Mutual Influences of Heat and Mass Transfer on MHD Flow through a Channel with Periodic Wall Concentration and Temperature

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***Abstract*: - Analytical examination of mutual influences of heat and mass transfer effects on MHD Couette flow through a channel with periodic concentration and temperature are studied. The obtained governing coupled partial differential equations are transformed into coupled ordinary differential equations using similarity transformation technique and then solved using method of undetermined coefficient. The solutions for the velocity, temperature and concentration fields are obtained. Through the use of standard parameters values, the velocity, temperature and concentration are displayed with plots. From the plots, it is observed that increase in the magnetic parameter yields to a decrease in the velocity, whereas increase in the Grash of number leads to an increase in the velocity. Again, a decrease in the temperature predicted an increase in the Prandtl number and radiation parameter, and an increase in the Schmidt number leads to a decrease in the concentration.**

***Keywords:* Heat and mass transfer, MHD, periodic wall concentration and temperature**

I. INTRODUCTION

Magneto hydrodynamics popularly referred to as MHD involves electrically conducting fluid. The effect magnetic field created on electrically conducting fluid has a wide range of significance. Its importance is seen in the extrusion of plastics while manufacturing rayon and nylon, textile industry, etc. Owing to its significance, many researchers have done a lot of works on it. Achogo et al(2020) considered the effect of magnetic field in their study of the effect of heat source on free convection. Buggaramulu and Venkata(2017) examined the impact of magnetic field on the convection of Kuvshinski in an infinite plate. Achogo W. H. et al(2020) considered the effect of magnetic field on convective periodic flow of a viscous incompressible fluid in an inclined channel with thermal radiation. Shakhaoath et al(2012) looked into the effect of magnetic field on unsteady free convection boundary layer flow of nanofluid on a stretching sheet. Fazie and Halima(2019) studied magnetic effect on multiple slips effects on thermo-solutal nanofluid flow. Dileep and Priyanka(2010) considered radiation effects on natural convection in a rotating vertical porous channel.

Heat is transferable when there is temperature difference and mass is also transferable when there is concentration difference. Heat and mass transfer are very crucial in many phase of life. It can be seen in petroleum production, the processes of separation in chemical engineering, soil physics, filtration of solids from liquids, biological systems, etc. Meisam (2015) studied heat and mass transfer in entropy analysis over a plate. Sandeep et al.(2012) free convective flow on transient MHD through a porous media. Arman and Floryan (2017) studied natural convection and thermal drift. Reddy and Reddy(2011) looked into mass and heat transfer in MHD free convection flow past an inclined channel. Salawu et al.(2018) radiation effect on transient analysis of hydromagnetic poiseuille fluid flow. Gerard et al.(2016) studied mixed convection interaction in a vertical porous channel. Heat transfer in mixed convection was studied by Aeniyan and Abioye(2016). Heat transfer in three dimensional free convective flow in a porous medium was studied by Ahmed N. and Sarma D.(1997). Heat transfer was considered by Shateyi et al.(2015) on Maxwell fluid. Free convection was studied by Mamta(2017) on unsteady magneto hydrodynamic flow along a semi infinite vertical porous plate. Unsteady MHD convection of second grade fluid through a porous medium was studied by Veera et al.(2016).

Heat generation/ absorption was understudied by radiative and free convective effects on MHD flow through a porous medium with periodic wall temperature and heat generation or absorption was studied by Sharma et al(2014). Transient free convection in a vertical channel with variable temperature and mass diffusion by Mandal (2014). Unsteady free convection in a fluid past an inclined in a porous medium by Uddin and Kumar(2010). Free convective MHD flow over a stretching sheet in a presence of radiation and viscous dissipation with variable viscosity and thermal conductivity was studied by Joydeep and Hazarika(2018).

In this paper, we have been able to analyze the mutual influences of heat and mass transfer effects on MHD flow through a channel with periodic wall concentration and temperature. The governing equations were analytically solved. The solutions for the velocity, temperature and concentration were obtained in lieu of exponential functions.

II. FORMULATION OF THE PROBLEM

We consider the unsteady Couette, viscous, incompressible and electrically conducting optically thin fluid flow, in two vertical parallel plates embedded with porous medium. The axis is chosen such that the $x'-axis$ is taken along one of the vertical plates and $y'-axis$ normal to the plate. A uniform transverse magnetic field of strength β_o is placed perpendicular to the flow direction. It is assumed that the temperature and concentration are high enough to induce radiative heat mass transfer. Under the usual Boussinesq approximation, the governing equations are as follows:

$$\frac{\partial u'}{\partial t'} = \upsilon\frac{\partial^2 u'}{\partial y'^2} + g\beta_T(T'-T_0') + g\beta_C(C'-C_0') - \frac{\upsilon}{K'}u' - \frac{\sigma\beta_o^2 u'}{\rho} \quad (1)$$

$$\rho C_P \frac{\partial T'}{\partial t'} = k\frac{\partial^2 T'}{\partial y'^2} - \frac{\partial q_r}{\partial y'} - Q_O(T'-T_0') \quad (2)$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} - Kr'\ (C'-C_0') \quad (3)$$

where u', t', Q_O, K', ρ, g, β_T, β_C, σ, q, y', T', K, Kr', D and C' are the axial velocity, time, heat generation/absorption constant, permeability of porous medium, fluid density, acceleration due to gravity, thermal and mass expansion coefficients, electric conductivity, radiative heat flux normal to the plate, axis normal to the plate, the fluid temperature, thermal conductivity, chemical reaction constant, mass diffusivity and the fluid concentration respectively.

The boundary conditions expedient to the study are given as

$$y' = 0 : u'(y',t') = \cup_0(1+\varepsilon e^{i\omega' t'}), T'(y',t') = T_1' + (T_1' - T_0')$$
$$y' = h : u'(y',t') = 0, T'(y',t') = T_1', C'(y',t') = C_1' + (C_1' - C_0') \quad (4)$$

We assumed that the fluid is optically thin having a relatively low density. Hence the heat flux according to Cogley et al.(1968) is expressed as;

$$\frac{\partial q'}{\partial y'} = 4\alpha^2(T'-T_0') \quad (5)$$

where α is the mean absorption coefficient.

Removing the dimensions in equations(1-5) by using the quantities below

$$y = \frac{y'}{h},\ u = \frac{u'}{\cup_0},\ t = \frac{t'\nu}{h^2},\ \omega = \frac{\omega' h^2}{\nu},\ \theta = \frac{T'-T_0'}{T_1'-T_0'},\ \emptyset = \frac{C'-C_0'}{C_1'-C_0'}$$

$$\Pr = \frac{\nu\rho C_p}{K},\ K^2 = \frac{h^2}{K'},\ Gr = \frac{g\beta h^2(T'-T_0')}{\nu\cup_0},\ M^2 = \frac{\sigma\beta_0^2 h^2}{\rho\nu},\ R = \frac{4\alpha h^2}{k},\ Gm = \frac{g\beta h^2(C'-C_0')}{\nu\cup_0},$$

$$S = \frac{Q_0 h^2}{K},\ Sc = \frac{\upsilon}{D},\ Kr = \frac{Kr' h^2}{D} \quad (6)$$

we get

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + Gm\phi - (K^2 + M^2)u \quad (7)$$

$$\Pr\frac{\partial\theta}{\partial t} = \frac{\partial^2\theta}{\partial y^2} - (R^2 + S)\theta \quad (8)$$

$$Sc\frac{\partial\phi}{\partial t} = \frac{\partial^2\phi}{\partial y^2} - KrSc\phi \quad (9)$$

where R is the radiation parameter, S is the generation/absorption parameter, u the dimensiionless velocity, $\cup_0$ the mean flow velocity, y the dimensionless coordinate axis normal to the plates, t the dimensionless time, θ the dimensionless temperature, Gr the thermal Grashof number, Gm the mass Grashof number, Pr the Prandtl number, K the porosity parameter, M the magnetic parameter , Kr the chemical reaction parameter and Sc the Schmidt number.

And the boundary conditions in dimensionless forms are stated as;

$$y = 0 : u(y,t) = 1 + \varepsilon e^{i\omega t}, \theta(y,t) = 1 + \varepsilon e^{i\omega t}, \phi(y,t) = 1 + \varepsilon e^{i\omega t}$$
$$y = 1 : u(y,t) = 0, \theta(y,t) = 1, \phi(y,t) = 1 \quad (10)$$

III. METHOD OF SOLUTION

Now we seek to convert equations (7-10) to a space dependent coordinate only by assuming the velocity, temperature and concentration expanded as given below since $\varepsilon \ll 1$

$$u(y,t) = u_0(y) + \varepsilon u_1 e^{i\omega t} + O(\varepsilon^2) \quad (11a)$$

$$\Theta(y,t) = \Theta_0(y) + \varepsilon\Theta_1 e^{i\omega t} + O(\varepsilon^2) \quad (11b)$$

$$\emptyset(y,t) = \emptyset_0(y) + \varepsilon\emptyset_1 e^{i\omega t} + O(\varepsilon^2) \quad (11c)$$

On neglecting the coefficient of $O(\varepsilon^2)$, we have;

$$\frac{d^2u_0}{dy^2} - (K^2 + M^2)u_0 = -Gr\theta_0 - Gm\phi_0 \quad (12)$$

$$\frac{d^2\theta_0}{dy^2} - (R^2 + S)\theta_0 = 0 \quad (13)$$

$$\frac{d^2\phi_0}{dy^2} - KrSc\phi_0 = 0 \quad (14)$$

$$\frac{d^2u_1}{dy^2} - (K^2 + M^2 + i\omega)u_1 = -Gr\theta_1 - Gm\phi_1 \quad (15)$$

$$\frac{d^2\theta_1}{dy^2} - (R^2 + S + i\omega\Pr)\theta_1 = 0 \quad (16)$$

$$\frac{d^2\phi_1}{dy^2} - (Kr + i\omega)Sc\phi_1 = 0 \quad (17)$$

with the boundary conditions as

y=0: u_0 =1, u_1 =1, θ_0 =1, θ_1 =1, ϕ_0 =1, ϕ_1 =1

y=1: u_0 =0, u_1 =0, θ_0 =1, θ_1 =0, ϕ_0 =1, ϕ_1 =0 (18)

Hence we obtained coupled second order ordinary differential equations.

Solving (12-17) using the boundary conditions(18) corresponding to them.

We have;

$$U_0(y)=D_5e^{\alpha_5 y} + D_6e^{\alpha_6 y}+D_7e^{\alpha_2+\alpha_1 y} + D_8e^{\alpha_1+\alpha_2 y}+D_9e^{\alpha_2 y}+D_{10}e^{\alpha_1 y}+D_{11}e^{\alpha_4+\alpha_3 y}+D_{12}e^{\alpha_3 y}+D_{13}e^{\alpha_4 y}+D_{14}e^{\alpha_3+\alpha_4 y} \quad (19)$$

$$\theta_0(y)= A_1 (e^{\alpha_2+\alpha_1 y} - e^{\alpha_1+\alpha_2 y} + e^{\alpha_2 y} - e^{\alpha_1 y}) \quad (20)$$

$$\phi_0(y)= A_2 (e^{\alpha_4+\alpha_3 y} - e^{\alpha_3+\alpha_4 y} + e^{\alpha_4 y} - e^{\alpha_3 y}) \quad (21)$$

$$U_1(y)=D_{21}e^{\alpha_{11} y} + D_{22}e^{\alpha_{12} y}+D_{23}e^{\alpha_8+\alpha_7 y} + D_{24}e^{\alpha_7+\alpha_8 y}+D_{25}e^{\alpha_{10}+\alpha_9 y}+D_{26}e^{\alpha_9+\alpha_{10} y} \quad (22)$$

$$\theta_1(y)= A_3 (e^{\alpha_8+\alpha_7 y} - e^{\alpha_7+\alpha_8 y}) \quad (23)$$

$$\emptyset_1(y)= A_4 (e^{\alpha_{10}+\alpha_9 y} - e^{\alpha_9+\alpha_{10} y}) \quad (24)$$

By putting (19-24) into equations(11a-11c). We found the solutioins for the velocity, temperature and concentration thus as follows;

$$U(y,t)= D_5e^{\alpha_5 y} + D_6e^{\alpha_6 y}+D_7e^{\alpha_2+\alpha_1 y} + D_8e^{\alpha_1+\alpha_2 y}+D_9e^{\alpha_2 y}+D_{10}e^{\alpha_1 y}+D_{11}e^{\alpha_4+\alpha_3 y}+D_{12}e^{\alpha_3 y}+D_{13}e^{\alpha_4 y}+D_{14}e^{\alpha_3+\alpha_4 y}+ \varepsilon[D_{21}e^{\alpha_{11} y} + D_{22}e^{\alpha_{12} y}+D_{23}e^{\alpha_8+\alpha_7 y} + D_{24}e^{\alpha_7+\alpha_8 y}+D_{25}e^{\alpha_{10}+\alpha_9 y}+D_{26}e^{\alpha_9+\alpha_{10} y}]\, e^{i\omega t} \quad (25)$$

$$\theta(y,t) = A_1 (e^{\alpha_2+\alpha_1 y} - e^{\alpha_1+\alpha_2 y} + e^{\alpha_2 y} - e^{\alpha_1 y})+ \varepsilon[A_3 (e^{\alpha_8+\alpha_7 y} - e^{\alpha_7+\alpha_8 y})]\, e^{i\omega t} \quad (26)$$

$$\phi(y,t) = A_2 (e^{\alpha_4+\alpha_3 y} - e^{\alpha_3+\alpha_4 y} + e^{\alpha_4 y} - e^{\alpha_3 y})+ \varepsilon[A_4 (e^{\alpha_{10}+\alpha_9 y} - e^{\alpha_9+\alpha_{10} y})]\, e^{i\omega t} \quad (27)$$

The expressions for the constants are clearly stated in the appendix.

The shear stress, Nusselt number and Sherwood number on the walls respectively are determined as follows;

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

$$=\alpha_5D_5 + \alpha_6D_6+\alpha_1D_7e^{\alpha_2} + \alpha_2D_8e^{\alpha_1}+\alpha_2D_9+\alpha_1D_{10}+\alpha_3D_{11}e^{\alpha_4}+\alpha_3D_{12}+\alpha_4D_{13}+\alpha_4D_{14}e^{\alpha_3} + \alpha_{11}D_{21} + \alpha_{12}D_{22}+\alpha_7D_{23}e^{\alpha_8} + \alpha_8D_{24}e^{\alpha_7}+\alpha_9D_{25}e^{\alpha_{10}}+\alpha_{10}D_{26}e^{\alpha_9}$$

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = -A_1 (\alpha_1e^{\alpha_2} - \alpha_2e^{\alpha_1} + \alpha_2 - \alpha_1) - A_3 (\alpha_7e^{\alpha_8} - \alpha_8e^{\alpha_7})$$

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} = -A_2 (\alpha_3e^{\alpha_4} - \alpha_4e^{\alpha_3} + \alpha_4 - \alpha_3) - A_4 (\alpha_9e^{\alpha_{10}} - \alpha_{10}e^{\alpha_9})$$

IV. RESULTS AND DISCUSSIONS

Owing to the availability of Lorentz force in the magnetic field, it is found that increase in the magnetic field significantly decreases the velocity of the fluid as seen in figure 1. Figure 2 shows the effect of porosity variation on the velocity of the fluid. Porosity is a component of the channel, physically increase in the porosity gives way for the passage of more fluid. Increase in the Schmidt number decreases the velocity of the fluid as depicted in figure 3. The thermal Grashof number increases the velocity of the fluid. This is because increase in the thermal buoyancy force increases the boundary layer of the fluid as observed in figure 4. Figure 5 depicts the impact of mass Grashof number variation on the velocity. It is found that increase in the mass Grashof number increases the velocity of the fluid. Figure 6 shows the impact cause by the radiation parameter variation on the velocity of the fluid. It is discovered that increase in the radiation parameter causes an decrease in the velocity of the fluid this is as a result of the decrease in the momentum boundary layer. Heat generation parameter has been found to decrease the velocity of the fluid as shown in figure 7. Figure 8 shows a decrease in the velocity of the fluid due to an increase in the chemical reaction parameter. Figure 9 displays the effect of Prandtl number on the velocity of the fluid. It is found that increase in the Prandtl number causes a decrease in the velocity of the fluid. Figure 10 shows the impact caused by an increase in the radiation parameter on the temperature; it is found that the increase in the radiation parameter leads to a decrease in temperature of the fluid. Heat generation variation has been found to lead to a decrease in the temperature of the fluid as displayed in figure 11. Figure 12 depicts the impact cause by the increase in Prandtl number on the temperature of the fluid. Here increase in the Prandtl number causes a decrease in the temperature of the fluid because increase in Prandtl number decreases the thermal conductivity of the fluid. The increase in chemical reaction parameter decreases the concentration of the fluid as depicted in figure 13. Figure 14 shows the effect of Schmidt number variation on the concentration of the fluid; it is found that its increase causes a decrease in the concentration of the fluid.

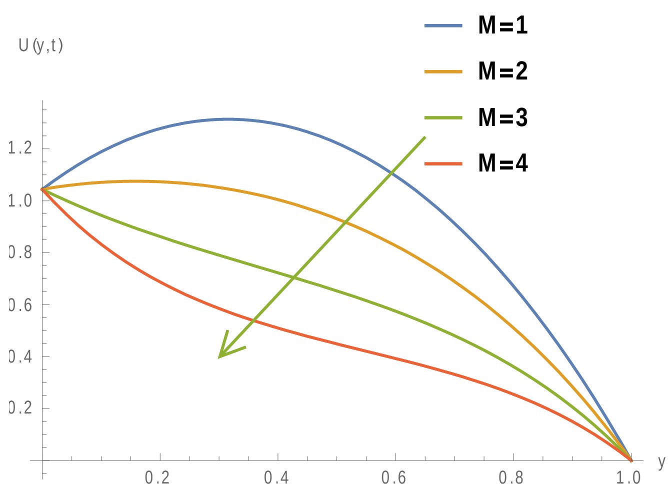

Figure1: Impact of variation of M on the velocity for K=0.3, Sc=0.2, Gr=2, Gm=5, R=0.5, S=0.2, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

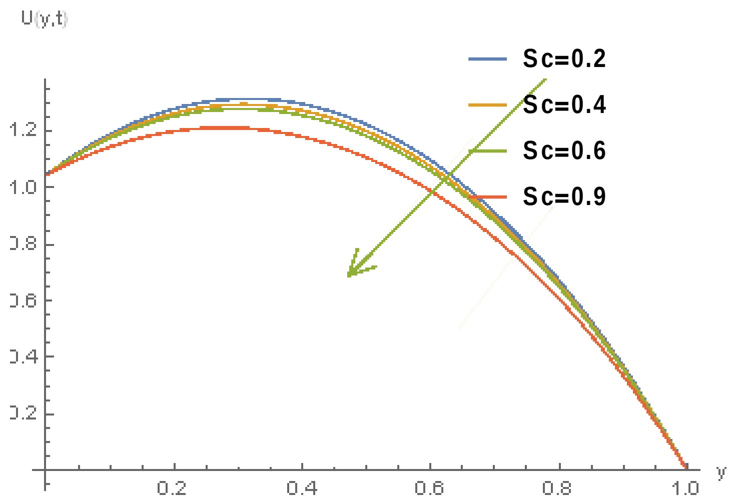

Figure3: Impact of variation of Sc on the velocity for K=0.3, M=1, Gr=2, Gm=5, R=0.5, S=0.2, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

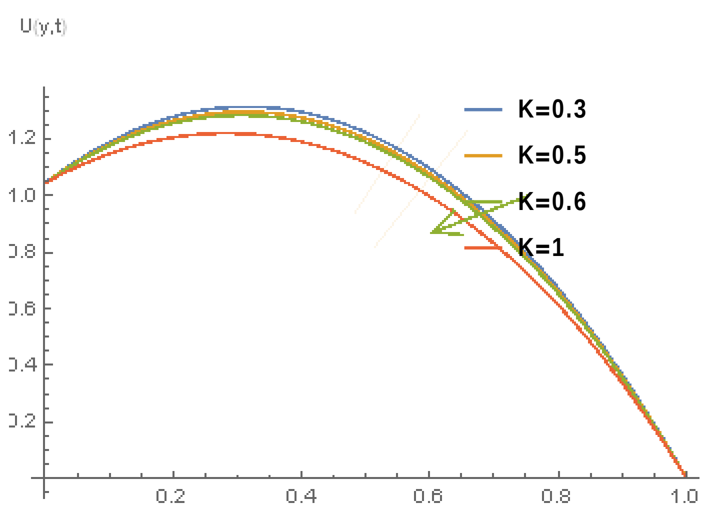

Figure2: Impact of variation of K on the velocity for M=1, Sc=0.2, Gr=2, Gm=5, R=0.5, S=0.2, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

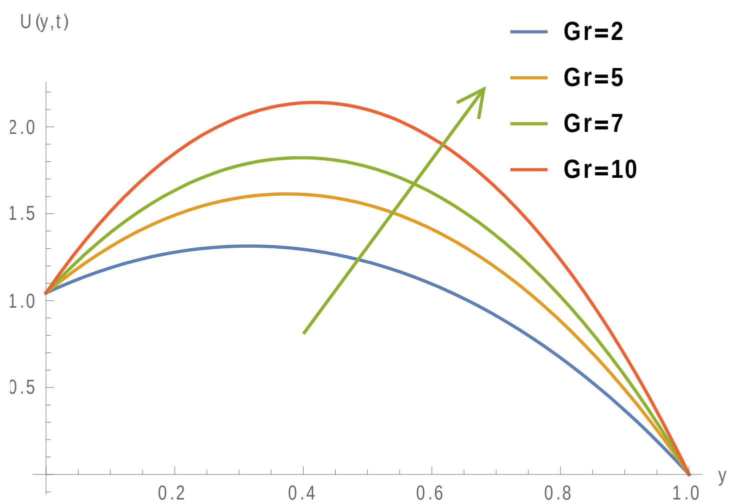

Figure4: Impact of variation of Gr on the velocity for K=0.3, Sc=0.2, M=1, Gm=5, R=0.5, S=0.2, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

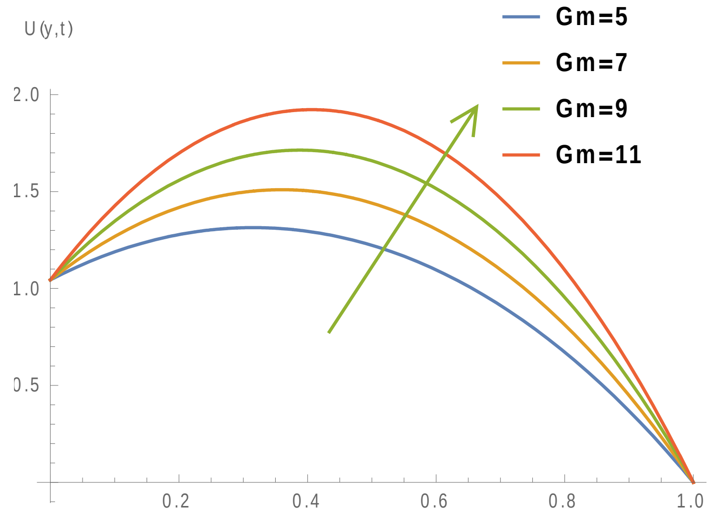

Figure5: Impact of variation of Gm on the velocity for K=0.3, Sc=0.2, Gr=2, M=1, R=0.5, S=0.2, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

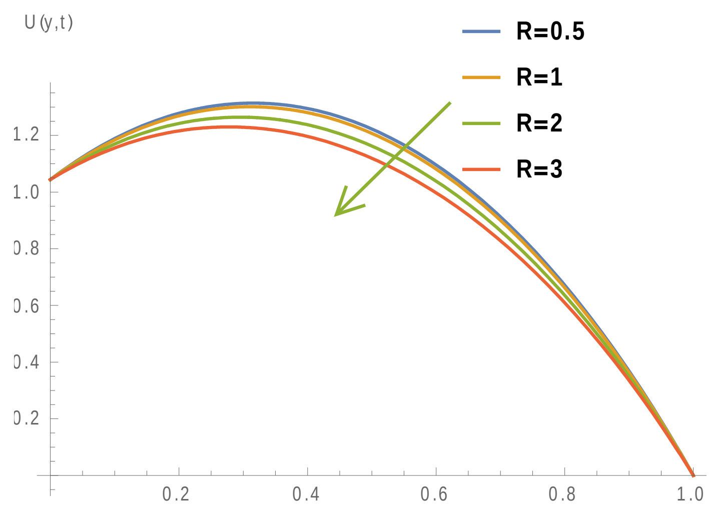

Figure6: Impact of variation of R on the velocity for K=0.3, Sc=0.2, Gr=2, Gm=5, M=1, S=0.2, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

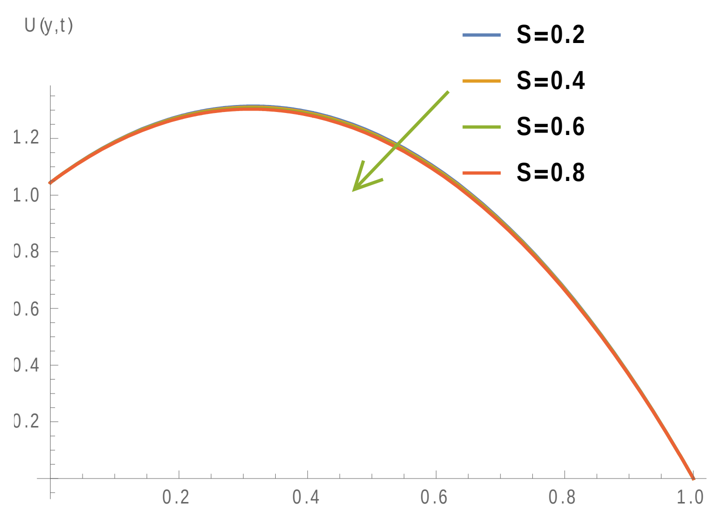

Figure7: Impact of variation of S on the velocity for K=0.3, Sc=0.2, Gr=2, Gm=5, R=0.5, M=1, Kr=0.3, Pr=0.71, ω=0.5, ϵ=0.05

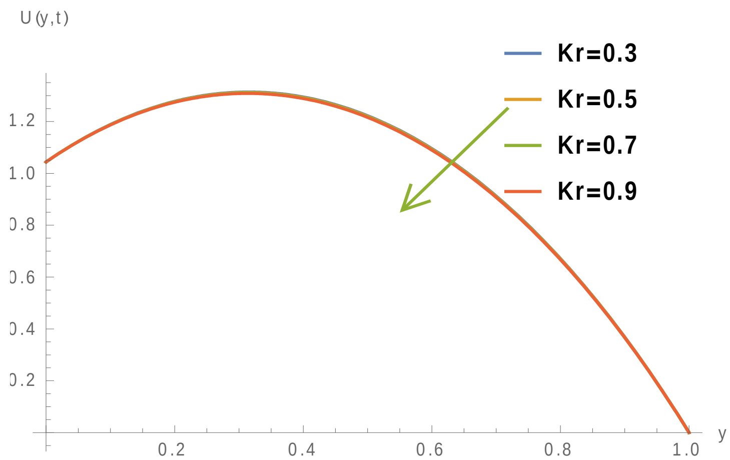

Figure8: Impact of variation of Kr on the velocity for K=0.3, Sc=0.2, Gr=2, Gm=5, R=0.5, S=0.2, M=1, Pr=0.71, ω=0.5, ϵ=0.05

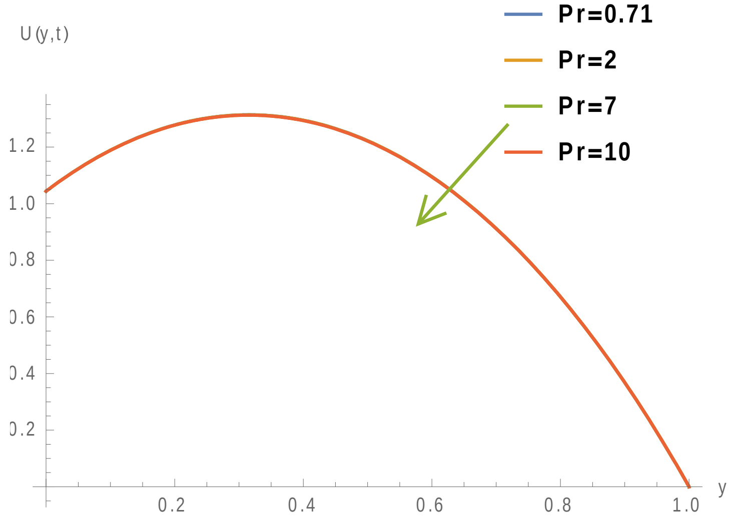

Figure9: Impact of variation of Pr on the velocity for K=0.3, Sc=0.2, Gr=2, Gm=5, R=0.5, S=0.2, Kr=0.3, M=1

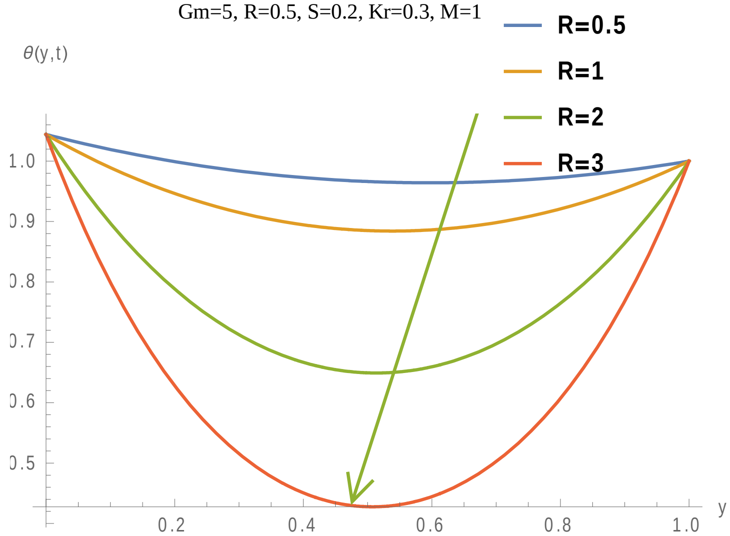

Figure10: Impact of variation of R on the temperature for S=0.2, Pr=0.71, ω=0.5, ϵ=0.05

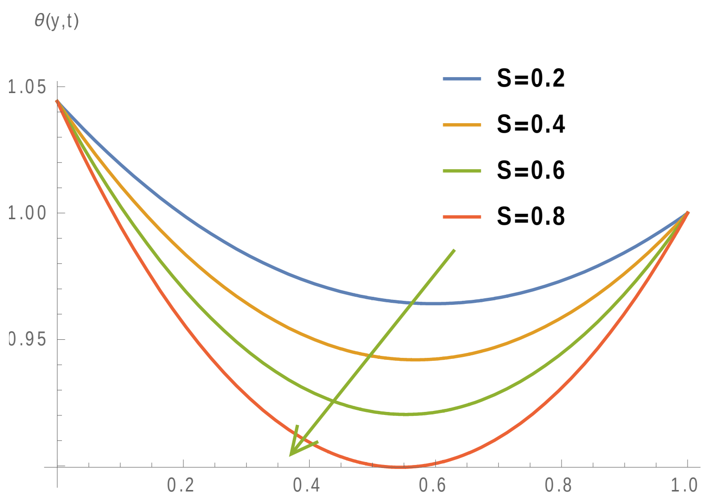

Figure11:Impact of variation of R on the temperature for R=0.5, Pr=0.71, ω=0.5, ϵ=0.05

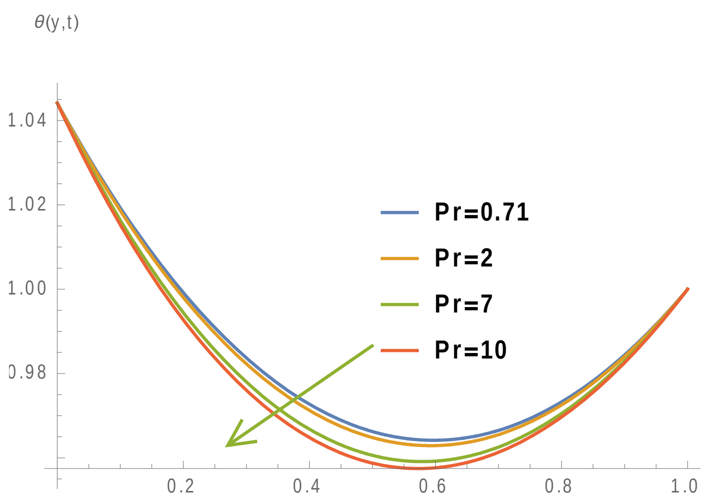

Figure12:Impact of variation of Pr on the temperature for S=0.2, R=0.5, ω=0.5, ϵ=0.05

V. CONCLUSION

In this paper, we have analyzed the mutual influences of heat and mass transfer on MHD flow through a channel with periodic wall concentration and temperature. The governing equations were analytically solved. The solutions for the velocity, temperature and concentration were obtained in lieu of exponential functions. From the results obtained, the following were observed:

1. Increase in magnetic parameter led to a decrease in the velocity of the fluid.
2. A decrease is noted in the temperature of the fluid when Prandtl number is increased.
3. It is observed that increase in Schmidt number led to a decrease in the concentration of the fluid.
4. It is noted that increase in the Grashof number increase the fluid velocity.

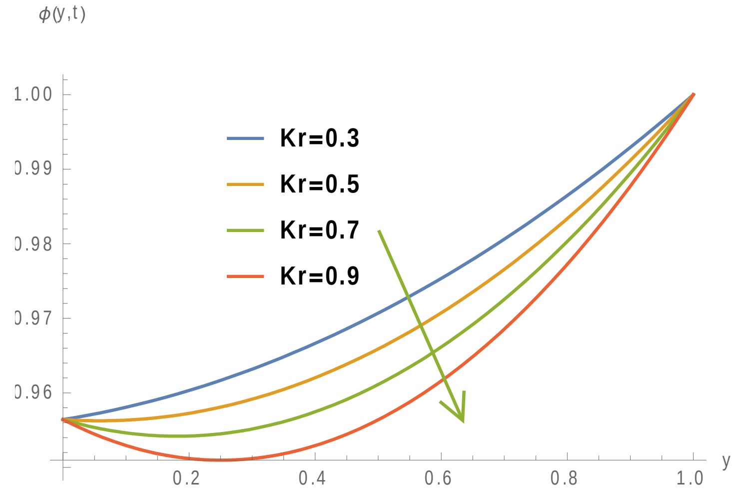

Figure13: Impact of variation of Kr on the concentration for Sc=0.2, ω=0.5, ϵ=0.05

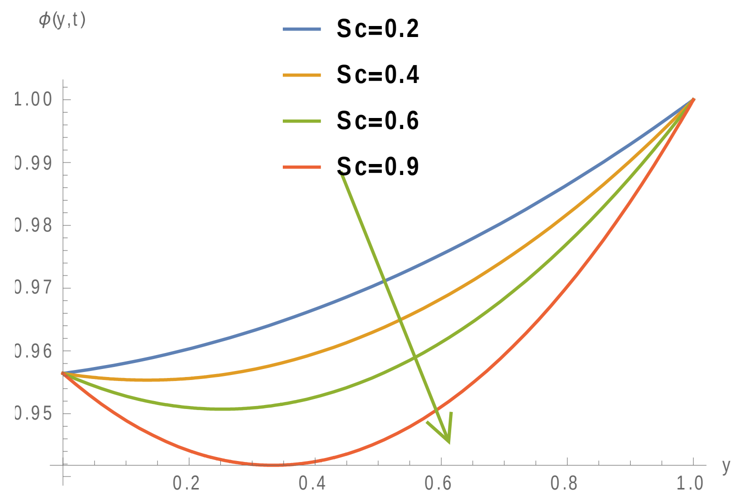

Figure14: Impact of variation of Sc on the concentration for Kr=0.3, ω=0.5, ϵ=0.05

5. It is seen that increase in the chemical reaction parameter decreases the concentration of the fluid.

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APPENDIX

$\alpha_1 = \sqrt{R^2+S}$, $\alpha_2 = -\sqrt{R^2+S}$, $\alpha_3 = \sqrt{KrSc}$, $\alpha_4 = -\sqrt{KrSc}$, $D_1 = \frac{e^{\alpha 2}-1}{e^{\alpha 2}-e^{\alpha 1}}$, $D_2 = \frac{1-e^{\alpha 2}}{e^{\alpha 2}-e^{\alpha 1}}$, $D_4 = \frac{1-e^{\alpha 3}}{e^{\alpha 4}-e^{\alpha 3}}$, $D_{17} = \frac{e^{\alpha 8}}{e^{\alpha 8}-e^{\alpha 7}}$, $D_{18} = \frac{-e^{\alpha 7}}{e^{\alpha 8}-e^{\alpha 7}}$,

$D_{19} = \frac{e^{\alpha 10}}{e^{\alpha 10}-e^{\alpha 9}}$, $D_{20} = \frac{-e^{\alpha 9}}{e^{\alpha 10}-e^{\alpha 9}}$, $\alpha_5 = \sqrt{K^2+M^2}$, $\alpha_6 = -\sqrt{K^2+M^2}$, $\alpha_9 = \sqrt{KrSc+i\omega Sc}$, $\alpha_{10} = -\sqrt{KrSc+i\omega Sc}$

$\alpha_7 = \sqrt{R^2+S+i\omega Pr}$, $\alpha_8 = -\sqrt{R^2+S+i\omega Pr}$, $A_1 = \frac{1}{e^{\alpha 2}-e^{\alpha 1}}$, $A_3 = \frac{1}{e^{\alpha 8}-e^{\alpha 7}}$, $A_2 = \frac{1}{e^{\alpha 4}-e^{\alpha 3}}$, $A_5 = \frac{1}{e^{\alpha 6}-e^{\alpha 5}}$, $A_6 = \frac{1}{e^{\alpha 12}-e^{\alpha 11}}$, $A_4 = \frac{1}{e^{\alpha 10}-e^{\alpha 9}}$, $\alpha_5 = \sqrt{K^2+M^2}$, $\alpha_6 = -\sqrt{K^2+M^2}$,

$\alpha_{11} = \sqrt{K^2+M^2+i\omega}$, $\alpha_{12} = -\sqrt{K^2+M^2+i\omega}$, $D_6 = \frac{1}{e^{\alpha 6}-e^{\alpha 5}}[-e^{\alpha_5} + D_{15}e^{\alpha_5} - D_{16}]$

, $D_5 = 1 - \frac{1}{e^{\alpha 6}-e^{\alpha 5}}[-e^{\alpha_5} + D_{15}e^{\alpha_5} - D_{16}]$-$D_{15}$, $D_{14} = \frac{1}{e^{\alpha 8}-e^{\alpha 7}}[-e^{\alpha_7} + D_{17}e^{\alpha_7} - D_{18}]$

, $D_{21} = 1 - \frac{1}{e^{\alpha 12}-e^{\alpha 11}}[-e^{\alpha_{11}} + D_{27}e^{\alpha_{11}} - D_{28}]$-$D_{27}$, $D_7 = \frac{-Gr A_1}{\propto_1^2-(K^2+M^2)}$, $D_8 = \frac{Gr A_1}{\propto_2^2-(K^2+M^2)}$,

$D_9 = \frac{-Gr A_1}{\propto_2^2-(K^2+M^2)}$, $D_{10} = \frac{Gr A_1}{\propto_1^2-(K^2+M^2)}$, $D_{15} = \frac{-Gr A_3}{\propto_3^2-(K^2+M^2+i\omega)}$, $D_{16} = \frac{Gr A_3}{\propto_4^2-(K^2+M^2+i\omega)}$, $D_{11} = \frac{-Gm A_2}{\propto_3^2-(K^2+M^2)}$, $D_{12} = \frac{Gm A_2}{\propto_3^2-(K^2+M^2)}$, $D_{13} = \frac{-Gm A_2}{\propto_4^2-(K^2+M^2)}$, $D_{14} = \frac{Gm A_2}{\propto_4^2-(K^2+M^2)}$, $D_{23} = \frac{-Gr A_3}{\propto_7^2-(K^2+M^2+i\omega)}$, $D_{24} = \frac{Gr A_3}{\propto_8^2-(K^2+M^2+i\omega)}$, $D_{25} = \frac{-Gm A_4}{\propto_9^2-(K^2+M^2+i\omega)}$, $D_{26} = \frac{Gm A_4}{\propto_{10}^2-(K^2+M^2+i\omega)}$,