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MHD Rotating Flow through a Porous Medium Embedded In a Second Grade Fluid

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Abstract

In this article the study of heat transfer by generating /absorbing second grade fluid surface on the laminar flow has been investigated. The governing equations in terms of velocity, temperature and concentration profiles are solved analytically and its solutions were discussed graphically with various non- dimensional parameters. Numerical computations are carried out to understand various flow characteristics such as Skin friction, Nusselt number and Sherwood number

Keywords: Hall effect, Porous medium, Rotating channel, MHD

1. Introduction

The study related to free heat flow has aroused great interest from many researchers in the existence of a heat source over the past few decades. Since its wide application in astrophysical sciences, cosmological studies, etc., these flows play a vital role in chemical engineering and space technology, and thus in many fields such as papermaking and other technological fields are applications of unstable oscillatory flows. The effect of viscous fluid in rotational flow has its applications in jet engines, pumps, and vacuum cleaners as well as geophysical flows.

Asghar *et al* [1] studied the second-order fluid model can predict normal variations in stress which is characteristic of non-Newtonian fluids, does not take shear thinning and Phenomena of thickening a plate that is porous due to oscillations caused by the flow of a non-Newtonian fluid. Choudhury and Das [2] explored the free heat flow of a hydrodynamic viscoelastic magnetic material through porous media with radiation and the chemical interaction of heat and mass transfer thus the visco-elastic effects on the fluid slide field along with other flow parameters intricate in the problem. Deka *et al* [3] discussed about the effects on MHD flow past an infinite vertical plate embedded in porous media with constant heat flux by Laplace-transform technique for small values of magnetic parameter. Das *et al* [4] studied the effects on the free MHD convective flow of a viscous fluid bounded by an oscillating porous plate in the sliding flow of mass transfer with the heat source. Ellahi *et al* [5] have discussed Prandtl fluid blood flow and the hybrid method through permeable walls that narrows enlarged arterioles based on pseudo-least-squares spectral clustering testing the flow of non-Newtonian fluids MHD. Ellahi *et al* [6] discussed about a hybrid method based on pseudo-spectral aggregation, thus a least square method applied to examine MHD the flow of non-Newtonian fluids. Hayat *et al* [7] studied the flow of a viscoelastic fluid on a swinging plate, the thickness of the boundary layer is decrease/increase for suction/inflation and amplitude of oscillation increases/decreases for acceleration/deceleration in the state of the second-grade fluid is greater than a viscous case. Hussain *et al* [8] developed a modified Darcy's Law Class II fluid using a porous medium at the expense of the Hall current, the flow of a viscous elastic fluid through a porous medium in the presence of a magnetic field of the basis of many scientific and engineering applications. Jasmine Benazir *et al* [9] presented Casson fluid over a vertical cone in which an incompressible fluid and a flat plate saturated with a porous medium with variable viscosity is electrically conductive. Jasmine Benazir *et al* [10] Viscosity effect check dissipation, joule heating, and double dispersion in the unsteady state MHD Casson fluid flow over vertical cone and flat plate subject to variable viscosity and variable electrical conductivity. Jha and Ajibade [11] introduced a thermodynamic flow of a heated incompressible viscous fluid in infinite vertical parallel plates through suction/injection based on heat generation/absorption of fluids over time. Jhansi rani and Ramana Muthy [12] discussed the unstable heat flow of a past semi-infinite inclined permeable plate embedded in a porous medium with heat and mass transfer through the influence of radiation and absorption. Kalpana and Bhuvana Vijaya [13] investigated the unstable second-order fluid flow with non-uniform wall temperature through a vertical channel taking up the hall stream. Lokanadham and Shiva Prasad [14] considered that heat is immersed over a vertical plate embedded in a porous medium through a semi-infinite plate in a viscous flow. Makinde *et al* [15] explored the combined effects of the show magnetic field and radiative heat transfer on unsteady absorption flux optically thin fluid through a channel filled with a soaked porous medium and asymmetrical wall temperature. Mehmood and Ali [16] studied the case of the effect of slip on the unstable MHD oscillatory flow of a viscous fluid due to a saturated porous medium in a flat channel such that the liquid sliding into the bottom wall, thus the study slip on the velocity field and the effect of other parameters present in fluid Slip Equations. Manna *et al* [17] studied the effect of radiation on MHD the free heat flow of an electrically incompressible viscous of fluids via a vertical oscillating porous plate embedded in a penetrable medium in the presence of a consistent horizontal magnetic field. Oahimire and Olajuwon [18] discussed the effect of the hall current on the heat and mass transfer MHD of a fine polar fluid flow through a porous medium by integrating the momentum and concentration angular equations with thermal radiation and chemical reaction conditions in the absence of a viscous term to study the current hall and thermal radiation on heat and mass fluctuating transfer MHD from a chemically reacting micro polar through a porous medium. Prakash and Muthtamilselvan [19] investigated MHD the flow of a micro polar fluid traversing forcing radiation between porous channels of type III boundary conditions. Rashidi *et al* [20] the effect of the transverse magnetic fields of current in a laminar system is simulated under a two-dimensional fluid flow mathematical model. Sadiq basha and Nagarathna [21] have studied the unstable two-dimensional MHD flow of blood in a porous material in a uniform magnetic field in a parallel plate displaying the oscillating flow. Sheikholeslami *et al* [22] studied the effect of thermal radiation on MHD the Nano-fluid flow between two horizontal rotating plates in a current work made for a fully developed flow analysis of incompressible Nano-fluid flow between two horizontal rotations plates in the presence of heat radiation and a magnetic field. Shen *et al* [23] investigated the Stokes on Rayleigh problem for a heated generalized second-order liquid with a fractional derivative model that the temperature distribution in a generalized second-order liquid subject to flow on a heated flat plate and into a heated interior the edge was determined using the sinusoidal Fourier transform and the Laplace fractional transformed derivatives. Singh and Gupta [24] studied free heat flow in a viscous fluid through a porous medium bounded by a porous plate in sliding flow that incompressible convection flow of a non-Newtonian fluid through a porous medium above a porous plate oscillates in the presence of a transverse magnetic the field has been considered. Sudharsan Reddy and Viswanatha Reddy [25] have studied the flow of a second-order viscous conductive MHD oscillating convective fluid in a pore circulating in the slip flow in heat and mass transfer. Swarnalathamma and Veera Krishna [26] discussed about the theoretical and computational study of peristalsis the hemodynamic flow of a couple stress fluids through a porous medium under the influence of a magnetic field with the wall slip case. Veera Krishna and Swarnalathamma [27] investigating in the effect of an inclined magnetic field on the peristaltic flow of an electrically incompressible fluid through a porous medium in the presence of heat and mass transfer. Veera Krishna and Gangadhar Reddy [28] MHD is discussed free rotating heat flow of viscoelastic fluid after oscillating porous plate in an electrically incompressible porous medium bound by a class II viscous fluid. Veera Krishna and Subba Reddy [29] discussed about the MHD that the heat flow of a second-order fluid through a permeable medium in a revolve parallel plate. Veera Krishna *et al* [30] MHD discussed incompressible and electrically conductive fluid flows on unstable oscillating blood flow through porous arterioles.

Based on the above facts, the heat generation/absorption of the permeable surface on a second-order liquid which is observed in the boundary layer region as the surface porosity with the presence of temperature and concentration where the chemical reaction and radiation with porous medium are presented in a semi-vertical plate are investigated.

MATHEMATICAL FORMULATION

Consider an unsteady convective flow of a viscous laminar with heat and mass transfer in which heat engrossing second grade fluid over a semi-infinite vertical plate that embedded in a uniform porous medium in the presence of chemical reaction and radiation. Thus, we take z axis along with the plate in which x axis perpendicular to the plate and suction velocity w_o flow through the z direction in which rotation takes place in it, thus magnetic induction along with the x axis. The linear momentum equations of all thermo physical properties are supposed to be invariable under the Boussinesq's approximation. Therefore, the plate is extended to infinity of the functions of z and the time t only. The equation governing the fluid flow with respect to heat and mass transfer is given by

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0 \tag{1}$$

$$\frac{\partial u}{\partial t}+w\frac{\partial u}{\partial z}-2\Omega v=-\frac{1}{\rho}\frac{\partial p}{\partial x}+v\frac{\partial^2 u}{\partial z^2}+\frac{\propto}{\rho}\frac{\partial^3 u}{\partial z^2\partial t}-\frac{\sigma B_o^2}{\rho}u-\frac{v}{k}u+g\beta_T(T-T_\infty)+g\beta_C(C-C_\infty) \tag{2}$$

$$\frac{\partial v}{\partial t}+w\frac{\partial v}{\partial z}+2\Omega u=-\frac{1}{\rho}\frac{\partial p}{\partial y}+v\frac{\partial^2 v}{\partial z^2}+\frac{\propto}{\rho}\frac{\partial^3 v}{\partial z^2\partial t}-\frac{\sigma B_o^2}{\rho}v-\frac{v}{k}v \tag{3}$$

$$\frac{\partial T}{\partial t}+w\frac{\partial T}{\partial z}=\frac{1}{\rho C_p}\left(k_1\frac{\partial^2 T}{\partial z^2}\right)-Q_0(T-T_\infty)+Q_1(C-C_\infty)-\frac{\partial q_1}{\partial z} \tag{4}$$

$$\frac{\partial C}{\partial t}+w\frac{\partial C}{\partial z}=D\frac{\partial^2 C}{\partial z^2}+K_C(C-C_\infty)+D_1\frac{\partial^2 T}{\partial z^2} \tag{5}$$

The temperature and concentration at the wall of the suction velocity in the porous plate with an invariable velocity budge in the direction of the fluid flow is varying exponentially with time and the boundary conditions are,

$$q=U_o,\ \ T=T_o+\varepsilon(T_w+T_\infty)e^{iwt},\ \ C=C_o+\varepsilon(C_w+C_\infty)e^{iwt} \qquad at\ \ Z=0 \tag{6}$$

$$q\to U_\infty,\quad T\to T_\infty,\quad C\to C_\infty \qquad as\ \ Z\to\infty \tag{7}$$

Equation (1) shows the suction velocity of the plate is constant or fraction of time then the w_o is a non-zero constructive constant of the mean suction velocity and ε.

$$w=-w_0(1+\varepsilon Ae^{iwt}) \tag{8}$$

The optimistic invariable are A and ε that satisfies the condition $\varepsilon A\ll 1$. Then the suction indicates the negative sign is towards the plate.

Set $q=u+iv\ and\ \xi=x-iy$ and combine the equation (1) and (2),

$$\frac{\partial q}{\partial t}+w\frac{\partial q}{\partial z}+2i\Omega q=-\frac{1}{\rho}\frac{\partial p}{\partial \xi}+v\frac{\partial^2 q}{\partial z^2}+\frac{\propto}{\rho}\frac{\partial^3 q}{\partial z^2\partial t}-\frac{\sigma B_o^2}{\rho}q-\frac{v}{k}q+g\beta_T(T-T_\infty)+g\beta_C(C-C_\infty) \tag{9}$$

The boundary layer of equation (9) follows,

$$-\frac{1}{\rho}\frac{\partial p}{\partial \xi}=\frac{\partial U_\infty}{\partial t}+\left[\frac{\sigma B_o^2}{\rho}+\frac{v}{k}\right]U_\infty \tag{10}$$

The non-dimensional variables are introduced,

$$q^* = \frac{q}{w_0}, w^* = \frac{w}{U_0}, Z^* = \frac{U_o Z}{v},\ U_\infty^* = \frac{U_\infty}{U_0}, t^* = \frac{tU_0^2}{v}, \theta = \frac{T-T_\infty}{T_w-T_\infty}, \phi = \frac{C-C_\infty}{C_w-C_\infty}.$$

Uses of non-dimensional variables then the equations are reduced to,

$$\frac{\partial q}{\partial t} + 2iE^{-1}q - \left(1 + \varepsilon A e^{iwt}\right) = \frac{dU_\infty}{dt} + \frac{\partial^2 q}{\partial z^2} + S\frac{\partial^3 q}{\partial z^2 \partial t} + \left(M^2 + \frac{1}{k}\right) q + G_r\theta + G_C\phi \tag{11}$$

$$\frac{\partial \theta}{\partial t} - \left(1 + \varepsilon A e^{iwt}\right)\frac{\partial \theta}{\partial Z} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial z^2} - (\phi_1 + N^2)\theta + Q\phi \tag{12}$$

$$\frac{\partial C}{\partial t} - \left(1 + \varepsilon A e^{iwt}\right)\frac{\partial C}{\partial Z} = \frac{1}{S_C}\frac{\partial^2 C}{\partial z^2} - k_C C + S_0\frac{\partial^2 \theta}{\partial Z^2} \tag{13}$$

The boundary conditions are,

$$q = U_0, \quad \theta = 1 + \varepsilon e^{iwt}, \ \phi = 1 + \varepsilon e^{iwt} \qquad at\ Z = 0 \tag{14}$$

$$q = 0, \ \theta = 0, \ \ \phi = 0 \qquad as\ Z \to \infty \tag{15}$$

Thus $M^2 = \frac{\sigma B_0^2 v}{\rho U_0^2}$ is the Hartmann number (Magnetic field parameter), $k = \frac{kU_0^2}{v^2}$ is the permeability parameter, $P_r = \frac{v\rho C_p}{k_1} = \frac{v}{\propto}$ is the Prandtl number, $E = \frac{U_0^2}{\Omega v}$ is the Rotation parameter , $G_r = \frac{v\beta g_T(T_w - T_\infty)}{U_0^3}$ is the thermal Grashof number, $G_C = \frac{v\beta g_C(C_w - C_\infty)}{U_0^2}$ is the modified Grashof number, $k_C^* = \frac{k_C\gamma}{U_0^2}$ is the chemical reaction parameter, $s = \frac{U_0^2\alpha}{\rho v^2}$ is the second grade fluid parameter, $S_C = \frac{v}{D}$ is the Schmidt number, $N = \frac{2\alpha U_0}{v\sqrt{k_1}}$is the Radiation parameter,$Q = \frac{Q_1 v(C_w - C_\infty)}{\rho C_p u_0^2(T_w - T_\infty)}$ is the Radiation absorption number, $S_0 = \frac{D_1(T_w - T_\infty)}{v(C_w - C_\infty)}$ is the soret number, $\phi_1 = \frac{vQ_0}{\rho C_p u_0^2}$ is the Heat absorption number.

METHOD OF SOLUTION

The dimensionless parameter under boundary conditions with the governing equations by using perturbation technique then the velocity, temperature and concentration are assumed to form,

$$q = q_0(Z) + \varepsilon e^{iwt} q_1(Z) + O(\varepsilon^2) \tag{16}$$

$$\theta = \theta_0(Z) + \varepsilon e^{iwt}\theta_1(Z) + O(\varepsilon^2) \tag{17}$$

$$\phi = \phi_0(Z) + \varepsilon e^{iwt}\phi_1(Z) + O(\varepsilon^2) \tag{18}$$

In equations (11), (12) and (13) substitute in (16), (17) and (18) respectively, obtain the zero th and first order such as,

$$\frac{d^2 q_0}{dZ^2} + \frac{dq_0}{dz} - \left(M^2 + 2iE^{-1} + \frac{1}{k}\right) q_0 = -G_r\theta_0 - G_C\phi_0 \tag{19}$$

$$\frac{d^2\theta_0}{dZ^2} + P_r \frac{d\theta_0}{dz} - P_r(\phi_1 + N^2)\theta_0 = 0 \quad (20)$$

$$\frac{d^2\phi_0}{dZ^2} + S_C \frac{d\phi_0}{dz} - k_C S_C \phi_0 = -S_C S_0 \frac{d^2\theta_0}{dZ^2} \quad (21)$$

$$(1 + Siw)\frac{d^2 q_1}{dZ^2} + \frac{dq_1}{dz} - \left(M^2 + 2iE^{-1} + \frac{1}{k}\right) q_1 = -G_r\theta_1 - G_C\phi_1 - A\frac{dq_0}{dz} - iw \quad (22)$$

$$\frac{d^2\theta_1}{dZ^2} + P_r \frac{d\theta_1}{dz} - P_r(iw + \phi_1 + N^2)\theta_1 = 0 \quad (23)$$

$$\frac{d^2\phi_1}{dZ^2} + S_C \frac{d\phi_1}{dz} + (1 - k_C)S_C\phi_1 = S_C S_0 \frac{d^2\theta_1}{dZ^2} - S_C \frac{dC_0}{dz} \quad (24)$$

The boundary conditions are,

$$q_0 = U_p,\ \ q_1 = 0, \theta_0 = 1, \theta_1 = 1, \phi_0 = 1, \phi_1 = 1 \quad at\ Z = 0 \quad (25)$$

$$q_0 = 0, q_1 = 0, \theta_0 = 0, \theta_1 = 0, \phi_0 = 0, \phi_1 = 0 \quad at\ Z \to \infty \quad (26)$$

Using equations (25) and (26) and solve equations (19) to (24) then,

$$q = ([U_P - (a_2 + a_4 + a_3)]e^{-m_3 z} + (a_2 + a_4)e^{-m_1 z} + a_3 e^{-m_2 z}) + \varepsilon[Ae^{-m_6 z} + (a_{10} + a_{13})e^{-m_4 z} + (a_{11} + a_{14} + a_{17})e^{-m_1 z} + a_{12}e^{-m_5 z} + (a_{15} + a_{18})e^{-m_2 z} + a_{16}e^{-m_3 z}]e^{iwt} \quad (27)$$

$$\theta = e^{-m_1 z} + \varepsilon(A_1 e^{-m_4 z} + a_5 e^{-m_1 z})e^{iwt} \quad (28)$$

$$\phi = Ae^{-m_2 z} + a_1 e^{-m_1 z}) + \varepsilon(Ae^{-m_5 z} + a_6 e^{-m_4 z} + (a_7 + a_9)e^{-m_1 z} + a_8 e^{-m_2 z})e^{iwt} \quad (29)$$

SKIN FRICTION

The non-dimensional skin friction at the plate $z = 0$ is given by,

$$\tau = \left(\frac{dq}{dz}\right)_{z=0} = \left(\frac{dq_0}{dz}\right)_{z=0} + \varepsilon\left(\frac{dq_1}{dz}\right)_{z=0} e^{iwt}$$

$$= (m_3[U_P - (a_2 + a_4 + a_3)] + m_1(a_2 + a_4) + m_2 a_3) + \varepsilon[m_6 A - m_4(a_{10} + a_{13}) - m_1(a_{11} + a_{14} + a_{17}) - m_5 a_{12} - m_2(a_{15} + a_{18}) - m_3 a_{16}]e^{iwt} \quad (30)$$

NUSSELT NUMBER

The non-dimensional form in which rate of heat transfer as Nusselt number N_u is given by,

$$N_u = \left(\frac{dT}{dz}\right)_{z=0} = \left(\frac{dT_0}{dz}\right)_{z=0} + \varepsilon\left(\frac{dT_1}{dz}\right)_{z=0} e^{iwt}$$

$$= -m_1 - \varepsilon(A_1 m_4 + a_5 m_1)e^{iwt} \quad (31)$$

SHERWOOD NUMBER

The non-dimensional form in which rate of mass transfer as Sherwood number S_h is given by,

$$S_h = \left(\frac{dC}{dz}\right)_{z=0} = \left(\frac{dC_0}{dz}\right)_{z=0} + \varepsilon\left(\frac{dC_1}{dz}\right)_{z=0} e^{iwt}$$

$$= (m_2A - m_1a_1) + \varepsilon(m_5A + m_4a_6 + m_1(a_7 + a_9) + m_2a_8)e^{iwt} \quad (32)$$

RESULTS AND DISCUSSION

An unsteady MHD flow of a second grade fluid parameters through porous medium embedded in an infinite plate is analysed with parameters like Hartmann number, thermal Grashof number, modified Grashof number, permeability parameter , rotation parameter, second grade fluid, Prandtl number, chemical reaction parameter, Schmidt number, heat absorption parameter, radiation parameter and time t. Based on the above obtained solutions velocity, temperature and concentration profiles are shown graphically below figures (1-16) respectively.

Figure (1) shows the velocity profile increases with increase in Hartmann's number. This is due to the presence of Lorentz force that affects the magnetic field on the fluid flow in the absence of the field values. Figure (2) signifies the porous channel that decreases the permeability parameter in the velocity profile where the medium of permeability decreases the fluid velocity placed in the path of the free flow. Figure (3) depicts the rotation rate in the axial flow which decreases the high rotation rate at which the pressure gradient and the tube that rotates on the axis is perpendicular to the duct. Figure (4) explains that the second-grade fluid decreases because of the magnetic field in the stress strain tensor decreases. In figures (5) and (6) it is noticed that the effects of thermal Grashof number Gr, and mass Grashof number Gm in the velocity profiles increases the ratio of buoyancy force and viscous force while the plate cooling, it has the tendency to increase the buoyancy effect that flow transport induced which gives rise to the plate increases while heating. Figure (7) demonstrates the velocity profiles in different values of Prandtl number Pr, while the flow field decreases when the values of Prandtl number increases, this is because of transferring heat from momentum thickness which controls the relativity and the boundary layer that indicates convection is comparatively significant. Figure (8) displays the presence of chemical reaction parameter which affects both the profiles, and then the chemical reaction parameter decreases, when its values increase. Figure (9) shows the effect of Schmidt number Sc, where the velocity fluid decreases, as the Schmidt number increases, in these profiles reductions is accompanied by simultaneous process in which the momentum of boundary layer thickness increases. Figure (10) represents the heat absorption parameter which decreases in velocity profile, when its values increase. Figure (11) demonstrates the velocity components u and v, in which radiation parameter increases because of the left half channel decreases, thus the effect of radiation parameter on the velocity is insignificant due to the right half of the channel velocity decreases of radiation parameter in which velocity profiles of the radiation parameter decreases with respect to time within the boundary layer. In figures (12) and (13) represents the temperature profiles with various values of Prandtl number, frequency of oscillation, heat absorption and radiation parameters and results in decreases in Prandtl number alone rather it increases in all other quantities. Figure (14) shows the concentration distribution in term of Schmidt number and increases the frequency of oscillation which causes the concentration buoyancy effects to decrease, which yields the fluid velocity accompanied by simultaneous reduction of boundary layers. In figures (15) and (16) determines the heat absorption against chemical reaction parameter, second grade parameter, radiation parameter and Prandtl number decreases due to the buoyancy effects, when their values increase.

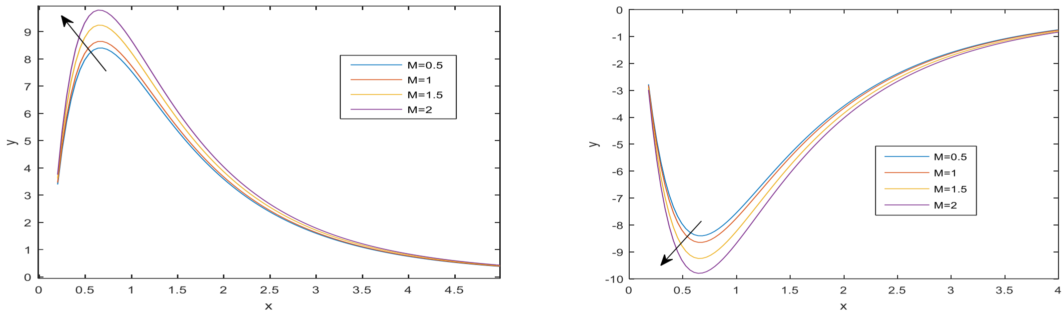

FIGURE 1: *Velocity Profile u and v against Hartmann Number (M), K=0.5, E=0.1, S=1, Gr=5*G_c*=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1,* $\omega=\pi/6$*, t=0.1, N=1*

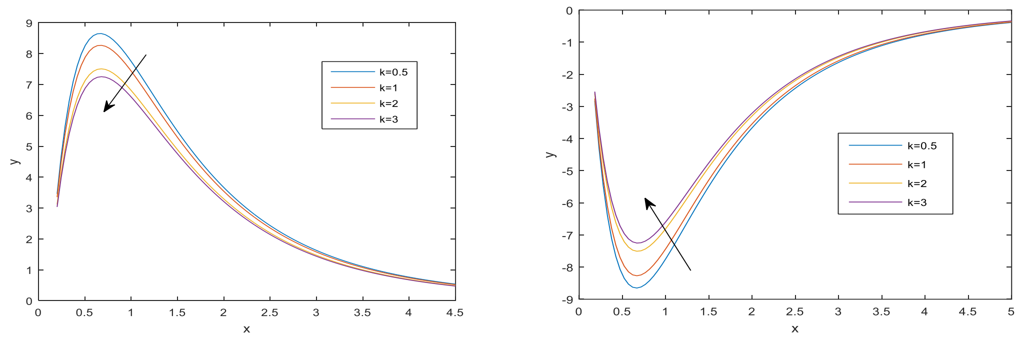

FIGURE 2: *Velocity Profile u and v against Permeability (K), M=0.5, E=0.1, S=1,Gr=5,* G_c*=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1,* $\omega=\pi/6$*, t=0.1, N=1*

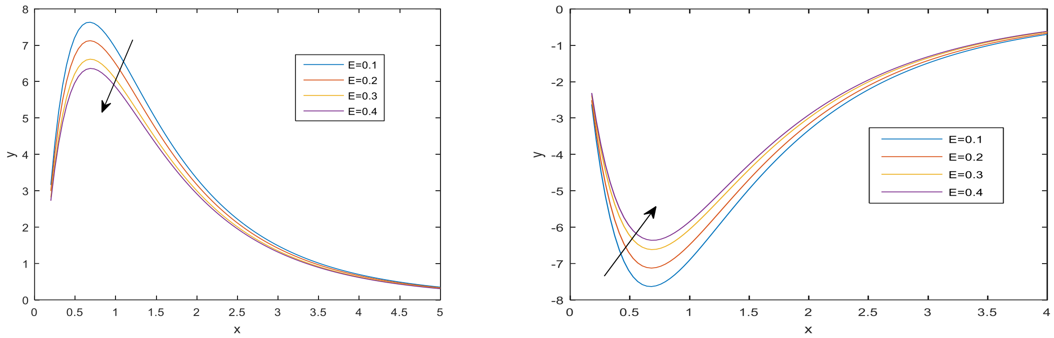

FIGURE 3: *Velocity Profile u and v against Rotation Parameter (E), M=0.5, K=0.5, S=1, Gr=5, G_c=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1, ω=π/6, t=0.1, N=1*

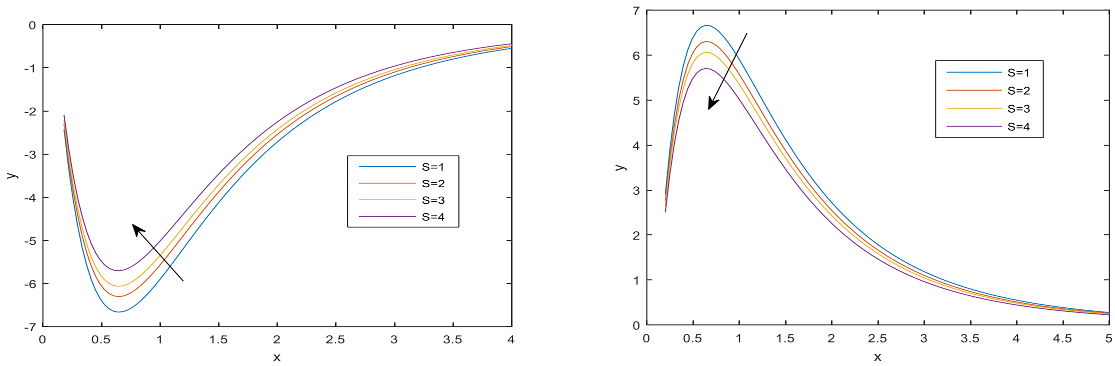

FIGURE 4: *Velocity Profile u and v against Second Grade Parameter (S), M=0.5, K=0.5, E=0.1, Gr=5, G_c=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1, ω=π/6, t=0.1, N=1*

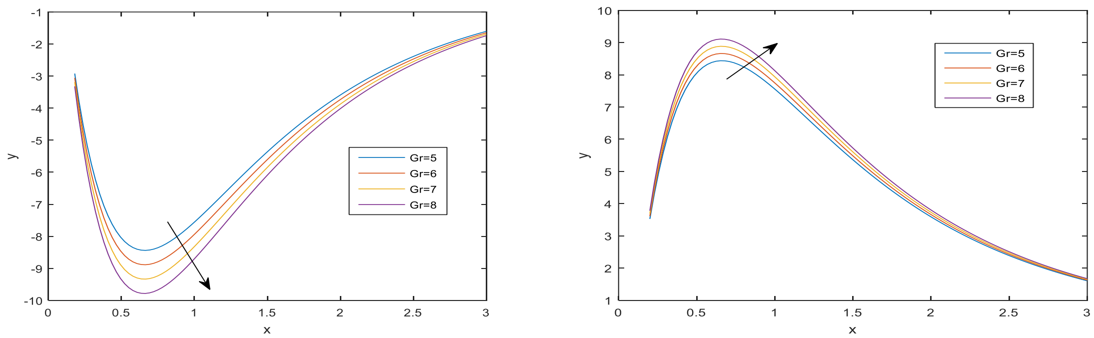

FIGURE 5: *Velocity Profile u and v against Thermal Grashof Number (G_r,) M=0.5, K=0.5, E=0.1, S=1, G_c=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1, ω=π/6, t=0.1, N=1*

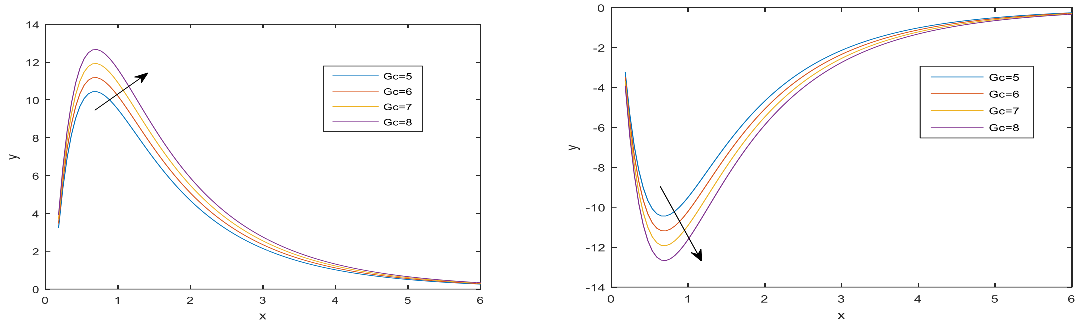

FIGURE 6: *Velocity Profile u and v against Modified Grashof Number (G_c), M=0.5, K=0.5, E=0.1, S=1, Gr=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1, ω=π/6, t=0.1, N=1*

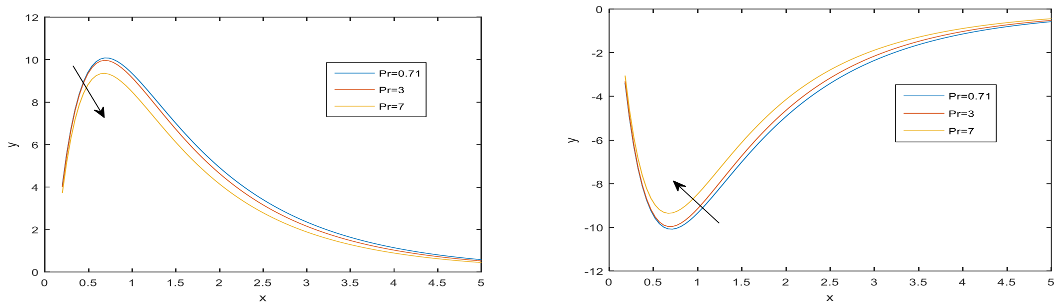

FIGURE 7: *Velocity Profile u and v against Prandtl Number (P_r), M=0.5, K=0.5, E=0.1, S=1, Gr=5, G_c=5, Sc=0.22, Kc=1, ∅=1, ω=π/6, t=0.1, N=1*

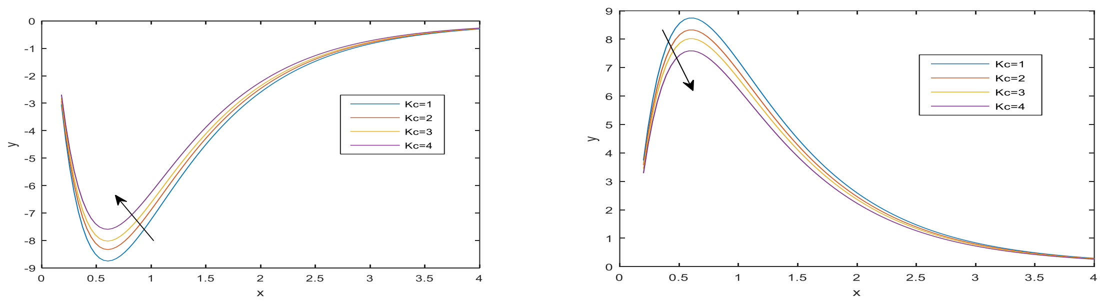

FIGURE 8: *Velocity Profile u and v against Chemical reaction Parameter (K_c), M=0.5, K=0.5, E=0.1, S=1, Gr=5,G_c=5, Pr=0.71, Sc=0.22, ∅=1, ω=π/6, t=0.1, N=1*

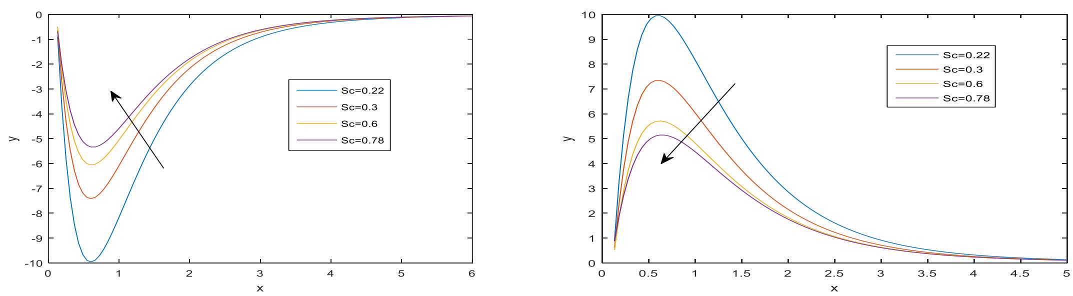

FIGURE 9: *Velocity Profile u and v against Schmidt Number (S_C), M=0.5, K=0.5, E=0.1, S=1,Gr=5,G_c=5, Pr=0.71, Kc=1, ∅=1, ω=π/6, t=0.1, N=1*

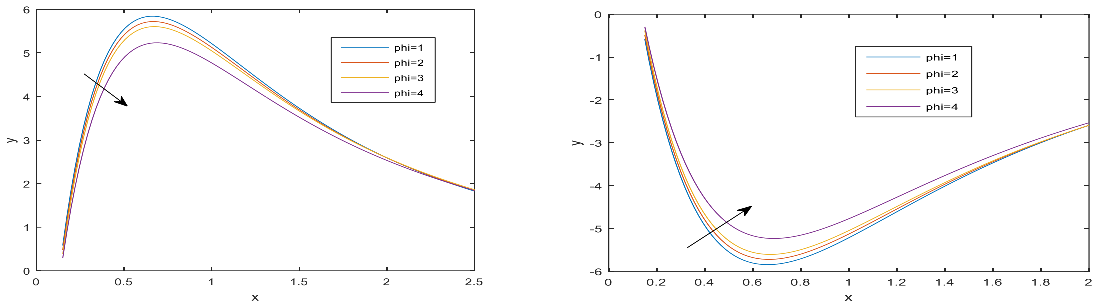

FIGURE 10: *Velocity Profile u and v against Heat Absorption parameter (∅), M=0.5, K=0.5, E=0.1, S=1, Gr=5,G_c=5, Pr=0.71, Sc=0.22, Kc=1, ω=π/6, t=0.1, N=1*

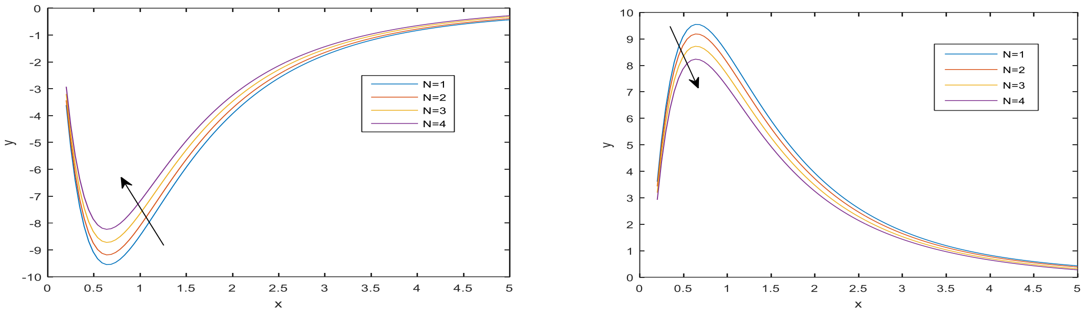

FIGURE 11: *Velocity Profile u and v against Radiation Parameter (N), M=0.5, K=0.5, E=0.1, S=1, Gr=5, G_c=5, Pr=0.71, Sc=0.22, Kc=1, ∅=1, ω=π/6, t=0.1*

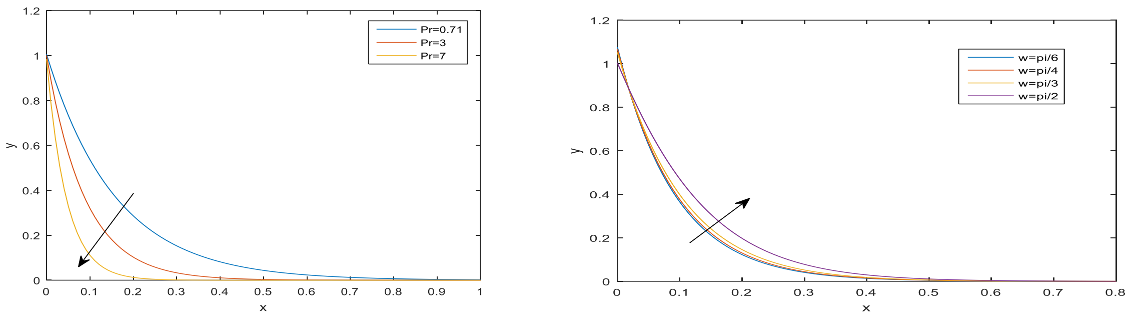

FIGURE 12: *The temperature profiles for θ against P_r and ω with ∅=1, N=1*

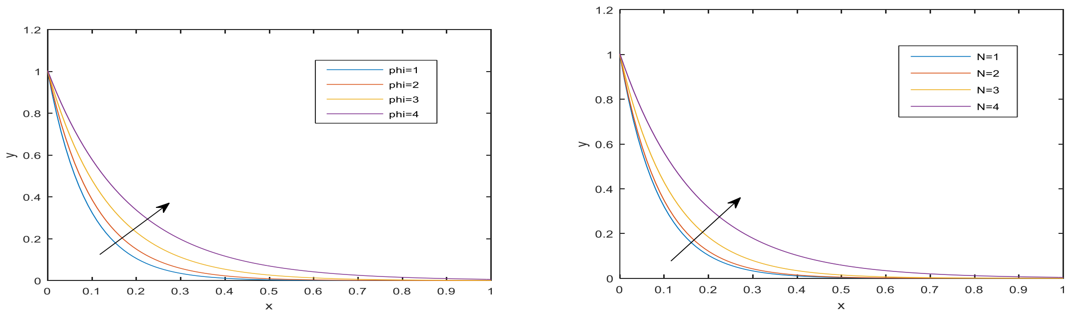

FIGURE 13: *The temperature profiles for θ against ∅ and N with Pr=0.71, ω=π/6*

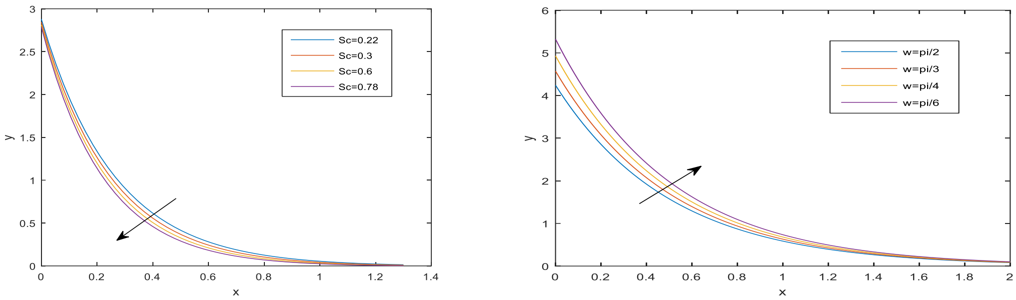

FIGURE 14: *The concentration profiles for* $\emptyset$ *against* ω *and* Sc *with S=1, Pr=0.71, Kc=1, N=0.1*

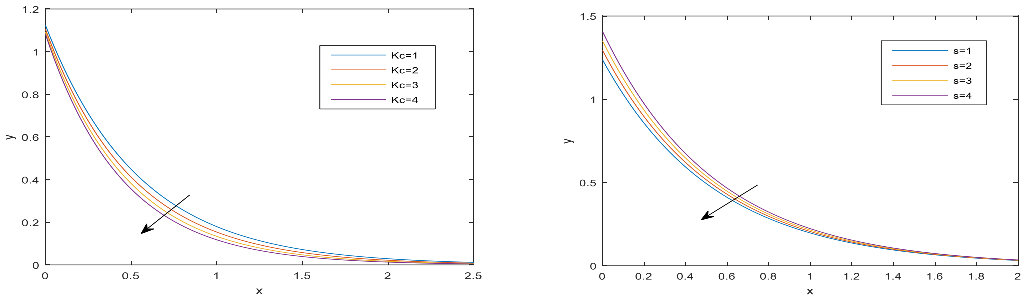

FIGURE 15: *The concentration profiles for* $\emptyset$ *againsts and* Kc *with Pr=0.71, Sc=0.22,* $\omega=\pi/6$*, N=0.1*

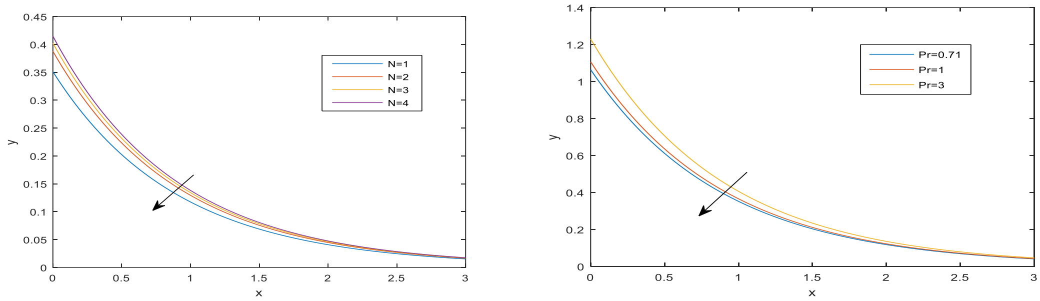

FIGURE 16: *The concentration profiles for* $\emptyset$ *against* N *and* Pr*with S=1, Sc=0.22, Kc=1,*$\omega=\pi/6$

Table (1) represents the skin-friction values of τ_{xz} andτ_{yz}. The negative value in this table has a phase lag which increase of non-dimensional parameters such as Hartmann Number, Thermal Grashof number, Chemical Reaction parameter, Heat Absorption Number and decreases in the terms of permeability parameter, rotation parameter, second Grade parameter, Modified Grashof Number, Prandtl Number, and Schmidt Number. Table (2) shows that increase in Prandtl number and radiation parameter and then decrease the frequency of the oscillation and heat absorption parameter in the Nusselt number. Table (3) represent the Sherwood number which increases in the second-grade fluid, Prandtl number and radiation parameter then decreasing the frequency of the oscillation, chemical reaction parameter and Schmidt number.

Table 1: *Skin Friction*

M	K	E	S	G_r	G_c	P_r	K_c	S_c	Ø	τ_{xz}	τ_{yz}
1	0.5	0.1	1	5	5	0.71	1	0.22	0.1	0.341090	-0.341090
1.5	0.5	0.1	1	5	5	0.71	1	0.22	0.1	0.343973	-0.343973
0.5	**1**	0.1	1	5	5	0.71	1	0.22	0.1	0.288934	-0.288934
0.5	**1.5**	0.1	1	5	5	0.71	1	0.22	0.1	0.273677	-0.273677
0.5	0.5	**0.2**	1	5	5	0.71	1	0.22	0.1	0.288934	-0.288934
0.5	0.5	**0.3**	1	5	5	0.71	1	0.22	0.1	1.273677	-1.273677
0.5	0.5	0.1	**2**	5	5	0.71	1	0.22	0.1	0.259084	-0.259084
0.5	0.5	0.1	**3**	5	5	0.71	1	0.22	0.1	0.193241	-0.193241
0.5	0.5	0.1	1	**6**	5	0.71	1	0.22	0.1	0.332806	-0.332806
0.5	0.5	0.1	1	**7**	5	0.71	1	0.22	0.1	0.342457	-0.342457
0.5	0.5	0.1	1	5	**6**	0.71	1	0.22	0.1	0.359988	-0.359988
0.5	0.5	0.1	1	5	**7**	0.71	1	0.22	0.1	0.099668	-0.099668
0.5	0.5	0.1	1	5	5	**3**	1	0.22	0.1	0.198952	-0.198952
0.5	0.5	0.1	1	5	5	**7**	1	0.22	0.1	0.257975	-0.257975
0.5	0.5	0.1	1	5	5	0.71	**2**	0.22	0.1	0.215539	-0.215539
0.5	0.5	0.1	1	5	5	0.71	**3**	0.22	0.1	0.246063	-0.246063
0.5	0.5	0.1	1	5	5	0.71	1	**0.3**	0.1	0.173594	-0.173594
0.5	0.5	0.1	1	5	5	0.71	1	**0.4**	0.1	0.317088	-0.317088
0.5	0.5	0.1	1	5	5	0.71	1	0.22	**0.2**	0.310175	-0.310175
0.5	0.5	0.1	1	5	5	0.71	1	0.22	**0.3**	0.322424	-0.322424

Table 2: *Nusselt Number*

P_r	Ø	ω	N	N_u
0.71	1	$\pi/6$	0.1	0.2172
3	1	$\pi/6$	0.1	0.2698
7	1	$\pi/6$	0.1	0.6113
0.71	**2**	$\pi/6$	0.1	0.5056
0.71	**3**	$\pi/6$	0.1	-0.5136
0.71	1	$\boldsymbol{\pi/4}$	0.1	0.2148
0.71	1	$\boldsymbol{\pi/2}$	0.1	0.2113
0.71	1	$\pi/6$	**0.2**	0.3183
0.71	1	$\pi/6$	**0.3**	0.8060

Table 3: *Sherwood Number*

ω	K_c	S_c	S	P_r	N	S_H
$\pi/6$	1	0.22	1	0.71	0.1	-0.1698
$\boldsymbol{\pi/4}$	1	0.22	1	0.71	0.1	-0.1737
$\boldsymbol{\pi/2}$	1	0.22	1	0.71	0.1	-0.1846

$\pi/6$	**2**	0.22	1	0.71	0.1	9.9339
$\pi/6$	**3**	0.22	1	0.71	0.1	-5.6030
$\pi/6$	1	**0.3**	1	0.71	0.1	2.7124
$\pi/6$	1	**0.6**	1	0.71	0.1	-14.0850
$\pi/6$	1	0.22	**2**	0.71	0.1	0.6050
$\pi/6$	1	0.22	**3**	0.71	0.1	1.3799
$\pi/6$	1	0.22	1	**3**	0.1	-1.3229
$\pi/6$	1	0.22	1	**7**	0.1	-2.3179
$\pi/6$	1	0.22	1	0.71	**0.2**	-0.2405
$\pi/6$	1	0.22	1	0.71	**0.3**	-0.3286

CONCLUSION

An unsteady MHD second grade fluid in a porous medium under the influence of magnetic field in a parallel plate has been taken into an account and obtained the following results as follows:

- The velocity profile increases in Hartmann number because of Lorentz force, thermal Grashof number based on its buoyancy force, modified Grashof number.

- The velocity profile decreases with permeability parameter in terms of porous channel, rotation parameter in which high rotation rate takes place, second grade fluid, Prandtl number, chemical reaction parameter, Schmidt number, heat absorption parameter, radiation parameter.

- The temperature profile increases based upon heat absorption parameter, ω, radiation parameter and decreases due to Prandtl number.

- The concentration profile increases in terms of ω and decreases with second grade fluid, Prandtl number, chemical reaction parameter, Schmidt number, radiation parameter.

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