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RESEARCH ARTICLE

Hall Effect on MHD Flow of a Visco-Elastic Fluid through Porous Medium Over an Infinite Vertical Porous Plate with Heat Source

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ABSTRACT

In this article, we've studied the unsteady movement of an incompressible viscoelastic fluid (Walter's B) in conjunction with the heat transfer near an oscillating plate that incorporates a porous channel taking the current into consideration. When the governing equations are broken into small segments and the problem has a small elasticity, a perturbation procedure is applied to each segment. Main, secondary, and transverse velocity, have been analytically and computationally studied using graphs as well as with relation to the skin-friction data, and mathematical functions.

Keywords: Hydromagnetic, Viscoelastic, Hall Effect, Porous medium, Slip-flow regime, heat generation.

INTRODUCTION

Applied by a vast numbers of researchers to this slip-flow model is the idea that several different values are approached when using differing products and procedures, it's because of this broad range of applications that people have seen. During this modern times of complex technology and rapid industrialization, societal and global change, knowing how to maximise the flow of information becomes ever more critical. Any particles located on a surface move at the same speed with respect to the surface (it no longer matters whether it is fluid or solid) The electron on the particle's surface has a tangential velocity that can be calculated; it skips around the surface. One of the assumptions behind expandable sets is that slip must be considered, and cannot be overlooked. Often known as “thin film hydrophobic coat on moving plate", "nano-membrittainleylic hydrophobic coating of the body", is the slippage phenomenon at the solid boundary seen in micro channels and thin oil films of light oils or light hydrophobic coatings applied to items, where the surface is treated with monolayer hydrophobic coating. Free convection past a semi-infinite semi-infinite semi-conducting, viscous fluid surface with an aligned magnetic and latent heat mechanism while passing over an infertile, compared to all authors in Alam et al. [2] which compared free convection in the influence and mass transfer over a surface on electrically conducting and nonviscous viscous in the presence of a magnetic flow. Kesava and Venkavulu studied unsteady Couette radiative mass transfer in semi-infinite vertical channel with heat absorption, Chamkha explored convective heat and chemical reaction in vertical porous plates. The invention of impulsively initiated plates to deal with expansion and resistance-visc heat and mass transfer has been classed as the vertically limitless plate inelastic-viscs heat and mass tramp fluid they found (1982) that Derek, et al. (1982) researched the apparent fluid slippage at the hydrophobic channels, meaning, is the presence of a thin layer of lubricant on the outer surface of another item or on the working surface of a system which there is apparent slip of a lubricant (sliding over another), where the surfaces are oiled to reduce friction and similar studies found that heat and mass transfer occur in a viscoelastic fluid as a volumically driven horizontal flow through a catalytic reactor with chemical reaction to be inconsistent with an assumed non-elasticity The authors Hady and associates [8] studied the issue of free convection through vertically-embedded wavy channels embedded in conducting media that are concentrated or actively absorbing heat, particularly in the presence of internal generation of said to be fully or distribution of an impact for moisture, for his doctoral dissertation. Hossein and his colleagues [9] investigated the issue of natural convection occurring in vertical laminar fashion on a wavy surface with a surface that generates or absorbs heat uniformly. in a paper presented in "Flow of a viscoel fluid between coaxial rotating discs at uniform pressure or pressure injection," "Flow of a viscoel fluid between coaxial rotating discs,"

The most numerous instances in which convective flows provide both thermal and mass transfer to occur with a magnetic forces under the control of a reaction is in the research and engineering divisions are in the transport applications. This phenomenon has significant applications in the drying of solvents, the fabrication of metal vapour deposition, chemical vapour deposition of surfaces, and cooling of nuclear reactors, as well as in the power and refrigeration industries. Consequently, on account of natural convection, temperatures becoming lower, density increasing is a lot. A variation in temperature may cause certain concentrations to expand or contract. For example, flow is caused by changes in temperature as well as in the environment as well as a difference in concentration in water vapour concentrations in the atmosphere. Khalid and Vafai developed an expression for free convection in the unsteady, nonlinear magnetohydrostatic field for periodical and constant velocity, Jain and Gupta examined unsteady unsteady unsteady convection in the flow-expand regime, and Vaimationarity with variable permeability, and constant heat flux, and V for steady state and flux, and Vafai found an expression for unsteady regular magnetohydrodynamic field for constant and periodic flows. Flow over a channel with permeable boundaries having been explored by Makind and Osalusi [see Makind-Osalusi (2011, Chapter 11) for a discussion of slip conditions] slip and concentration tested the idea of flow across porous media by means of both, and Mansour et al. [14] performed the tests of convective micro-micropicity over temperature and concentration. Dong et al. [15] have analysed the slippage in Couette flow with regard to its affect on the plate motion helical rod, with unsteady convective heat and mass transfer in a vertical column with Viscoelastic flow has been covered by Mehmood and Ali in the Mehmood and associates' article 'Progress in Thermal Analysis of Viscoelastic Flow through Helical Rods' and by Mohiddin and associates (or Mohiddin et al.). Because irradiation of unsteady fluid flows may potentially occur in a turbulent shear cases with a heated surface, Srinathuni Lavanya et al. [18] stated that the impact of radiation on the unsteady convection of viscous MHD flows in unsteady shear MHD flow has also to be investigated. two impermeable planar-parallel media. Prasuna et al. [19] studied an unsteady flow of a viscoelastic fluid that flows across a porous medium from two impermeable plates. Using the unsteady viscoel MHD flow from Oldroyd in a flow streamtube apparatus, Rahmann and Sarkar [20] examined unsteady MHD motion in a channel with a rectangular cross-channel sensor system.

Oil, some silicone solution, some stains, as well as certain synthetic polymers, and many of the latest compounds are thinning liquids, although many of the older compounds show different characteristics, in particular viscosity. Due to the aforementioned, the visco-elastic nature of these fluids, there is a good deal of study being done on them. it has been seen in fluid flowing from a thin plate with an infinite/semi-compressible viscous wall to a thick plate without altering the speed of the movement of the viscous fluid Effervescent fluid flow has caught the interest of scientists and engineers because of its notable use in the movement of oil through porous rocks, the processing of energy from geothermal resources, the production of effluents from landfills, and the flow of solids through porous media for human administration, as well as skin-derived substances. Conventional recovery techniques work for water miscible fluids cannot be used for the separation of crude oil from reservoir rocks as effectively as with natural crude oils. Ground water and runoff issues often affect adsorption and filtration. to Rajagopallis, who expanded the Walter model, which is in the forced convection of a viscoelastic fluid, Rajagari [21]looked the heat transfer. Rajagasthan [22] conducted extensive studies on the electric oscillation of viscoelastic fluids in a saturated porous medium over stretching, with the medium in an oscillatory state. Mallikarjuna Reddy et al. [23] has included unsteady convective viscous free-diffusion past an infinite vertical plates in the scope of results generated by radiation and diffusion on a field visco-porous heat source, and Sharma [24] addressed unsteady viscous unstressed convective fluid flow in an immiscible flow that operates in a transd cyclic regime with periodic heat source application. Via viscoelastic movement, Singh and Oldroyd [25] via viscoelastic (RMP) flow of a dusty fluid in a parallel configuration, Singh and Singh [study MHD flow of a viscoelastic (PA) fluid) between two plates tilted to the horizon] It is not possible to ignore the Hall current's influence on the magnetic field intensity when the strength of the magnetic is high. it is important to learn how the influence of stream flow resistance on the outcome of hydro-dynamic problems is. Rashidic and Kumar [26] investigated the exact solution of an oscillatory MHD flow through a porous medium situated in a revolving channel that is bounded by a porous wall to see whether it exhibited existing blockage. The slip flow regime can also occur in the working fluid containing concentrated suspensions Soltani and Yilmazer [27]. Chenna Kesavaiah et. al. [28] has been studied The results of a chemical reaction on MHD flow in a vertical tube on a porous medium Bhavana and Chenna Kesavaiah [29] has been discussed perturbation solution for thermal diffusion and chemical reaction effects on MHD flow in vertical surface with heat generation, In the experiments described here, unsteady fluid flow was driven past an infinite-porosity vertical plate at a given rate, through a porous media with differing flow generation coefficients were combined with heat generation, and thus a particular emphasis was placed on understanding the effect of those on the unsteadiness.

Mathematical Formulation

We consider the unsteady flow of a viscous incompressible and electrically conducting visco - elastic fluid with oscillating temperature and heat generation taking in to an account. The flow occurs over an infinite vertical porous plate. The x^*-axis is assumed to be oriented vertically upwards along the plate and y^*-axis is taken normal to the plane of the plate. It is assumed that the plate is electrically non-conducting and a uniform magnetic field of strength B_0 is applied normal to the plate. The induced magnetic field is assumed to be negligible so that $\vec{B}(0, B_0, 0)$. The plate is subjected to a constant suction velocity V_0.

The constitutive equations for the theological equation of the state for the visco-elastic fluid (Walter's liquid B') are:

$$p_{ik} = pg_{ik} + p^*_{ik} \tag{1}$$

$$p_{ik} = 2\int_{-\infty}^{t} \psi\left(t-t^*\right) e^{(1)}_{ik}\left(t^*\right) dt^* \tag{2}$$

In which $\psi\left(t-t^*\right) = \int_{-\infty}^{t} \frac{N(\tau)}{\tau} e^{\left[\left(t-t^*\right)/\tau\right]} d\tau$

$N(\tau)$ is the distribution function of relaxation times τ. In the above equation p_{ik} is the stress tensor, p is an arbitrary isotropic pressure, g_{ik} is the metric tensor of a fixed coordinate system x_i, and $e_{ik}^{(1)}$ is the rate of strain tensor. It was shown by Walters [30] that equation (2) can be put in the following generalized form which is valid for all types of motion and stress

$$p^{*ik}\left(x,t\right)=2\int_{-\infty}^{t}\psi\left(t-t'\right)\frac{\partial x^{i}}{\partial x^{*m}}\frac{\partial x^{k}}{\partial x^{*\tau}}e^{[1]m\tau}\left(x,t\right)dt^{*} \quad (3a)$$

where x^{*i} is the position at times t^{*} of the element which is instantaneously at the point x^{i} at the time t. The fluid with equation of the state (1) to (3a) has been designated as the liquid B'. In the case of the liquid with short memories i.e. short relaxation times, the above equation can be written in the following simplified form:

$$p^{*ik}\left(x,t\right)=2\eta_0 e^{[1]ik}-2k_0\frac{\partial e^{(1)ik}}{\partial t} \quad (3b)$$

In which $\eta_0=\int_0^{\infty}N\left(\tau\right)d\tau$ is limiting viscosity at the small rates of shear,

$k_0=\int_0^{\infty}\tau N\left(\tau\right)d\tau$ and $\frac{\partial}{\partial t}$ denotes the convicted time derivative.

The equation of conservation of electric charge is $\Delta.\vec{j}=0$ which gives $j_y^{*}=$constant, where $\vec{j}=\left(j_x^{*},j_y^{*},j_z^{*},\right)$.

Since the plate is electrically non-conducting, $j_y^{*}=0$ and is zero everywhere in the flow. Considering the magnetic field strength to be very large the generalized Ohm's laws including Hall current, in the absence of electric field neglecting the ion-slip and thermo electric effect takes the following form

$$\vec{j}+\frac{\omega_e\tau_e}{B_0}\left(\vec{j}\times\vec{B}\right)=\sigma\left(\vec{V}\times\vec{B}\right) \quad (4)$$

Where $\vec{V}$ is the velocity vector, ω_e is the electron frequency, σ is electrical-conductivity and τ_e is the electron collision time and

$$j_x^{*}=\frac{\sigma B_0}{1+m^2}\left(mu^{*}-w^{*}\right)$$

$$j_z^{*}=\frac{\sigma B_0}{1+m^2}\left(mu^{*}-w^{*}\right)$$

where $m=\omega_e\tau_e$ is the hall current parameter

Since the plate is infinite in extent all physical quantities are the function of y^{*} and t^{*} only. Thus the governing equations of flow under the usual Boussinesq approximation are:

$$\frac{\partial v^{*}}{\partial y^{*}}\Rightarrow v^{*}=-V_0 \quad (5)$$

$$\frac{\partial u^{*}}{\partial t^{*}}+v^{*}\frac{\partial u^{*}}{\partial y^{*}}=\nu\frac{\partial^2 u^{*}}{\partial y^{*2}}-k_0\frac{\partial^3 u^{*}}{\partial y^{*2}\partial t^{*}}-\frac{\sigma\mu_e^2 H_0^{\,2}}{\rho}\left(u^{*}-mw^{*}\right)+g\beta\left(T^{*}-T_\infty^{*}\right)-\frac{\nu}{k^{*}}u^{*} \quad (6)$$

$$\frac{\partial w^{*}}{\partial t^{*}}+v^{*}\frac{\partial w^{*}}{\partial y^{*}}=\nu\frac{\partial^2 w^{*}}{\partial y^{*2}}-k_0\frac{\partial^3 w^{*}}{\partial t^{*}\partial y^{*2}}-\frac{\sigma\mu_e^2 H_0^{\,2}}{\rho}\left(w^{*}-mu^{*}\right)-\frac{\nu}{k^{*}}w^{*} \quad (7)$$

$$\frac{\partial T^*}{\partial t^*}+v^*\frac{\partial T^*}{\partial y^*}=\frac{k}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{Q_0}{\rho C_p}\left(T^*-T^*_\infty\right) \quad (8)$$

The boundary conditions are

$$\begin{aligned} &u^*=L^*\left(\frac{\partial w^*}{\partial y^*}\right), w^*=L^*\left(\frac{\partial w^*}{\partial y^*}\right), T^*=T^*_\infty+\left(T^*_w-T^*_\infty\right)e^{i\omega^* t^*} \quad at \;\; y^*=0 \\ &u^*\to 0, w^*\to 0, T^*\to T^*_\infty \qquad at \;\; y^*\to\infty \end{aligned} \quad (9)$$

Now we introduce the following non–dimensional parameters as follows:

$$\begin{aligned} &\eta=\frac{v_0}{v}y^*,\; t==\frac{v_0{}^2 t^*}{4v},\;\; u=\frac{u^*}{v_0},\;\; w=\frac{w^*}{v_0},\;\; \theta=\frac{T^*-T^*_\infty}{T^*_w-T^*_\infty} \\ &Gr=\frac{v\beta g\left(T^*_w-T^*_\infty\right)}{v_0{}^3},\qquad \Pr=\frac{v\rho C_p}{k},\qquad \phi=\frac{vQ_0}{\rho C_p v_0{}^2} \\ &\omega=\frac{4vw^*}{v_0{}^2}, h=\frac{v_0 L^*}{v}, M=\frac{\sigma B_0{}^2 v}{\rho v_0{}^2}, K=\frac{k^* v_0{}^2}{v^2},\;\; \alpha=\frac{k_0 v_0{}^2}{4v^2} \end{aligned} \quad (10)$$

where θ the dimensional less temperature is, Gr is the Grashoff number, M is the Hartmann number, $\Pr$ is the Prandtl number, α is the visco-elastic parameter, ω is the frequency of the oscillations, h is the slip parameter. $T_\infty{}'$ denotes the temperature of the fluid far away from the plate, $T_w{}'$ denotes the temperature of the fluid at the plate, K is the thermal conductivity, C_p is the specific heat at constant pressure, ρ is the density of the fluid, β is the volumetric coefficient of thermal expansion, g is the acceleration due to gravity, v is the molecular diffusivity, ϕ is heat generation and L^* is the characteristics length of the plate.

Equations (6) to (8) reduce to

$$\frac{1}{4}\frac{\partial u}{\partial t}+v^*\frac{\partial u}{\partial \eta}=\frac{\partial^2 u}{\partial \eta^2}-\alpha\frac{\partial^3 u}{\partial \eta^2\partial t}-\frac{M}{1+m^2}\left(mw+u\right)+Gr\theta-\frac{u}{K} \quad (11)$$

$$\frac{\partial w^*}{\partial t^*}+v^*\frac{\partial w^*}{\partial y^*}=v\frac{\partial^2 w^*}{\partial y^{*2}}-k_0\frac{\partial^3 w^*}{\partial t^*\partial y^{*2}}-\frac{\sigma\mu_e^2 H_0{}^2}{\rho}\left(w^*-mu^*\right)-\frac{v}{k^*}w^* \quad (12)$$

$$\frac{\partial T^*}{\partial t^*}+v^*\frac{\partial T^*}{\partial y^*}=\frac{k}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{Q_0}{\rho C_p}\left(T^*-T^*_\infty\right) \quad (13)$$

The corresponding boundary conditions become

$$\begin{aligned} &u=h\left(\frac{\partial u}{\partial \eta}\right), w=h\left(\frac{\partial w}{\partial \eta}\right), \theta=e^{i\omega t} \quad at \;\; \eta=0 \\ &u\to 0, \qquad w\to 0, \qquad \theta\to 0 \;\; at \;\; \eta\to\infty \end{aligned} \quad (14)$$

Method of Solution

Introducing $q = u(\eta, t) + iw(\eta, t)$ and $i = \sqrt{-1}$, the equations (11) and (12) transform to

$$\frac{1}{4}\frac{\partial q}{\partial t} - \frac{\partial q}{\partial \eta} = \frac{\partial^2 q}{\partial \eta^2} - \alpha \frac{\partial^3 q}{\partial t \partial \eta^2} - \frac{M}{1+m^2}(1-im)q - \frac{q}{K} + Gr\theta \quad (15)$$

The corresponding boundary conditions become

$$q = h\left(\frac{\partial q}{\partial \eta}\right), \theta = e^{i\omega t} \quad at \;\; \eta = 0$$
$$q \to 0, \qquad \theta \to 0 \quad at \; \eta \to \infty \quad (16)$$

In order to solve the equations (13) and (15) under the boundary conditions (16), we assume

$$q(\eta, t) = q_0(\eta)e^{i\omega t} \quad and \quad \theta(\eta, t) = \theta_0(\eta)e^{i\omega t} \quad (17)$$

Substituting (17) into equations (13), (15) and (16), we obtain

$$(1 - iA)q_0''(\eta) + q_0'(\eta) - [a_1 + i\,a_2]q_0(\eta) = -Gr\,\theta_0(\eta) \quad (18)$$

$$\theta_0''(\eta) + \Pr\theta_0'(\eta) - \left(\frac{i\omega\Pr}{4} + \phi\Pr\right)\theta_0(\eta) \quad (19)$$

The corresponding boundary condition reduce to

$$q_0 = h\left(\frac{\partial q_0}{\partial \eta}\right), \theta_0 = 1 \quad at \;\; \eta = 0$$
$$q_0 \to 0, \qquad \theta_0 \to 0 \quad at \; \eta \to \infty \quad (20)$$

Solving equations (18) and (19) under the boundary conditions (20) and using (17), we have

$$q(\eta, t) = \left[(a_{15} + i\,a_{16})e^{(a_3 + i\,a_4)\eta} - (a_1 + i\,a_2)e^{(a_5 + i\,a_6)\eta}\right]e^{i\omega t} \quad (21)$$

$$\theta(\eta, t) = \left[\Pr + \sqrt{\Pr^2 + (\phi\Pr + i\omega\Pr)}\right]e^{i\omega t - \frac{\eta}{2}} \quad (22)$$

Since $q = u(\eta, t) + iw(\eta, t)$, therefore from equation (21) we get

$$u(\eta, t) = e^{-a_3\eta}\left\{a_{15}\cos(\omega t - a_4\eta) + a_{16}\sin(\omega t - a_4\eta)\right\}$$
$$- e^{-a_5\eta}\left\{a_9\cos(\omega t - a_6\eta) + a_{10}\sin(\omega t - a_6\eta)\right\} \quad (23)$$

$$w(\eta, t) = e^{-a_3\eta}\left\{a_{15}\sin(\omega t - a_4\eta) + a_{16}\cos(\omega t - a_4\eta)\right\}$$
$$- e^{-a_5\eta}\left\{a_9\sin(\omega t - a_6\eta) + a_{10}\cos(\omega t - a_6\eta)\right\} \quad (24)$$

Separating (22) into real and imaginary parts, the real part is given by

$$\theta_r(\eta, t) = \cos\left[\omega t - \frac{\eta}{2}R_1\sin\frac{\beta_1}{2}\right]e^{\frac{\eta\left(\Pr + R_1\cos\frac{\beta_1}{2}\right)}{2}} \quad (25)$$

Skin-friction

The axial component of the skin friction at plate for primary velocity is:

$$\tau_1 = \left(\frac{\partial u}{\partial \eta}\right)_{\eta=0} = \left[\left(a_9 a_5 - a_3 a_{15} - a_4 a_{16} + a_6 a_{10}\right)\cos\omega t + \left(a_{10} a_5 - a_3 a_{16} + a_4 a_{15} - a_6 a_9\right)\sin\omega t\right] \quad (26)$$

The transverse component of the shearing stress at plate for secondary velocity is:

$$\tau_2 = \left(\frac{\partial w}{\partial \eta}\right)_{\eta=0} = \left[\left(a_9 a_5 - a_3 a_{15} - a_4 a_{16} + a_6 a_{10}\right)\sin\omega t + \left(a_3 a_{16} - a_5 a_{10} + a_4 a_{15} + a_6 a_9\right)\cos\omega t\right] \quad (27)$$

RESULTS AND DISCUSSIONS

To demonstrate the effect of different parameters on the velocity and stress profiles in the previous segment, temperature and axial stress were included in the computational solutions for which the numerical model was developed, thus producing velocity and stress profiles that exhibit a particular set of axial and transverse stresses. In the case of the Prandtl series, the increase is set at 3.0, 5.0, and 10. This value of Prandtl 3.0 is equivalent to the one found in Freon. For example, there are several types of CFCs which include Freon in trade and commerce and businesses, and industries that use many CFCs. The exponency of the Prandtl value of 10, denotes a one standard atmosphere of gasoline. tensions have both grown over time In a capricious manner, the values of other parameters are selected. When w varies according to Grashoff number m, Grashoff number u and Prandtl number m, show the variables in (1) to (d) and (1) to (2) for) Grashoff and Hartmann number. These two results indicate a slowdown in primary velocity with an increase in Grashoff number, and an increase in Hartman number, but an increased current in the secondary velocity with the moment current for the expansion design generated by Grashoff, Hall, and a slower primary velocity for the design with the Prandtl phenomenon. Figures 1 (e) to (f) and 2 (e) demonstrate the influence of the visco-elasticity parameter on the main and secondary velocities. (figs. 1: uniform 2: comparing two different values). The stress distribution may be reduced by making Figure 1(e) clearly illustrates that secondary flow is amplified when the viscosity parameter is increased (Moving away from the plate produces stress in other places.) Additional decrease in slip velocity was observed at the original slip to improve flow while preserving primary velocity was revealed in these estimates. The secondary velocity is seen to decrease with the rise in the viscous and slip variables are made more obvious in Figure 2 (e). as colours that which change for Figures 1 (h) with C and and the colour changes in Figures 2 (g) are plotted according to K and the above pictures can be seen in the diagrams shown (h). It is observed from these examples that the primary velocity drops with the rise in porous medium permeability K, but the secondary velocity increases with the rising frequency parameter X. In the figure, figures 3 (A) to (C), you will see that as the Prandtl number increases, the number of oscillations decreases, and heat production slows down. On the rise in frequency, however, a change in temperature is detected. Also, on the curve, it is discovered that the high temperatures occur approximately at and then begin to decrease. Tables (or on page 2) show how the axial stress and transverse stress vary depending on the Grashoff number, Hall parameter, and Hartmann number. It can be concluded from these measurements that increasing Prandtl number ultimately induces axial stress and subsequently decreases it. In the other hand, something else, the other dimensions are expanding. Table (2) illustrates the inverse relationship between Prandtl number and Hartmann tension, but, Grashoff and Hall Current seem to raise stress. Relaxation of the viscoelastic and translatory tension are shown in table (3) and K for viscoelastic and K for visicoelastic and media respectively. The viscoelastic stress increases with anisotropic parameter, however the slip parameter and anisotropic stress decrease with the viselporous parameter. The permeability of the porous media, resulting in a negative shear stress, interferes and expands the overall stress on the portion

CONCLUSIONS

The findings of the analysis lead to the following prediction: As the Hall current parameter is raised, the secondary velocity reduces, but the Grashoff numbers rise. An interesting fact to consider is that in relation to Non-Newtonian fluids is that the primary velocity rises while remaining constant when you move away from the plate, however the secondary velocity declines when you move to another place (3)The primary velocity initially rises, and then decreases when (but is at a lower velocity) as it moves from the slip regime into the flow regime. In relation to flow in slip-flow, the secondary velocity profiles decrease. The temperature rises steadily over the first few degrees and quickly gets lower, and by a steep slope afterwards. As opposed to the Non-Newtonian fluids, the axial tension is elevated for the Newtonian fluids. As no-slip velocity is applied, the axial stress is lower but the transverse stress is higher.

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APPENDIX

$$a_1 = \frac{M}{1+m^2} + \frac{1}{K},\ a_2 = \frac{\omega}{2} - \frac{mM}{1+m^2},\ a_3 = \frac{1 + R_2\cos\left(\frac{\beta_2}{2}\right) - R_2 A\sin\left(\frac{\beta_2}{2}\right)}{2\left(1+A^2\right)}$$

$$a_4 = \frac{A + R_2 A\cos\left(\frac{\beta_2}{2}\right) + R_2 A\sin\left(\frac{\beta_2}{2}\right)}{2\left(1+A^2\right)},\ a_5 = \frac{1}{2}\left[\Pr + R_1\cos\left(\frac{\beta_2}{2}\right)\right]\ a_6 = \frac{1}{2}\left[R_1\sin\left(\frac{\beta_1}{2}\right)\right]$$

$$a_7 = a_5^{\,2} - a_6^{\,2} + 2Aa_5a_6 - a_1 - a_5,\ a_8 = 2a_5a_6 - a_2 - a_6 + Aa_5^{\,2} + Aa_6^{\,2},\ a_9 = \left(\frac{a_7}{a_7^{\,2} + a_8^{\,2}}\right)$$

$$a_{10} = Gr\left(\frac{a_8}{a_7^{\,2} + a_8^{\,2}}\right),\ a_{11} = a_5a_9 + a_6a_{10},\ a_{12} = a_6a_9 - a_5a_{10},\ a_{13} = a_9 + ha_{11}\ a_{14} = a_{10} - ha_{12},$$

$$a_{15} = \frac{a_{13} + h(a_3a_{13} - a_4a_{14})}{(1+ha_3)^2 + (ha_4)^2},\ a_{16} = \frac{a_{14} + h(a_4a_{13} + a_3a_{14})}{(1+ha_3)^2 + (ha_4)^2}\ \beta_1 = \tan^{-1}\left(\frac{\omega}{\Pr}\right), A = \alpha\omega,$$

$$\beta_2 = \tan^{-1}\left[\frac{4(a_2 - Aa_1)}{1 + 4(a_1 + Aa_2)}\right],\ R_1 = \Pr^{\frac{1}{2}}\left[\left(\Pr^2 + 4\phi\Pr\right) + \omega^2\right]$$

$$R_2 = \left\{\left[1 + 4(a_1 + Aa_2)\right]^2 + 16(a_2 - Aa_1)^2\right\}^{\frac{1}{4}}$$

Table (1): Axial shearing stress τ_1

Gr	$\Pr$	m	M	τ_1
2	3	0.5	5	-0.35
4	3	0.5	5	-0.75
2	10	0.5	5	-0.01
2	2	1.0	5	-0.08
2	2	0.5	5	-0.08
2	2	0.5	10	-0.35

Table 2: Transverse shearing stress τ_2

Gr	$\Pr$	m	M	τ_2
2	3	0.5	5	0.25
4	3	0.5	5	0.52
2	10	0.5	5	0.10
2	2	1.0	5	0.28
2	2	0.5	5	0.31
2	2	0.5	10	0.20

Table 3: Axial shearing stress τ_1

α	h	K	τ_1
0.05	0.2	1.0	-0.038
0	0.2	1.0	-0.038
0.2	0.2	1.0	-0.038
0.05	0	1.0	-0.038
0.05	0.4	1.0	-0.030
0.05	0.2	3.0	-0.042

Table 4: Transverse shearing stress τ_2

α	h	K	τ_2
0.05	0.2	1.0	0.26
0	0.2	1.0	0.26
0.2	0.2	1.0	0.26
0.05	0	1.0	0.42
0.05	0.4	1.0	0.18
0.05	0.2	3.0	0.28

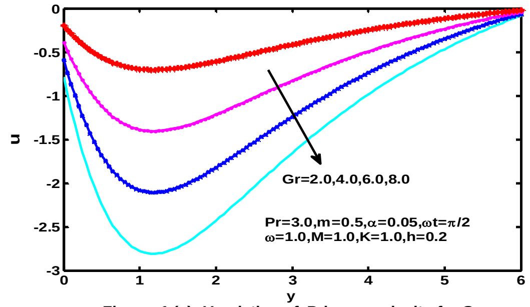

Figure 1 (a): Vaariation of Primary velocity for Gr

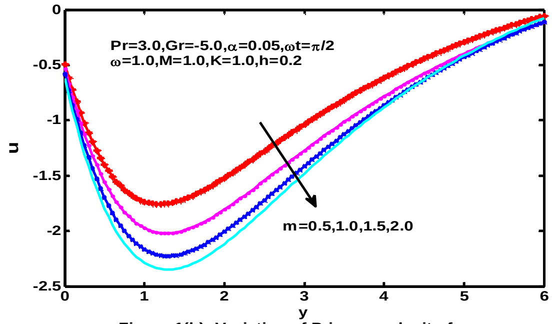

Figure 1(b); Variation of Primary velocity for m

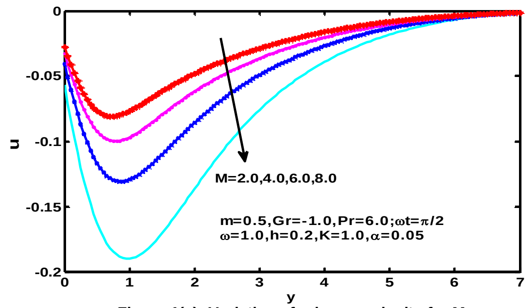

Figure 1(c): Variation of primary velocity for M

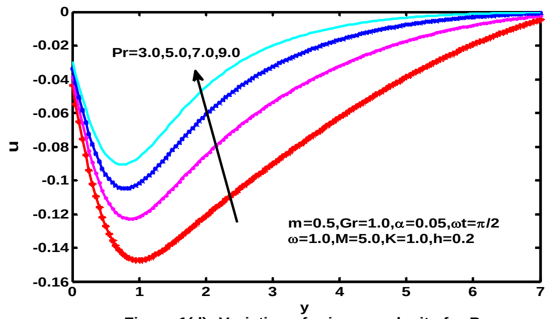

Figure 1(d): Variation of primary velocity for Pr

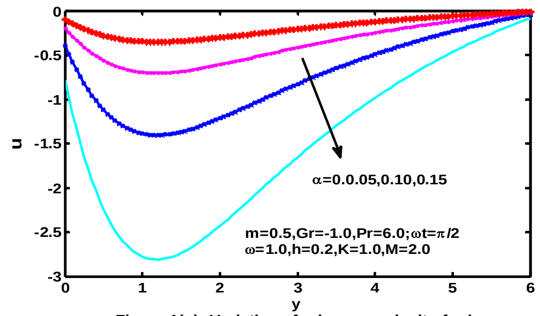

Figure 1(e): Variation of primarya velocity for h

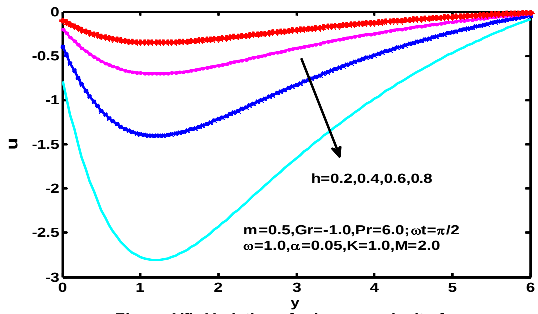

Figure 1(f): Variation of primarya velocity for α

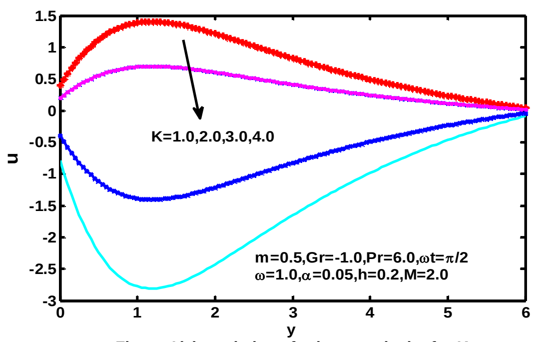

Figure 1(g): variation of primary velocity for K

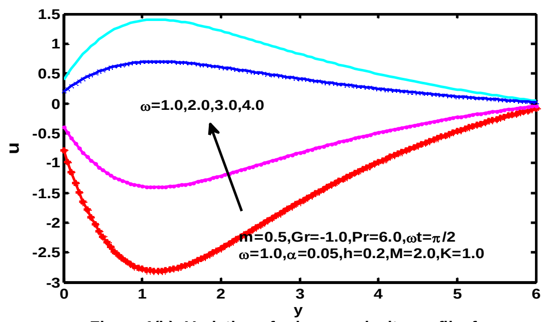

Figure 1(h): Variation of primary velocity profilesfor ω

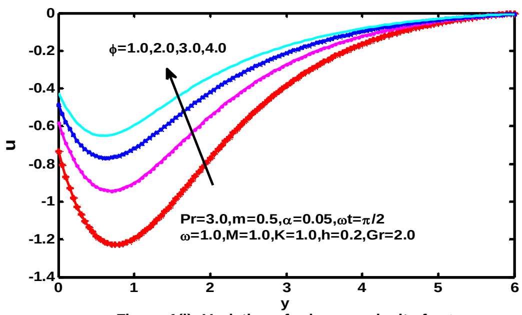

Figure 1(i): Variation of primary velocity for ϕ

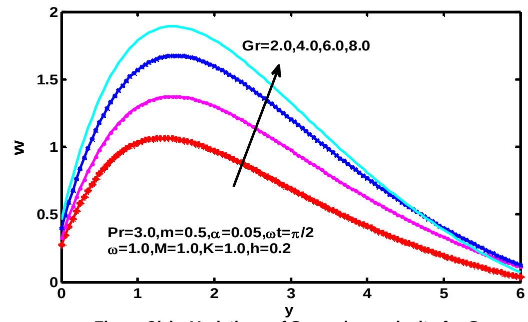

Figure 2(a): Variations of Secondary velocity for Gr

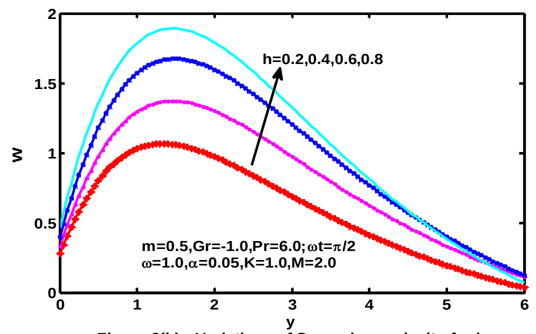

Figure 2(b): Variations of Secondary velocity for h

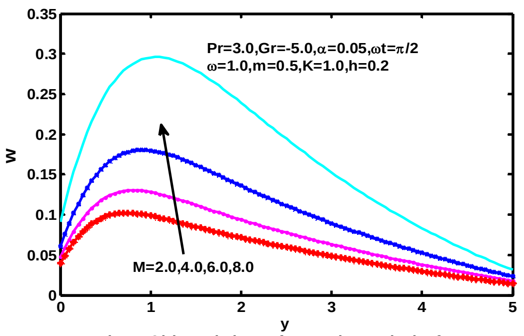

Figure 2(c): Variations of secondary velocity for M

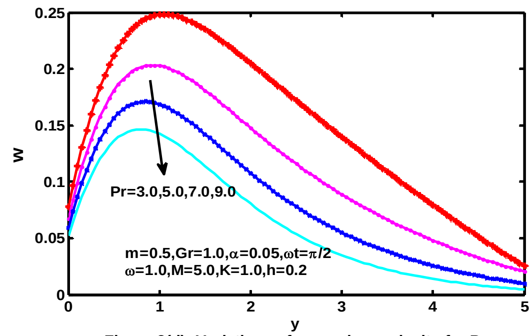

Figure 2(d): Variations of secondary velocity for Pr

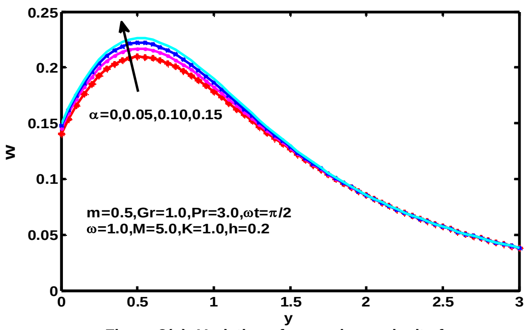

Figure 2(e): Variation of secondary velocity for α

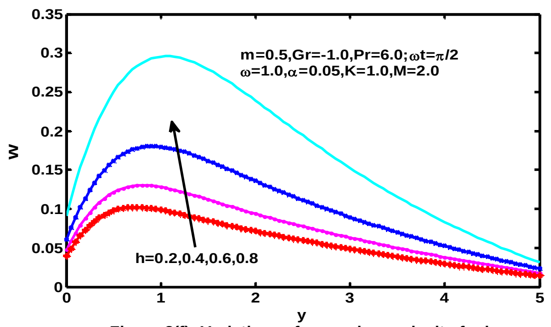

Figure 2(f): Variations of secondary velocity for h

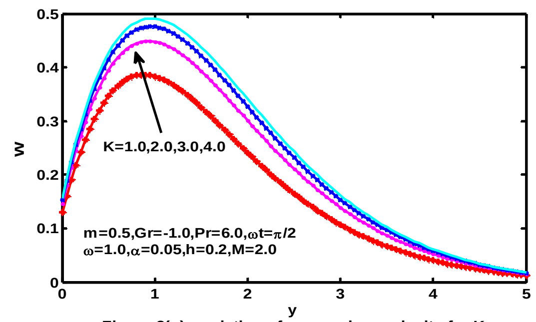

Figure 2(g): variation of psecondary velocity for K

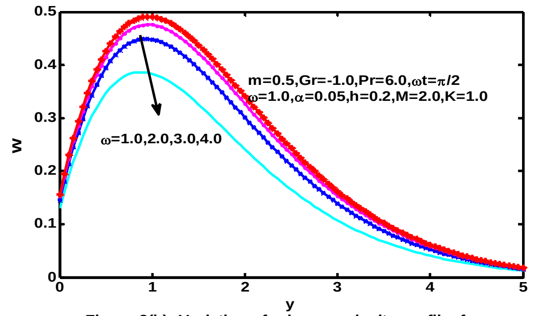

Figure 2(h): Variation of primary velocity profilesfor ω

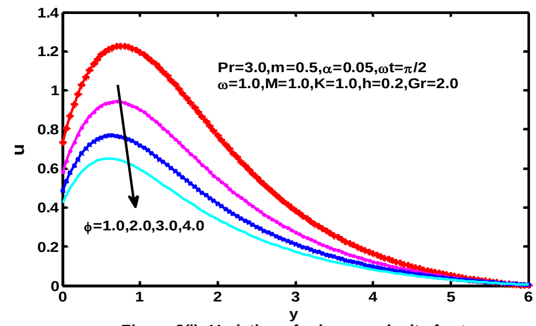

Figure 2(i): Variation of primary velocity for ϕ

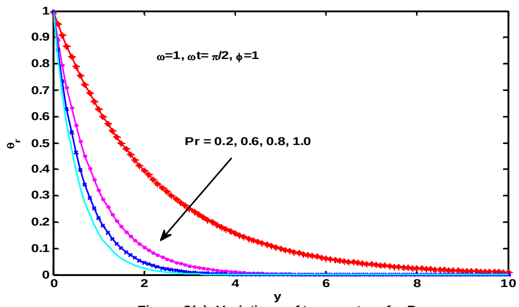

Figure 3(a): Variations of temperature for Pr

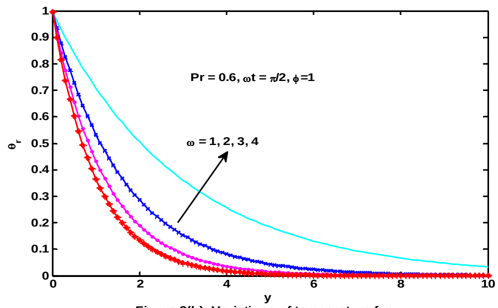

Figure 3(b): Variations of temperature for ω

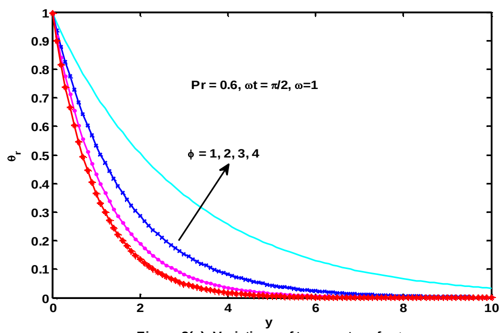

Figure 3(c): Variations of temperature for ϕ