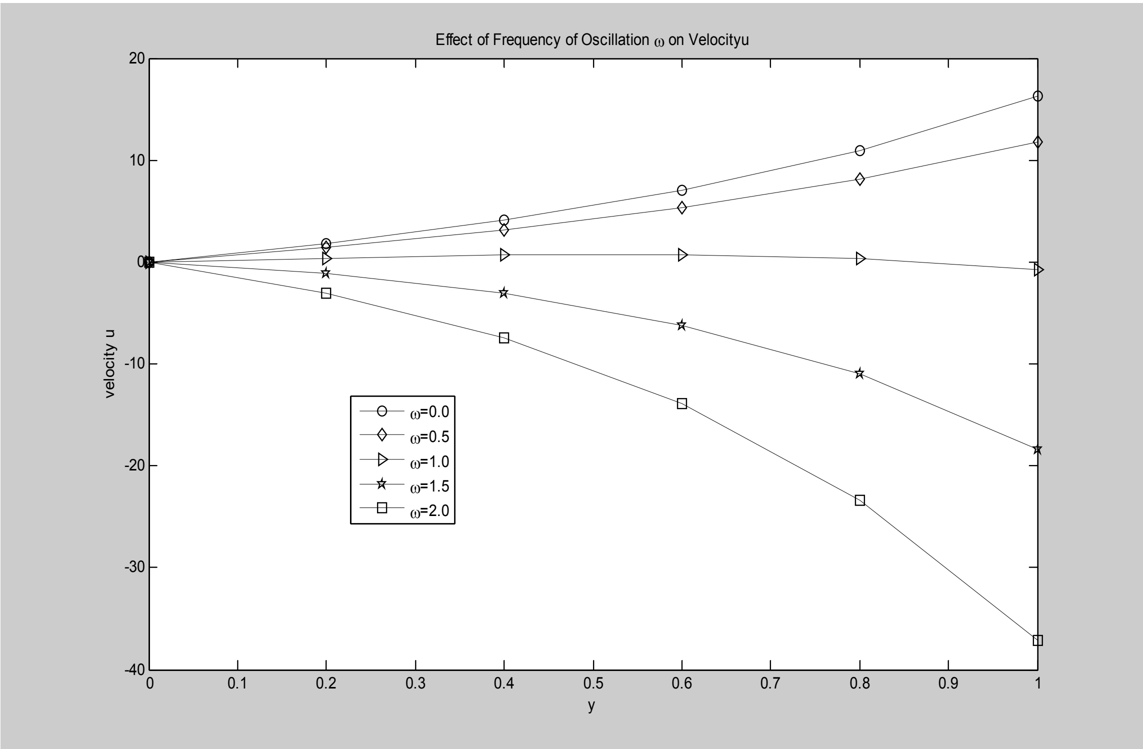

Figure 7. Effect of frequency of oscillation ω on velocity u with
$h = 1, Gr = 1, Gc = 1, Ha = 1, N = 1, Sc = 1, Pe = 1, Re = 1, K_c = 1$ and $t = 0.5$

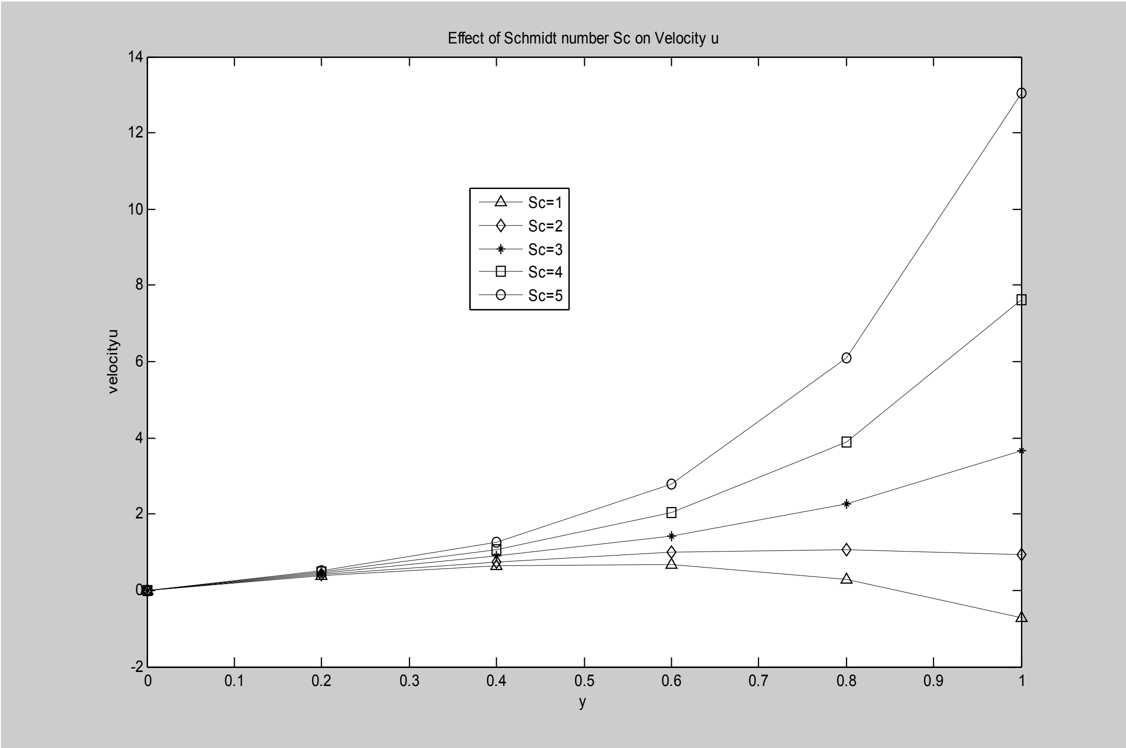

Figure 8. Effect of Schmidt number Sc on velocity u with
$h = 1, Gr = 1, Gc = 1, Ha = 1, N = 1, \omega = 1, Pe = 1, Re = 1, K_c = 1$ and $t = 0.5$

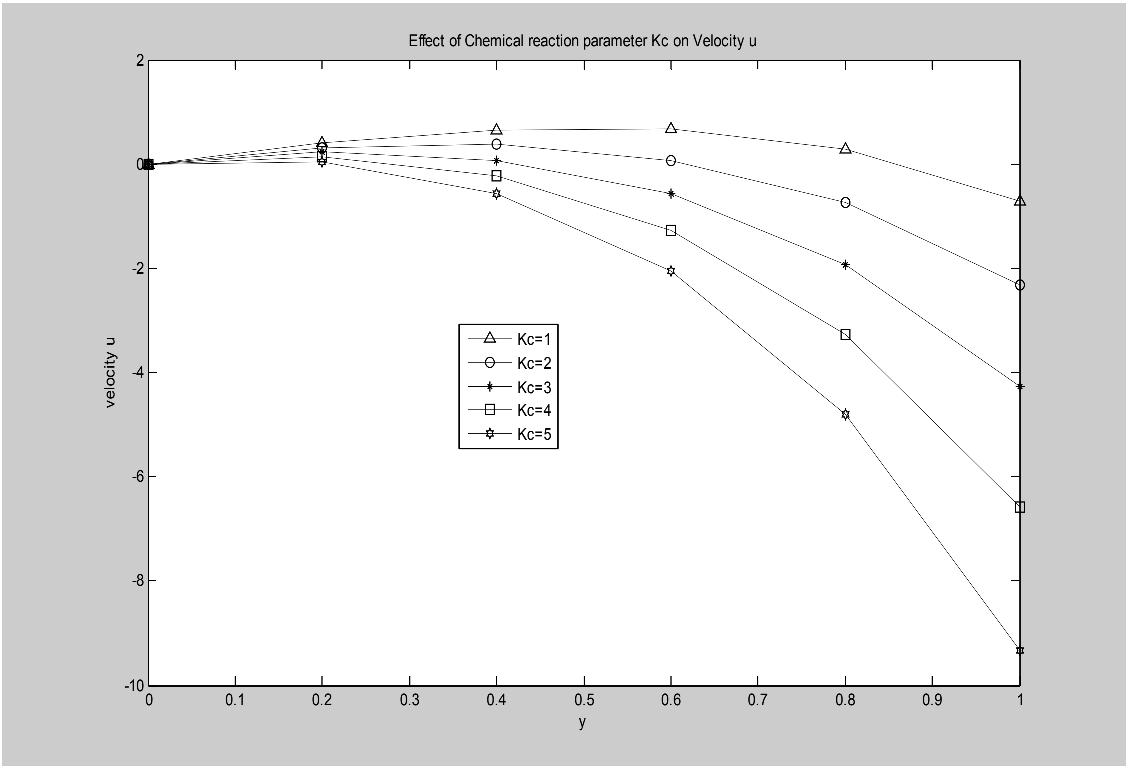

Figure 9. Effect of Chemical reaction Parameter K_c on velocity u with
$h = 1, Gr = 1, Gc = 1, Ha = 1, N = 1, \omega = 1, Pe = 1, Re = 1, Sc = 1$ and $t = 0.5$

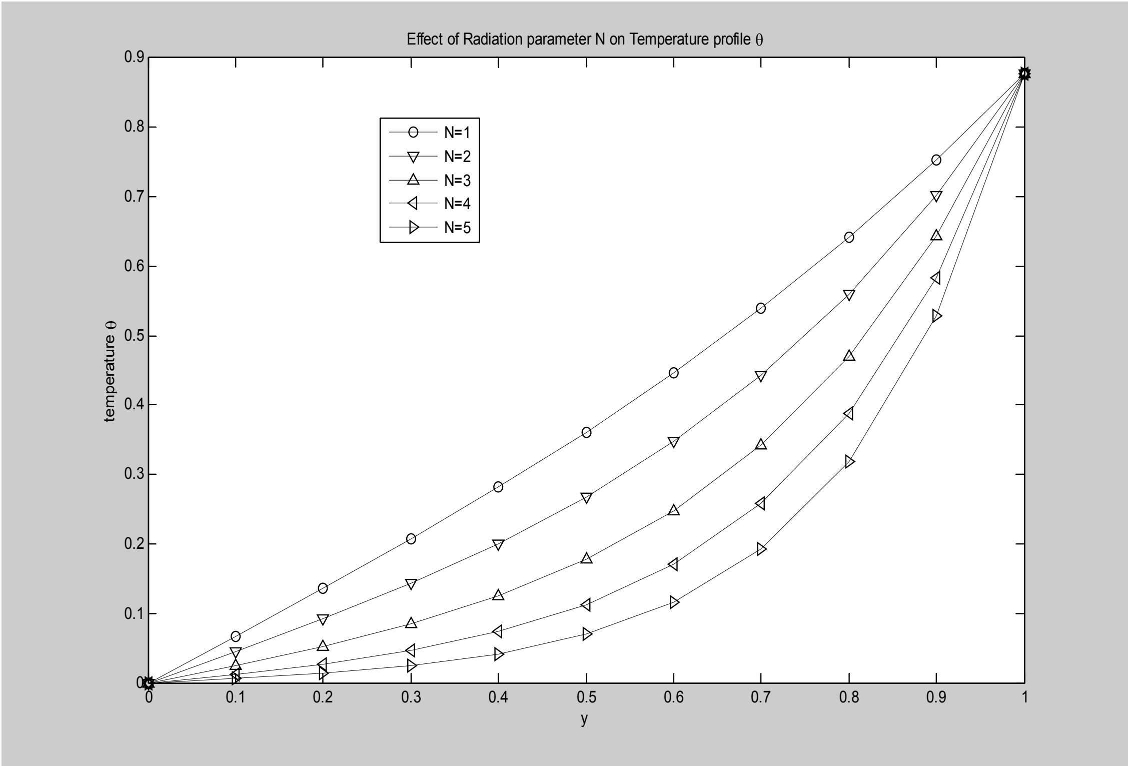

Figure 10. Effect of Radiation parameter N on Temperature θ with
$h = 1, Gr = 1, Gc = 1, Ha = 1, \omega = 1, Pe = 1, Re = 1, Sc = 1, K_c = 1 \; and \; t = 0.5$

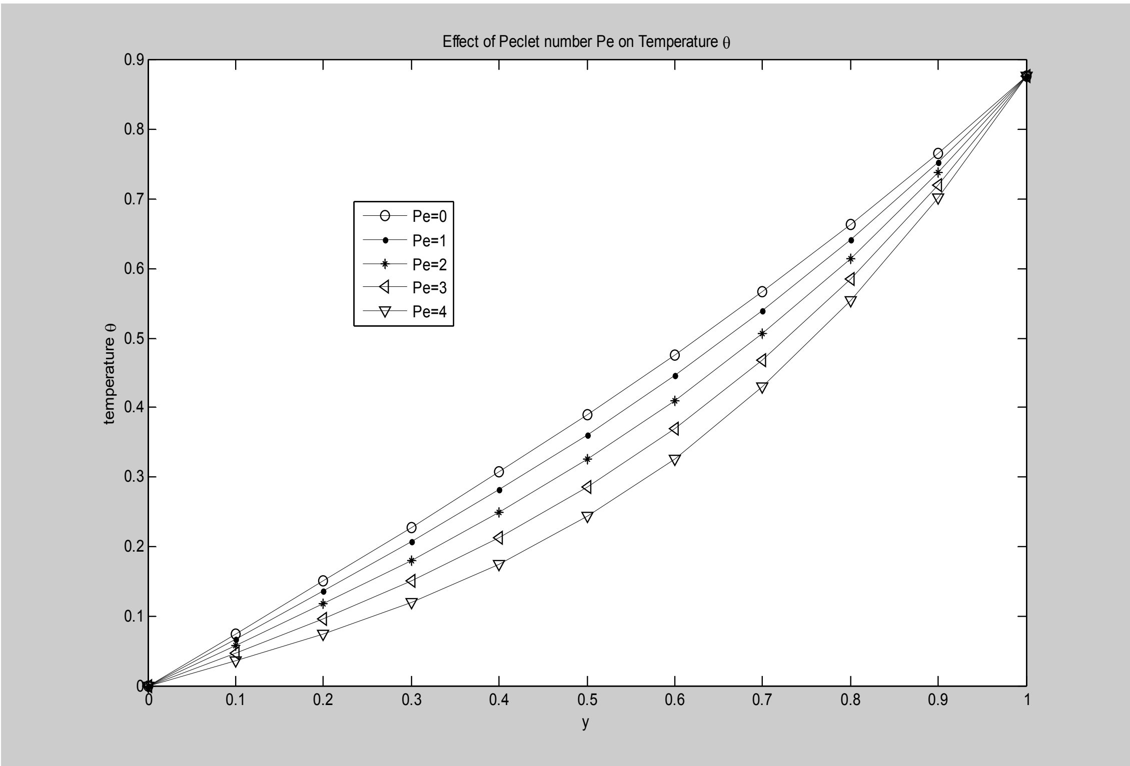

Figure 11. Effect of Peclet number Pe on Temperature θ with
$h = 1, Gr = 1, Gc = 1, Ha = 1, \omega = 1, N = 1, Re = 1, Sc = 1, K_c = 1 \; and \; t = 0.5$

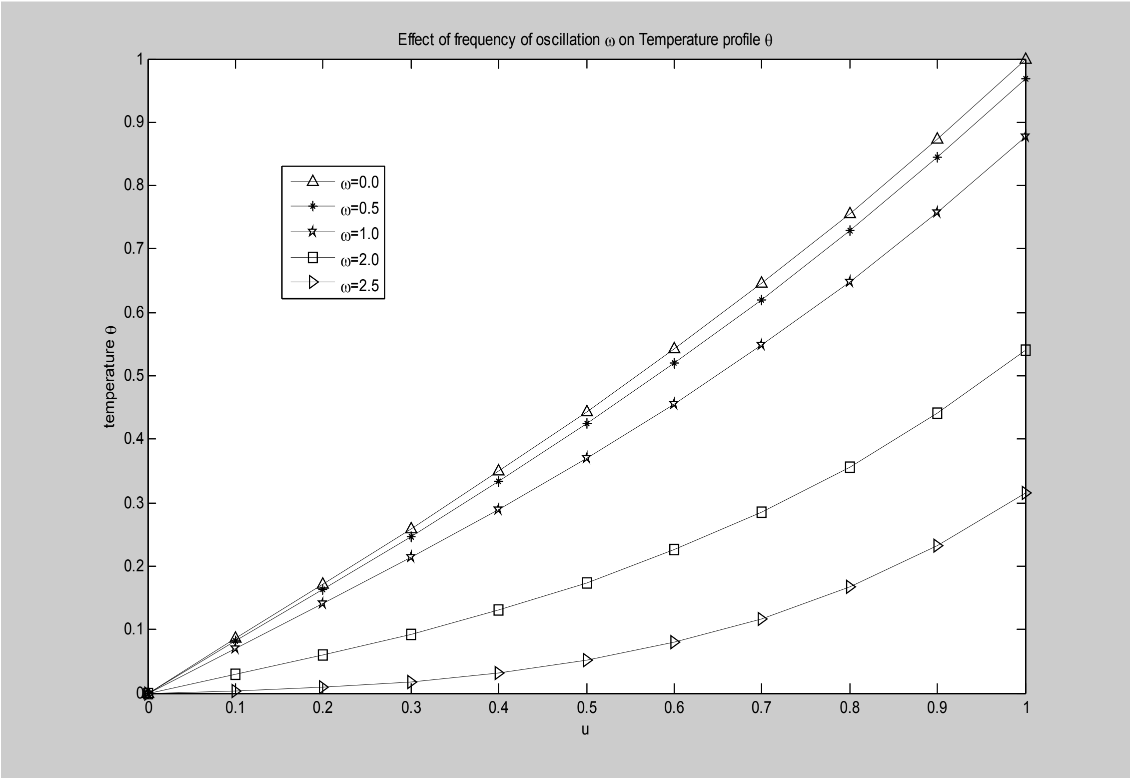

Figure 12. Effect of frequency of oscillations ω on Temperature θ with
$h = 1, Gr = 1, Gc = 1, Ha = 1, Pe = 1, N = 1, Re = 1, Sc = 1, K_c = 1 and\ t = 0.5$

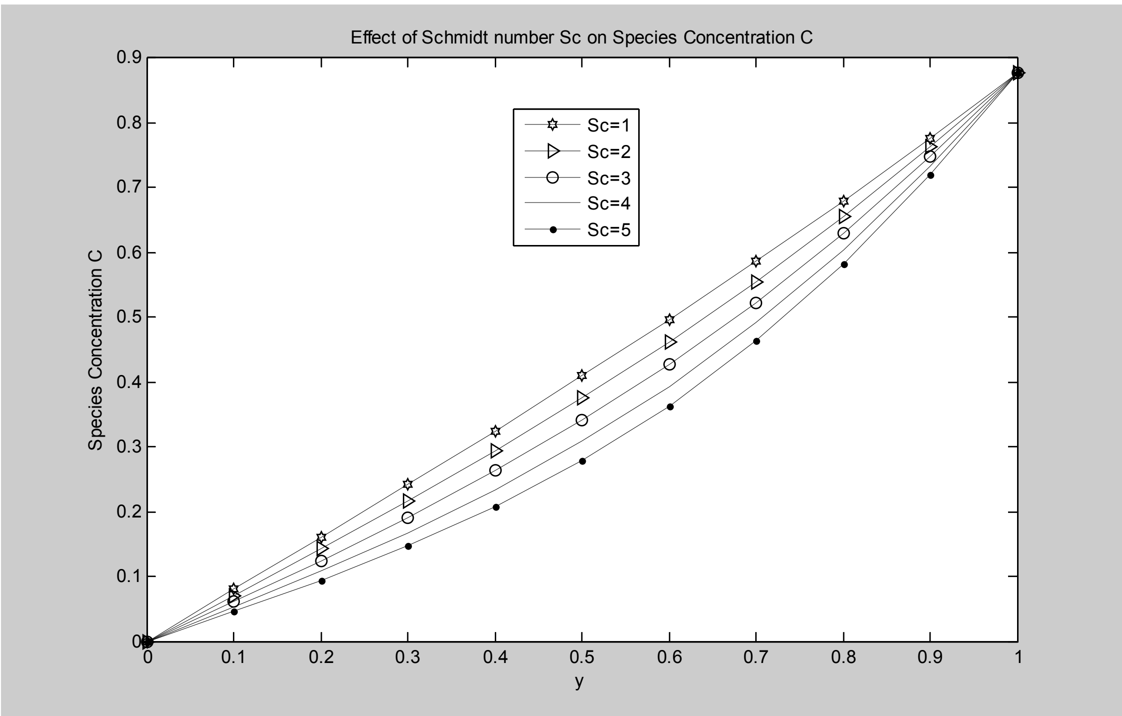

Figure 13. Effect of Schmidt number Sc on Species Concentration C with
$h = 1, Gr = 1, Gc = 1, Ha = 1, Pe = 1, N = 1, Re = 1, K_c = 1, \omega = 1\ and\ t = 0.5$

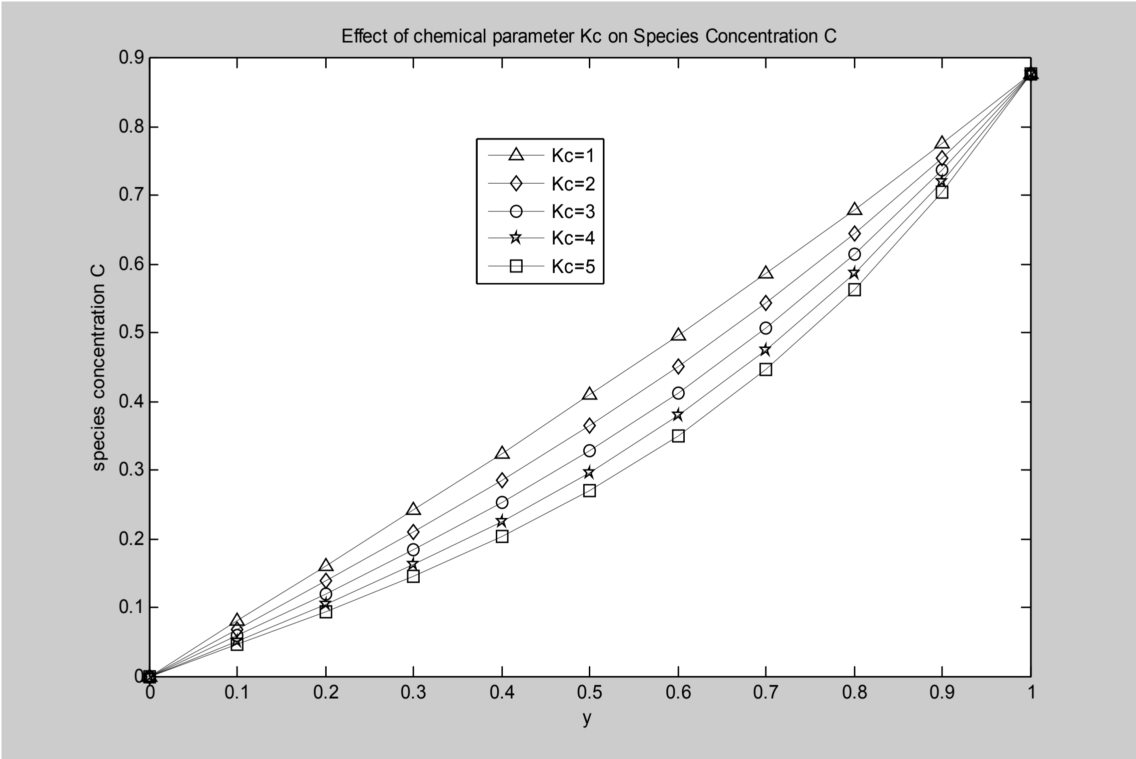

Figure 14. Effect of chemical reaction K_c on species concentration C with
$h = 1, Gr = 1, Gc = 1, Ha = 1, Pe = 1, N = 1, Re = 1, \omega = 1, Sc = 1 \text{ and } t = 0.5$

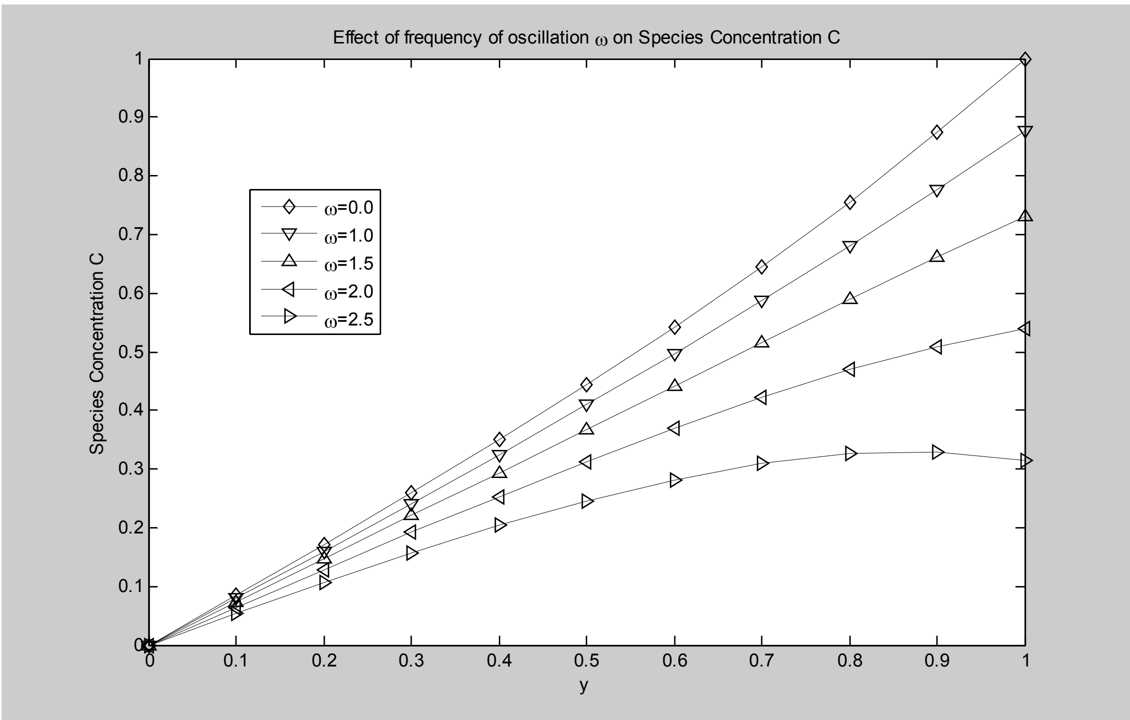

Figure 15. Effect frequency of oscillation ω on species concentration C with
$h = 1, Gr = 1, Gc = 1, Ha = 1, Pe = 1, N = 1, Re = 1, K_c = 1, Sc = 1 \text{ and } t = 0.5$

Summary and Conclusion

In this section, we studied the slip effect on MHD oscillatory flow of fluid in a porous channel with heat and mass transfer and chemical reaction. The governing equations, the momentum, energy and species equations have been written in dimensionless form using dimensionless parameters.

A closed form of analytical method has been employed to evaluate and solved the dimensionless velocity u, the dimensionless temperature θ,the dimensionless species concentration C skin frictions τ_0 and τ_1, Nusselt numbers Nu_0 and Nu_1 and Sherwood numbers Sh_0 and Sh_1. The main findings are summarized below;

i. Decrease in Grashof number for heat transfer Gr, Grashof number for mass transfer Gc and increase in Reynolds number Re, Schmidt number Sc and chemical parameter K_c have accelerating effects on velocity of the flow field.
ii. Increase in Hartman number Ha and frequency of oscillation ω decreases the velocity of the flow field.
iii. Decrease in the Radiation parameter N increases the velocity of the flow field.
iv. Increase in the Radiation parameter N, Peclet number Pe and frequency of oscillation ω retard the magnitude of temperature of the flow field.
v. Increase in Schmidt number Sc, chemical parameter K_c and frequency of oscillation ω decrease the species concentration or the concentration boundary layer thickness of the flow field.

This study is indeed useful in understanding the concept of the slip effect on MHD oscillatory flow of fluid in a porous channel with heat and mass transfer and chemical reaction. The study have potential applications in oil recovery, filtration systems and several applications as mentioned earlier.

REFERENCES

Das, S.S., M. Mohanty, S.K Panigrahi, R.K Padhy and M. Sahu 2012; Radiative Heat and Mass Effects on Naturatural Convection Couette Flow through a Porous Medium in the Slip Flow Regime, Int. J. Ren. Ener. Res. 1 (1): 1 – 14.

Nityananda Senapati and Rajendra Kumar Dhal 2013; Effect of Slip Condition on Unsteady MHD Oscillatory Flow in a Channel Filled with Porous Medium with Heat Radiation and Mass Transfer, Int. J. Appl. Math. Stat. Sci. 2 (3): 11 – 20.

Makinde, O.D. and P.Y. Mhone 2005; Heat Transfer to MHD Oscillatory Flow in a Channel Filled with Porous Medium, Rom. Journ. Phys. 50 (9 – 10): 931 – 938.

Aruna Kumari, B., K. Ramakrishna Prasad and K. Kavitha 2012; Slip Effects on MHD Oscillatory Flow of Jeffrey Fluid in a Channel with Heat Transfer, Int. J. Math. Arch. 3 (8): 2903 – 2911.

Gbadeyan, J.A. and M.S. Dada 2013; On the Influence of Radiation and Heat Transfer on an Unsteady MHD non – Newtonian Fluid Flow with Slip in a Porous medium, Journ. Math. Res. 5 (3): 40 – 50.

Hala Kahtanhamdi and Ahmed M. Abdulhadi 2012; The Effect of Slip Condition on Heat Transfer of MHD Oscillatory Third Order Fluid Flow in a Channel Filled with Porous Medium, Iragi Journal of Sci. 53 (2012): 887 – 893.

Raja Sekhar, K., G.V. Ramana Peddy and B.D.C.N. Prasad 2012; Chemically Reacting on MHD Oscillatory Slip Flow in a Planar Channel with Varying Temperature and Concentration, Adv. Appl. Sci. Res. 3 (5): 2652 – 2659.

Devika, B., P.V. Satya Narayana an S. Venkataramana 2013; MHD Oscillatory Flow of a Visco Elastic Fluid in a Porous Channel with Chemical Reaction, Int. J. Engr. Sci. Inv. 2 (2): 26 – 35.

Gital, A.Y. and M. Abdulhameed 2013; Mixed Convection Flow for Unsteady Oscillatory MHD Second Grade Fluid in a Porous Channel with Heat generation, Int. J. Sci. Engr. Res. 4 (9) ISSN 2229 – 5518.

Umavathi, C., A.J. Chankha, A. Mateen and A. Al – Mudhaf 2009; Unsteady Oscillatory Flow and Heat Transfer in a Horizontal Composite Porous medium Channel, Non linear Analysis: Modeling and Control, 14 (3): 397 – 425.

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