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Hall Effect on MHD Free Convection Flow of Viscous-Elastic Fluid Past Of Aninfinite Vertical Porous Flat Plate With Chemical Reaction

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ABSTRACT

The effect of chemical reaction in free convection MHD flow of elastic-viscous fluid past an infinite vertical porous flat plate is investigated when the presence of heat Source/sink, temperature and concentration are assumed to be oscillating with time and hall effect .The governing equations are solved by complex variable technique. The velocity , temperature and concentration distributions are derived and their profile for various physical parameters are shown through graphs . The influence of various parameters such as the Prandtl number, the Grash of number, modified Grash of number, the Schmidt number, the Hall parameter, Elastic parameter & Magnetic parameter on the flow field are discussed.

KEYWORD: MHD, free convective, viscous elastic , rotational, chemical reaction ,porous ,heat transfer, mass transfer ,suction and injection.

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INTRODUCTION

The convection problem in the combined effects of heat and mass transfer on the electrically conducting visco-elastic fluid past a flat plate through porous media has attracted the attention of scientists and engineers because of its importance notably in the flow of the oils through porous rocks, extraction of energy from geothermal regions, the filtration of the solids from liquid, drug permeation through human skin, purification of molten metal's from non-metallic inclusion, radio propagation through the ionosphere, design of MHD generators and accelerators in geophysics, in design of underground water energy storage system, soil-sciences, astrophysics, nuclear power reactors and so on. The phenomena of mass transfer is very common in theory of stellar structure ,burning a pool of oil, spray drying, adsorption, leaching and mass transport process in animal and plant life. The effect of hall current on the fluid flow with variable concentration has many applications in MHD power generation, in several astrophysical and meteorological studies as well as in plasma flow through MHD power generators.

The studies in convection flows of a viscous electrically conducting fluid in rotating channels partially filled with porous substrates in the presence of a magnetic field have a wide range of scientific and engineering applications. During alloy solidification convection effects are important because they affect the solid fluid content within a porous layer known as mushy layer. Further, these rotating flows are electromagnetically braked by a force (Lorentz force) and therefore have applications. Datta and Jana[1] have investigated the problem of flow and heat transfer in an elastic-viscous liquid over an oscillating plate in a rotating flame. Biswal et.al[2] have studied the hall effect on oscillatory hydro magnetic free convective flow of a viscous-elastic fluid past an infinite vertical porous flat plate with mass transfer . Acharya et al.[3] have studied the hall effect with simultaneous thermal and mass diffusion on unsteady hydro magnetic flow near an accelerated vertical plate. Aboeldahab et.al[4] have analyzed hall current effect on magneto hydrodynamics free convection flow past a semi-infinite vertical plate with mass transfer . Sheddeek[5] have studied heat & mass transfer on a stretching sheet with a magnetic field in a viscous-elastic fluid flow through a porous medium. Prasad et.al [6] have investigated the effect of variable viscosity on MHD viscous-elastic fluid flow and heat transfer over a stretching sheet. Senapati et. al [7] have discussed the effect of heat and mass transfer on MHD free convection flow past an oscillating vertical plate with variable temperature embedded in porous medium. Das et.al[8] have analysed the effects of chemical reaction on MHD unsteady free convective Walter's memory flow with constant suction and heat sink. Das et.al.[9] have studied the hall effect on MHD mixed convection flow of viscous-elastic incompressible fluid past of an infinite porous medium . Adesanya et.al[10] have analyzed the hydro magnetic natural convection flow between vertical parallel plates with time-periodic boundary condition. Krishna et.al[11] have studied the MHD free convective rotating flow of visco-elastic fluid past an infinite vertical oscillating porous plate with chemical reaction. Das et.al[12] have discussed the combined effect of chemical reaction, heat and mass transfer on an unsteady MHD free convective flow embedded in a porous medium with heat generation/absorption. Raj opal et.al[13] have examined for a special class of visco-elastic fluids known as second order fluids.

In the present analysis, it is proposed to study the effect of simultaneous heat and mass transfer on the flow of viscous-elastic fluid past an impulsively started infinite vertical plate with chemical reaction and taking hall effect into account. Closed form analytical solutions have been obtained for the velocity, temperature and concentration distributions and are shown graphically.

FORMULATION OF PROBLEMS:

Consider the unsteady flow of an electrically conducting fluid past an infinite vertical porous flat plate coinciding with the plane y=0 such that the x-axis is along the plate and y-axis is normal to it. A uniform magnetic field B_0 is applied in the direction y-axis and the plate is taken as electrically non-conducting. Taking z-axis normal to xy-plane and assuming that the velocity V and the magnetic H have components (u, v, w) and (H_x, H_y, H_z) respectively, the equation of of continuity $\nabla . v$=0 and solenoidal relation $\nabla . H = 0$ give v= -$v_0$constant , $v_0 > 0$ --------- (1)

From Maxwell's electromagnetic field equation $\frac{dHy}{dy}$=0 ------------- (2)

If the magnetic Reynolds number is small, induced magnetic field is negligible in comparison with the applied magnetic field, so that $H_x = H_y = 0$ and $H_y = B_0$ (constant) . If (J_x, J_y, J_z) are the components of electric current density $\vec{J}$,the equation of conservation of electric charge $\nabla . \vec{J} = 0$ gives

J_y = constant ------------ (3)

Since the plate is non-conducting, J_y at the plate and hence zero everywhere in the flow.

Neglecting polarization effect, we get $\vec{E} = 0$ ------------ (4)

Hence $\vec{J} = (J_x, 0, J_z)$, $\vec{H} = (0, B_0, 0)$,$\vec{V} = (u, V_0, w)$ ----------- (5)

The generalized Ohm's law, taking hall effect into account is given by

$$\vec{J} + \frac{w_e \tau_e}{B_0}(\vec{J} \times \vec{H}) = \sigma(\vec{E} + \vec{V} \times \vec{B} + \frac{1}{e\eta_e}\nabla P_e) \quad \text{-------------(6)}$$

Where $\vec{V}$ is the velocity vector, W_e is the electron frequency,τ_e is the electron collision time, e is the electron charge, η_e is the number density of electron, P_e is the electron pressure, σ is the electric conductivity and $\vec{E}$ is the electric field. In writing eq. (6) ion slip, thermoelectric effects and polarization effects are neglected. Further it is also assumed that $w_e\tau_e \approx 0$ and $w_e\tau_e \leq 1$

where w_e, w_i are cyclone frequency of electrons and ions and τ_e, τ_i are collision times of electrons and ions eq.(5) & eq.(6) yield

$$J_x = \frac{\sigma B_0(mu - w)}{1 + m^2}$$

$$J_y = \frac{\sigma B_0(u - mw)}{1 + m^2}$$

Where u & w are the x-component and z-component of $\vec{V}$ and $m = w_e\tau_e$ is the hall parameter. The equation of motion , energy and concentration governing the flow under the usual Bossiness approximation are

Equation of continuity

$$\frac{\partial v}{\partial y} = 0 \qquad \text{-----------} (7)$$

Since $v = -u_0$ where u_0 is constant suction velocity

Momentum equation

$$\frac{\partial u'}{\partial t'} + v\frac{\partial u'}{\partial y'} = v\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma B_0^2(u+mw)}{\rho(1+m^2)} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\upsilon u'}{k'} - k_0\frac{\partial^3 u'}{\partial y'^2\partial t'} \qquad \text{------}(8)$$

$$\frac{\partial w'}{\partial t'} + v\frac{\partial w'}{\partial y'} = v\frac{\partial^2 w'}{\partial y'^2} - \frac{\sigma B_0^2(w-mu)}{\rho(1+m^2)} - \frac{\upsilon w'}{k'} - k_0\frac{\partial^3 w'}{\partial y'^2\partial t'} \qquad \text{-----------} (9)$$

Energy equation

$$\frac{\partial(T-T_\infty)}{\partial t'} + v\frac{\partial(T-T_\infty)}{\partial y'} = \frac{k}{\rho C_p}\frac{\partial^2(T-T_\infty)}{\partial y'^2} - \frac{\partial q_r}{\rho C_p \partial y'} \qquad \text{-------------} (10)$$

Mass concentration equation

$$\frac{\partial(C-C_\infty)}{\partial t'} + v\frac{\partial(C-C_\infty)}{\partial y'} = D\frac{\partial^2(C-C_\infty)}{\partial y'^2} - k^*(C - C_\infty) \qquad \text{------------} (11)$$

Initial boundary conditions are

$$
\begin{aligned}
& t \leq 0 : u'(y,t) = w'(y,t) = 0, T = T_\infty, C = C_\infty && \text{for all } y. \\
& t > 0 : u' = 0, w' = 0, T = T_\infty + ae^{iwt}, C = C_\infty + be^{iwt} && \text{at } y=0 \qquad \text{--------------} (12) \\
& \qquad u' \to 0, w' \to 0, T \to T_\infty, C \to C_\infty && \text{as } y \to 0
\end{aligned}
$$

Introducing the following non-dimensional quantities

$$\eta = \frac{u_0\, y'}{v}, t = \frac{u_0^2 t'}{4v}, u = \frac{u'}{u_0}, w = \frac{w'}{u_0}, y = \frac{u_0 y'}{v}, \theta = \frac{T-T_\infty}{a}, \emptyset = \frac{C-C_\infty}{b},$$

$$Gr = \frac{4g\beta v_a}{u_0^3}, Gm = \frac{4g\beta^* v_b}{u_0^3}, M = \frac{4B_0^2\sigma v}{\rho u_0^3}, Pr = \frac{v_\rho C_p}{K}, Sc = \frac{v}{D}, \alpha = \frac{k_0 u_0^2}{v^2}, \qquad \text{---------------- (13)}$$

$$\Omega = \frac{4vw}{u_0^2}, Nr = \frac{16\sigma^* T_\infty^3}{3kk^*}, k = \frac{k' u_0^2}{4v^2}, k^* = \frac{k u_0^2}{v}.$$

In (8) and to (11), with the boundary condition are transformed to their corresponding non dimensional forms by dropping dashes as

$$\frac{\partial u}{\partial t} - 4\frac{\partial u}{\partial \eta} = 4\frac{\partial^2 u}{\partial \eta^2} - M\left(\frac{u+mu}{1+m^2}\right) + Gr\theta + Gm\emptyset - \frac{u}{k} - \alpha\frac{\partial^3 u}{\partial \eta^2 \partial t} \qquad \text{------------ (14)}$$

$$\frac{\partial w}{\partial t} - 4\frac{\partial w}{\partial \eta} = 4\frac{\partial^2 w}{\partial \eta^2} - M\left(\frac{w-mu}{1+m^2}\right) - \frac{w}{k} - \alpha\frac{\partial^3 w}{\partial \eta^2 \partial t} \qquad \text{----------- (15)}$$

$$\frac{\partial \theta}{\partial t} - 4\frac{\partial \theta}{\partial \eta} = \frac{4(1+Nr)}{Pr}\frac{\partial^2 \theta}{\partial \eta^2} \qquad \text{------------- (16)}$$

$$\frac{\partial \emptyset}{\partial t} - 4\frac{\partial \emptyset}{\partial \eta} = \frac{4}{Sc}\frac{\partial^2 \emptyset}{\partial \eta^2} - 4K\emptyset \qquad \text{-------------- (17)}$$

Where u is some reference velocity,Gr is the Grashof number for heat transfer ,Gm is the Modified Grashof number for mass transfer, Pr is the Prandtl number, Sc is the Schmidt number, M is the magnetic field parameter , K is the chemical reaction parameter , Nr is the radiation parameter and α is elastic parameter.

The modified boundary conditions becomes

$$t \le 0 : u(\eta, t) = w(\eta, t) = 0, \theta = 0, \emptyset = 0 \qquad \text{for all } \eta$$

$$t > 0 : \begin{cases} u(0,t) = w(0,t) = 0, \theta(0,t) = e^{iwt}, \emptyset(0,t) = e^{iwt} & at\ \eta = 0 \\ u(\infty,t) = w(\infty,t) = 0, \theta(\infty,t) = 0, \emptyset(\infty,t) = 0 & at\ \eta \to \infty \end{cases} \qquad \text{------------(18)}$$

METHOD OF SOLUTION:

The equation (14) & (15) can be combined using the complex variable

Ψ= u+iw ------------

(19)

Giving

$$\frac{\partial^2 \Psi}{\partial \eta^2} + \frac{\alpha}{4}\frac{\partial^3 \Psi}{\partial \eta^2 \partial t} - \frac{1}{4}\frac{\partial \Psi}{\partial t} + \frac{\partial \Psi}{\partial \eta} - \frac{1}{4}\left[\frac{M(1-im)}{1+m^2} + \frac{1}{k}\right]\Psi = -\frac{Gr\theta}{4} - \frac{Gm\emptyset}{4} \qquad \text{----------- (20)}$$

Introducing the non-dimensional parameter $\Omega = \frac{4vw}{u_0^2}$ and using equation (19),the boundary condition in equation (18) are transferred to

$$\Psi(0,t) = \Psi(\infty,t) = 0, \theta(0,t) = e^{i\Omega t}$$

$$\theta(\infty,t) = 0, \emptyset(\infty,t) = 0, \emptyset(0,t) = e^{i\Omega t} \quad \text{--------------- (21)}$$

Putting $\theta(\eta,t) = e^{i\Omega t} f(\eta)$ in equation(16),we get

$$f''(\eta) + \frac{Pr}{1+Nr} f'(\eta) - \frac{i\Omega f(\Omega) Pr}{4(1+Nr)} = 0 \quad \text{-------------- (22)}$$

Which has to be solved under the boundary condition

f(0) =1, f(∞) =0

Hence

$$f(\eta) = e^{\frac{1}{2(1+Nr)}[-Pr-\sqrt{\Pr(Pr+i\Omega(1+Nr)}]\eta}$$

$$\text{Now } \theta(\eta,t) = e^{i\Omega t+\frac{1}{2(1+Nr)}[-Pr-\sqrt{\Pr(Pr+i\Omega(1+Nr)}]\eta} \quad \text{------------ (23)}$$

Separating real and imaginary part, the real part is given by

$$\theta_r(\eta,t) = \mathrm{Cos}(\Omega t - \frac{\eta}{2(1+Nr)} R_1 Sin\frac{\beta_1}{2}) e^{\frac{-\eta}{2(1+Nr)}[Pr+R_1 Cos\frac{\beta_1}{2}]} \quad \text{---------- (24)}$$

Where

$$R_1 = Pr^{\frac{1}{2}}(Pr^2 + \Omega^2(1+Nr)^2)^{\frac{1}{4}} \quad \text{and} \quad \beta_1 = tan^{-1}(\frac{\Omega(1+Nr)}{Pr}) \quad \text{------------ (25)}$$

Putting $\emptyset(\eta,t) = e^{i\Omega t} g(\eta)$ in equation(17), we get

$$g''(\eta) + Scg'(\eta) - \frac{(i\Omega+4K)Scg(\eta)}{4} = 0 \quad \text{---------- (26)}$$

Which can be solved under boundary conditions:

g(0) =1, g(∞) =0

Hence

$$g(\eta) = e^{\frac{1}{2}[-Sc-\sqrt{\mathrm{Sc}(Sc+i\Omega+4K)}]\eta}$$

$$\text{Now } \emptyset(\eta,t) = e^{i\Omega t+\frac{1}{2}[-Sc-\sqrt{\mathrm{Sc}(Sc+i\Omega+4K)}]\eta} \quad \text{----------- (27)}$$

Separating real and imaginary part, the real part is given by

$$\emptyset_r(\eta,t) = \mathrm{Cos}(\Omega t - \frac{\eta}{2} R_2 Sin\frac{\beta_2}{2}) e^{\frac{-\eta}{2}[Sc+R_2 Cos\frac{\beta_2}{2}]}$$

Where

$$R_2 = Sc^{\frac{1}{2}}((Sc+4K)^2 + \Omega^2)^{\frac{1}{4}} \quad \text{and} \quad \beta_2 = tan^{-1}(\frac{\Omega Sc}{Sc^2+4KSc}) \quad \text{------------ (28)}$$

In order to solve in equation (20) by substituting $\Psi = e^{i\Omega t} F(\eta)$,using boundary conditions

F(0)=0, F(∞)=0 ----------- (29)

Separating real and imaginary part, we get

Real part

$$u = F_r = \begin{bmatrix} e^{\frac{-\eta}{2}(2+A_{10})}\left[-A_{15}Cos\left(-\frac{\eta}{2}A_9\right) + A_{18}Sin\left(-\frac{\eta}{2}A_9\right)\right] + \\ e^{\frac{-\eta}{2(1+Nr)}(Pr+a_7)}\left[A_{13}Cos\left(-\frac{\eta}{2}a_6\right) - A_{16}Sin\left(-\frac{\eta}{2}a_6\right)\right] + \\ e^{\frac{-\eta}{2}(Sc+a_9)}[A_{14}Cos\left(-\frac{\eta}{2}a_8\right) - A_{17}Sin\left(-\frac{\eta}{2}a_8\right)] \end{bmatrix} \quad \text{----------- (30)}$$

Imaginary part

$$w = F_i = \begin{bmatrix} e^{\frac{-\eta}{2}(2+A_{10})}\left[-A_{15}Sin\left(-\frac{\eta}{2}A_9\right) - A_{18}Cos\left(-\frac{\eta}{2}A_9\right)\right] + \\ e^{\frac{-\eta}{2(1+Nr)}(Pr+a_7)}\left[A_{13}Sin\left(-\frac{\eta}{2}a_6\right) + A_{16}Cos\left(-\frac{\eta}{2}a_6\right)\right] + \\ e^{\frac{-\eta}{2}(Sc+a_9)}[A_{14}Sin\left(-\frac{\eta}{2}a_8\right) + A_{17}Cos\left(-\frac{\eta}{2}a_8\right)] \end{bmatrix} \quad \text{-------------- (31)}$$

Here we have take

$$a_1 = \frac{1}{2}\left(1 + \frac{1}{k}\right), a_2 = \frac{M}{2(1+m^2)}, a_3 = \frac{1}{2}\left(\frac{Mm}{1+m^2}\right), a_4 = \frac{\alpha\Omega}{4}\left(\Omega - \frac{mM}{1+m^2}\right), a_5 = \frac{\Omega}{2}[\frac{\alpha M}{4(1+m^2)} + \frac{\alpha}{4k} - 1, a_6 = R_1 Sin\left(\frac{\beta_1}{2}\right), a_7 = R_1 Cos\left(\frac{\beta_1}{2}\right), a_8 = R_2 Sin\left(\frac{\beta_2}{2}\right), a_9 = R_2 Cos\left(\frac{\beta_2}{2}\right)]$$

$A_1 = a_1 + a_2 + a_4, A_2 = a_3 + a_5, A_3 = \sqrt{A_1^2 + A_2^2}, A_4 = \sqrt{A_3 + A_1}, A_5 = \frac{\alpha\Omega}{4}, A_6 = \sqrt{A_3 - A_1}, A_7 = A_5(1 + A_4), A_8 = A_5 \times A_6, A_9 = \frac{A_7 + A_6}{1 + A_5^2}, A_{10} = \frac{A_4 - A_8}{1 + A_5^2}, A_{11} = \frac{M}{1+m^2} + \frac{1}{k}, A_{12} = 2a_3 - \Omega, A_{13} = \frac{Gr \times A_{11}}{A_{11}^2 + A_{12}^2}, A_{14} = \frac{Gm \times A_{11}}{A_{11}^2 + A_{12}^2}, A_{15} = A_{13} + A_{14}, A_{16} = \frac{G \times A_{12}}{A_{11}^2 + A_{12}^2}, A_{17} = \frac{Gm \times A_{12}}{A_{11}^2 + A_{12}^2}, A_{18} = A_{16} + A_{17}$

$R_1 = Pr^{\frac{1}{2}}(Pr^2 + \Omega^2(1 + Nr)^2)^{\frac{1}{4}}, \beta_1 = tan^{-1}(\frac{\Omega(1+Nr)}{Pr})$

$R_2 = Sc^{\frac{1}{2}}((Sc + 4K)^2 + \Omega^2)^{\frac{1}{4}}, \beta_2 = tan^{-1}(\frac{\Omega Sc}{Sc^2 + 4KSc})$

RESULTS AND DISCUSSIONS:

In this paper we have studied the Hall effect on MHD free convection flow of viscous-elastic fluid past of an infinite vertical porous flat plate in presence of chemical reaction. The effect of Gr ,Gm ,M,K, Sc , Pr, Ω, α, Nr and t on flow characteristics have been studied and shown by means of graphs and tables. In the time of drawing the graphs, the real and imaginary parts of velocity and real part of temperature and mass concentration are taken as one axis.

Figure-(1) illustrates the effect of the parameters α, Pr and Sc on velocity profile (u) at any point of the fluid, when M=1,K=1,Gr=1,Gm=1,Ω=1,t=1,m=1 and Nr=1. It is noticed that the velocity decreases with the increase of Prandtl number (Pr) ,Schmidt number (Sc) and Elastic parameter (α).

Figure-(2) illustrates the effect of the parameters Gr, Gm and m on velocity profile (u) at any point of the fluid, when M=1,K=1,Pr=0.22,Sc=0.71,Ω=1,t=1 and Nr=1. It is noticed that the velocity increases with the increase of modified Grashof number (Gm) and Hall parameter(m) and decreases with the increase of Grashof number (Gr) .

Figure-(3) illustrates the effect of the parameters M,K and **Ω** on velocity profile (u) at any point of the fluid, when Gr=1,Gm=1,Pr=0.22,Sc=0.71,m=1,t=1 and Nr=1.It is noticed that the velocity decreases with the increase of magnetic parameter(M) and frequency parameter (**Ω**) and increases with the increase of porous parameter (K).

Figure-(4) illustrates the effect of the parameters α, Pr and Sc on velocity profile (w) at any point of the fluid, when M=1,K=1,Gr=1,Gm=1,**Ω**=1,m=1,t=1 and Nr=1.It is noticed that the velocity decreases with the increase of Prandtl number (Pr) and increases with the increase of Schmidt number (Sc) and Elastic parameter (α).

Figure-(5) illustrates the effect of the parameters Gr, Gm and m on velocity profile (w) at any point of the fluid, when M=1,K=1,Pr=0.22,Sc=0.71,**Ω**=1,t=1 and Nr=1.It is noticed that the velocity decreases with the increase of modified Grash of number(Gm) and increases with the increase of Grashof number (Gr) and Hall parameter(m) .

Figure-(6) illustrates the effect of the parameters M,K and **Ω** on velocity profile (w) at any point of the fluid, when Gr=1,Gm=1,Pr=0.22 ,Sc=0.71,m=1,t=1 and Nr=1. It is noticed that the velocity initially increases and then decreases with increase of magnetic parameter(M) . Again the velocity initially decreases and then increases with increase of porous parameter (K) and the velocity decreases with the increase of frequency parameter (**Ω**).

Figure-(7) illustrates the effect of the parameters Pr, t and **Ω** on temperature profile. It is noticed that the temperature falls with increase of frequency parameter (**Ω**), Prandtl number (Pr) and time(t).

Figure-(8) illustrates the effect of the parameters Pr, t and Nr on temperature profile. It is noticed that the temperature falls with increase of radiation parameter (Nr) , Prandtl number (Pr) and time(t).

Figure-(9) illustrates the effect of the parameters Sc, t and **Ω** on the mass concentration profile .It is noticed that the mass concentration decreases with increase of frequency parameter (**Ω**), Schmidt number (Sc) . Again the mass concentration initially increases and then decreases with the increase of time(t).

Figure-(10) illustrates the effect of the parameters Sc, t and K on the mass concentration profile .It is noticed that the mass concentration decreases with increase of chemical reaction parameter(K), Schmidt number (Sc) and time(t).

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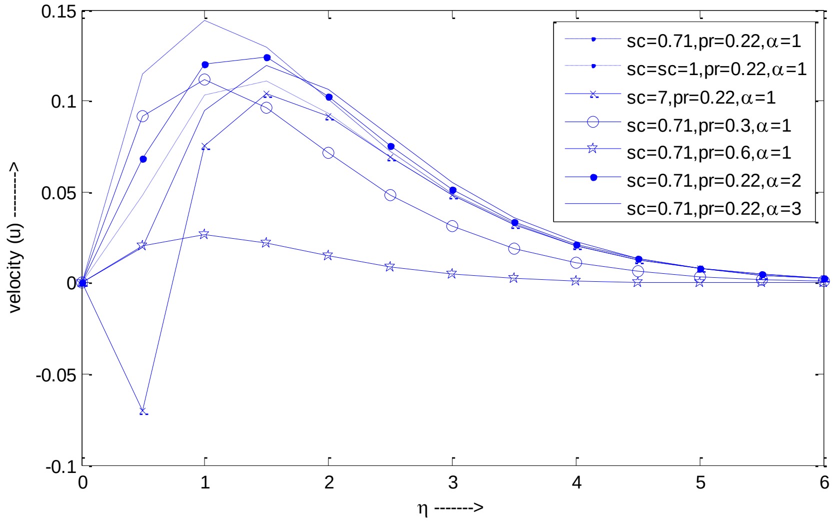

Fig.1: Efect of α ,Pr and Sc on velocity profile(u) when M=1,K=1,Gr=1,Gm=1,Ω=1,t=1,m=1,Nr=1.

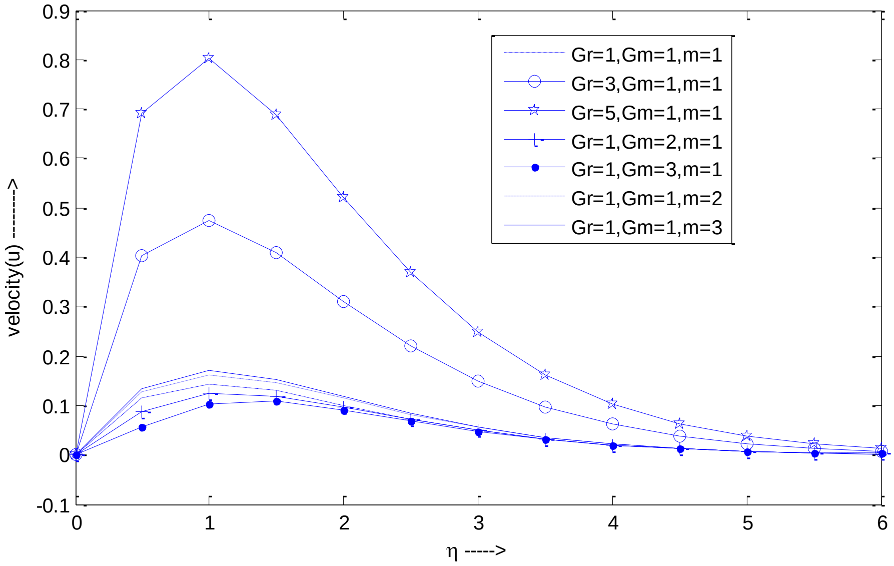

Fig.2: Effect of Gr ,Gm and m on velocity profile(u) when M=1,K=1,Pr=0.22,Sc=0.71,Ω=1,t=1,Nr=1.

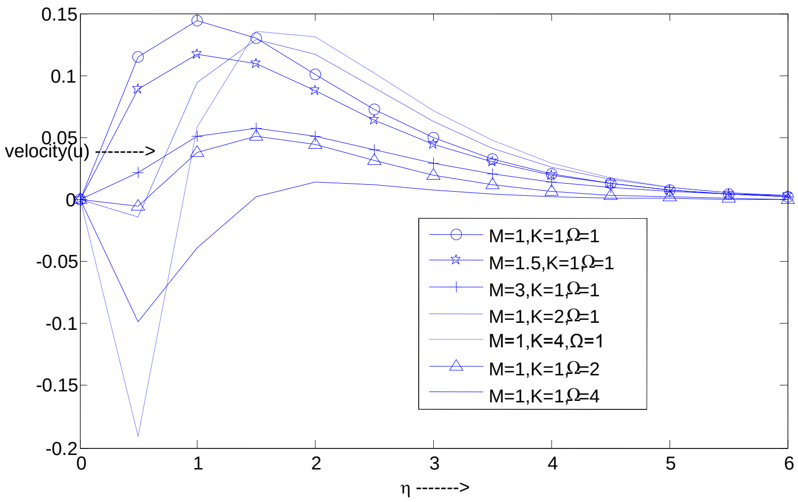

Fig.3: Effect of M ,K and Ω on velocity profile(u) when Gr=1,Gm=1,Pr=0.22,Sc=0.71,m=1,t=1,Nr=1.

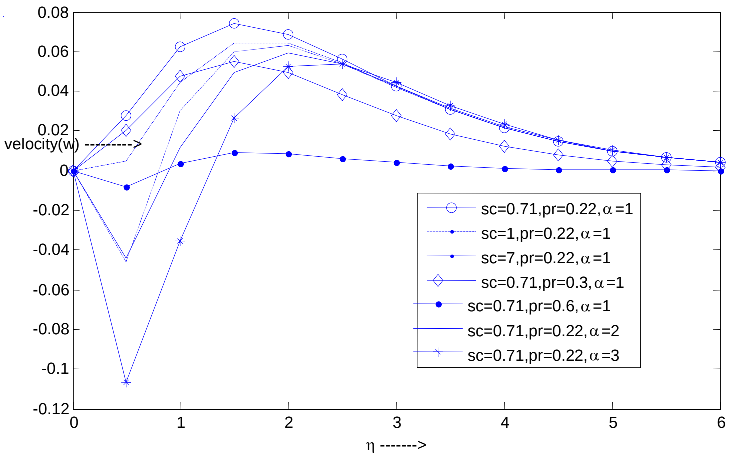

Fig.4: Effect of α ,Pr and Sc on velocity profile(w) when M=1,K=1,Gr=1,Gm=1,Ω=1,t=1,m=1,Nr=1.

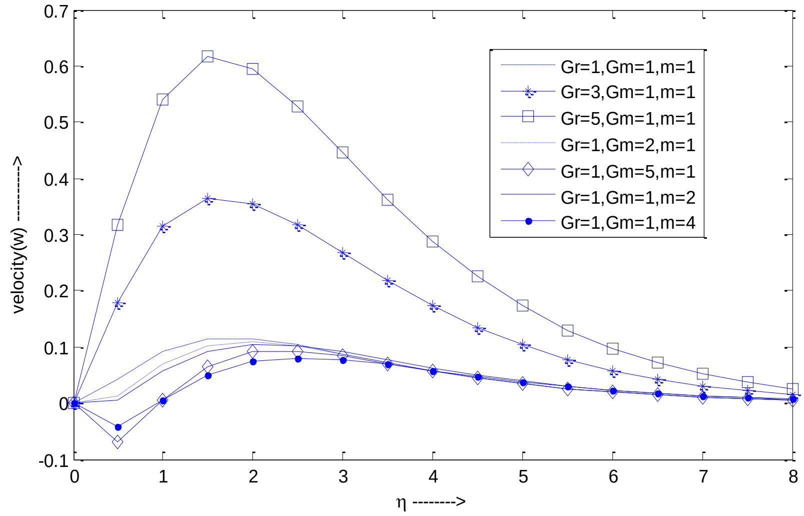

Fig.5: Effect of Gr ,Gm and m on velocity profile(w) when M=1,K=1,Pr=0.22,Sc=0.71,Ω=1,t=1,Nr=1.

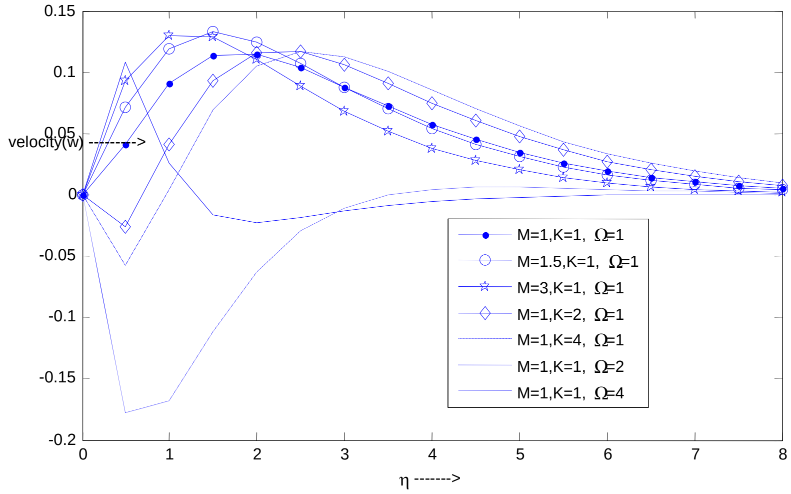

Fig.6: Effect of M ,K and Ω on velocity profile(w) when Gr=1,Gm=1,Pr=0.22,Sc=0.71,m=1,t=1,Nr=1.

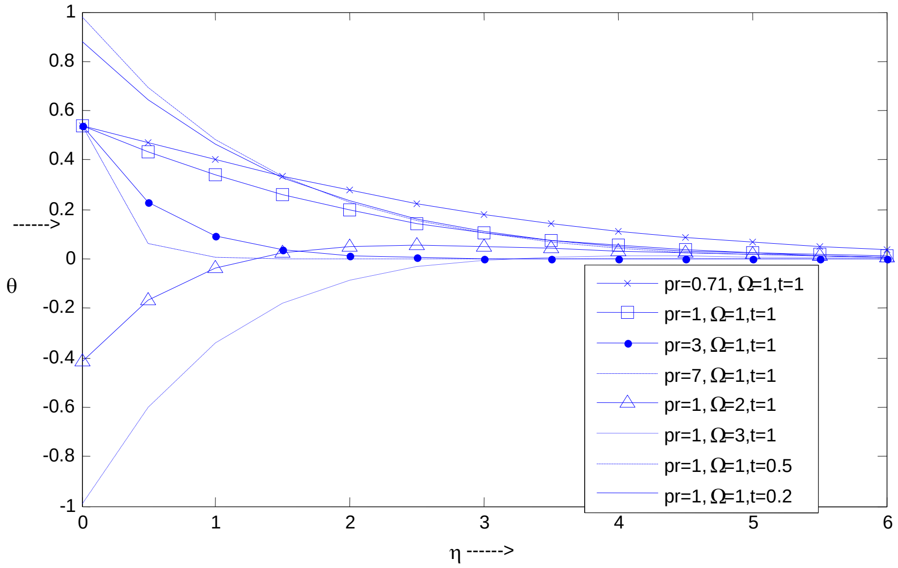

Fig.7: Effect of pr, t, and Ω on temperature profile (ϴr) when Nr=0.5.

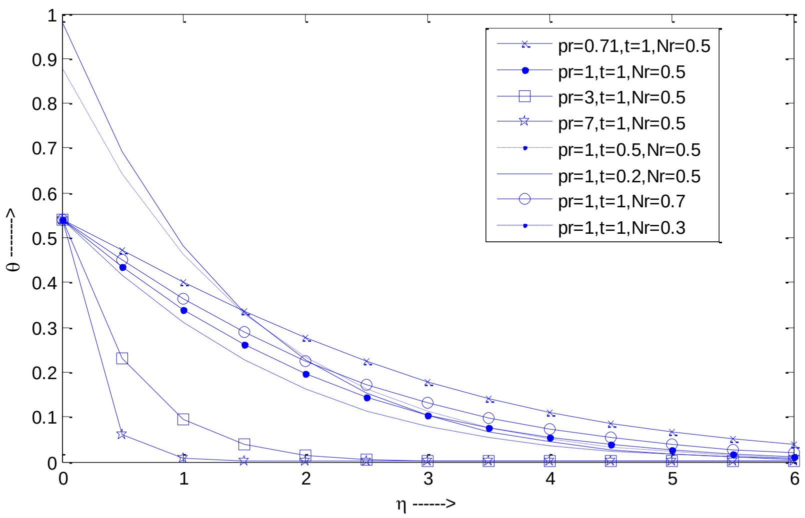

Fig.8: Effect of pr, t, and Nr on temperature profile (ϴr) when Ω=1

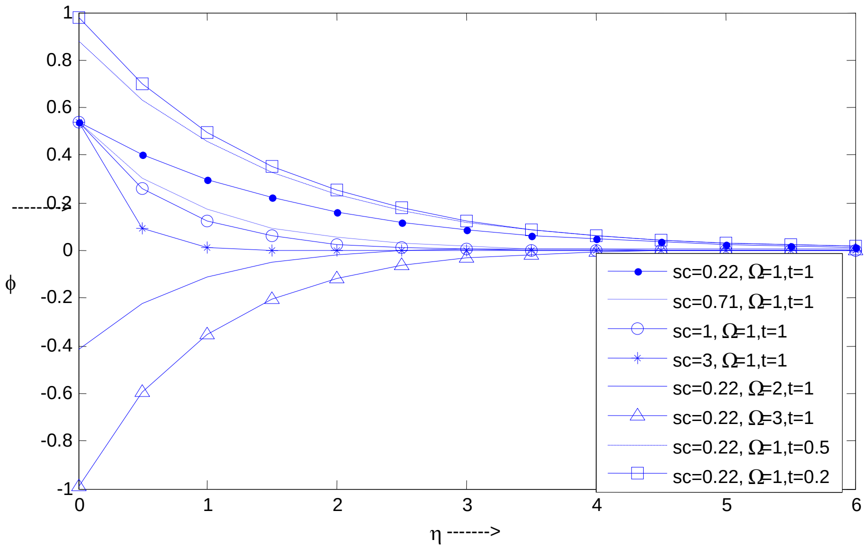

Fig.9: Effect of sc,t and Ω on mass concentration profile(φr) when k=1.

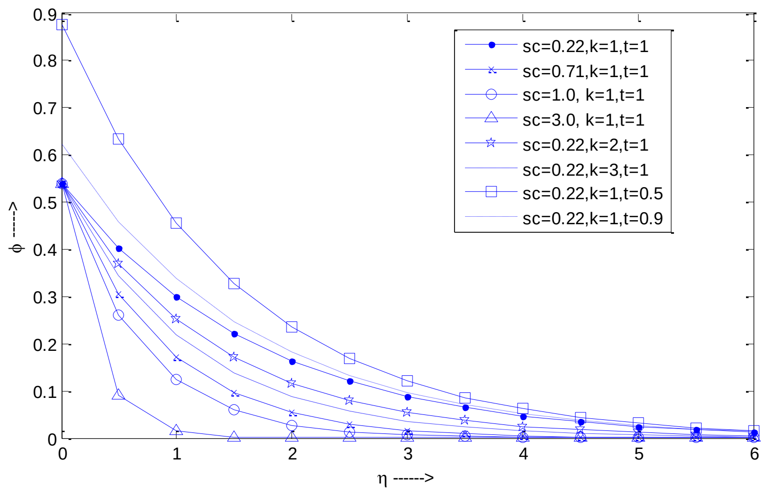

Fig.10: Effect of sc,t and k on mass concentration profile(φr) when Ω=1.

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