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Thermophoresis, Heat Source and Hall Current Effects on Dissipative Aligned MHD Convective Flow Embedded in a Porous Medium

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Abstract

The present work aims at thermophoresis, heat source and hall current effects on dissipative aligned MHD convective flow embedded in a porous medium using 2-term perturbation scheme. The influence of the effects of hall current, aligned magnetic, Soret, chemical reaction and heat source were examined. Graphs are plotted for the validation of results. Skinfriction, Nusselt number and Sherwood number are tabulated for various physical parameters. The results are good in agreement with the existing results.

Keywords: thermophoresis, heat sourse, hall current, MHD, porous medium

1. INTRODUCTION

The study of magnetohydrodynamics become important in engineering applications, such as in soil-sciences, astrophysics, nuclear power reactors designing cooling system with liquid metals, MHD generator and other devices in the petroleum industry. For ionized gases, the conventional magnetohydrodynamics is not valid under the strong electric field. In an ionized gas, the density is low and the magnetic field is very strong, the conductivity normal to the magnetic field is reduced due to the free spiraling of electrons and ions about the magnetic lines of force before suffering collisions, and also a current is induced in the direction normal to both electric and magnetic fields. This phenomenon is also known as the Hall Effect. The effect of Hall currents on hydromagnetic flow near an accelerated plate was analyzed by pop [1]. The effects of Hall current and rotation examined by Raptis and Ram [2].Hall Effect on hydromagnetic free convection flow along a porous flat plate with mass transfer studied by Hossain and Rashid [3]. The effect of Hall current on MHD mixed convection boundary layer flow over a stretched vertical flat plate presented by Ali et al. [4]. The effect of Hall current and rotation on chemically reacting and radiating MHD oscillatory dusty viscoelastic flow through porous vertical channel discussed by chanda and sanjeev [5]. The examination of the development of a fluid with hall current, chemical reaction, heat generation flows through porous surface is of significant theoretical excitement, which shows up in few connected issues in the following. Radiation effect on chemically reacting MHD boundary layer flow of heat and mass transfer through a porous vertical flat plate examined by Ibrahim and Makinde [6]. The effect of Hall current on unsteady hydromagnetic free convection flow near an infinite vertical porous plate discussed by Hossain [7]. The effect of Hall current on hydromagnetic free convection flow near an accelerated porous plate presented by Hossain and Mahammad [8]. The Effect of Hall currents and chemical reaction on a hydromagnetic flow of a stretching vertical surface with internal heat generation/absorption reported by Salem and Abd El-Aziz [9]. Hall effects on MHD flow in a rotating system with heat transfer characteristics analyzed by Ghosh et al. [10]. Heat transfer to MHD oscillatory flow in a channel filled with porous medium studied by Makinde and Mhone [11]. The effects of Variable Suction and Thermophoresis on Steady MHD Free-forced Convective Heat and Mass Transfer Flow over a Semi-infinite Permeable Inclined Flat Plate in the Presence of Thermal Radiation studied by Alam et al. [12]. Kabeir et al. [13] examined the combined Heat and Mass Transfer on Non-Darcy Natural Convection in a Fluid Saturated Porous Medium with Thermophoresis. Gnaneswara Reddy and Bhaskar Reddy [14] presented Mass transfer and heat generation effects on MHD free convection flow past an inclined vertical surface in a porous medium. Bhuvanseswari et al [15] reported exact analysis of radiation convective flow heat and mass transfer over an inclined plate in a porous medium. Chamkha [16] studied that Hydromagnetic natural convection from an isothermal inclined surface adjacent to a thermally stratified porous medium.

In recent years, mixed convection flows with hall current, chemically reactive heat transfer have mobilized some concentration, along with viscous dissipation and ohmic (Joule) heating has also prominent these days, in applications of materials fabrication operations. Which interested us to invoke joule dissipation term which is conventionally neglected on the premise that under normal conditions the

Eckert number is small based on an order of magnitude analysis. The effects of viscous dissipation and Joule heating or ohmic heating are usually characterized by the Eckert number and the product of the Eckert number and magnetic parameter, respectively. Chen [17] studied combined effects of Joule heating and viscous dissipation on Magnetohydrodynamic flow past a permeable, stretching surface with free convection and radiative heat transfer. Siva Reddy and Raju [18] presented soret effect on unsteady MHD free convective flow past a semi infinite vertical plate in the presence of viscous dissipation. Satyanarayana et al., [19] studied viscous dissipation and thermal radiation effects on Unsteady MHD convection flow past a semi infinite vertical permeable moving porous plate. Umamaheswar et al., [20] discussed unsteady magneto hydrodynamic free convective double diffusive viscoelastic fluid flow past an inclined permeable plate in the presence of viscous dissipation and heat absorption.

The study of heat generation or absorption in moving fluids for problems involving chemical reactions and those concerned with dissociating fluids. Particularly, the effects of heat generation may alter the temperature distribution, consequently affecting the particle deposition rate in nuclear reactors, electronic chips, and semiconductor wafers. Chamkha and Ahmed [21] studied similarity solution for unsteady MHD flow near a stagnation point of a three dimensional porous body with heat and mass transfer, heat generation or absorption and chemical reaction. Hady et al., [22] examined MHD free convection flow along a vertical wavy surface with heat generation or absorption effect. Ravi kumar et al., [23] studied Heat and mass transfer effects on MHD flow of viscous fluid through non-homogeneous porous medium in presence of temperature dependent heat source. Jha and Prasad [24] examined MHD free convection and mass transfer flow through a porous medium with heat source.

In general, the thermal diffusion effect is of a smaller order of magnitude and is often neglected in heat and mass transfer processes. However, the Soret effect, for instance, has been utilized for isotope separation and in mixtures between gases with very light molecular weight (H2, He). As of late exponential development of natural convection thermal diffusion flows has turned out to be one of most rapidly developed research fields. Dufour and Soret effects on steady mhd combined free-forced convective and mass transfer flow past a semi-infinite vertical plate analyzed by [25, 28, 32]. Osalusi et al., [26] examined that thermal-diffusion and diffusion-thermo effects on combined heat and mass transfer of a steady MHD convective and slip flow due to a rotating disk with viscous dissipation and Ohmic heating. Turkyilmazoglu and Pop [27] studied that soret and heat source effects on the unsteady radiative MHD free convection flow from an impulsively started infinite vertical plate. Gangadhar [29] presented that Soret and Dufour effects on hydro magnetic heat and mass transfer over a vertical plate with a convective surface boundary condition and chemical reaction. Enamul Karim et al.,[30] reported that Dufour and Soret effect on steady MHD flow in presence of Heat generation and magnetic field past an inclined stretching sheet. Sharma et al., [31] reported Soret and Dufour effects on steady MHD convective flow past a continuously moving porous vertical plate. Gnaneswara Reddy [33] studied the effects of thermophoresis, viscous dissipation and joule heating on steady MHD heat and mass transfer flow over an inclined radiative isothermal permeable surface with variable thermal conductivity. Jayaraj [34] presented that Thermophoresis in laminar flow over cold inclined plates with variable properties.

Combined heat and mass transfer problems with chemical reaction are of significance in several processes received an extensive amount of consideration in recent years. In processes such as evaporation at the surface of a water body, energy transfer in a wet cooling tower and the flow in a desert cooler, in chemical reaction engineering heat and mass transfer occur simultaneously. Hydrodynamic free connective flows involving heat and mass transfer with chemical reaction received a special attention by [35-40].

The objective of this paper is to study the influence of thermo-dissipation and Joule heating on the heat and mass transfer in MHD fluid flow over an inclined porous plate. The salient features of the results are analyzed and discussed.

2. FORMULATION AND SOLUTION OF THE PROBLEM

We have deemed the hall effects on the joint convection flow of an incompressible and electrically conducting viscous fluid about an inclined plate embedded in a porous medium with heat source, Soret and Joule dissipation effects. We considered the Cartesian co-ordinate system such that x^*-axis is taken along the plate in upward direction and y^*-axis is normal to it (Fig. 1).

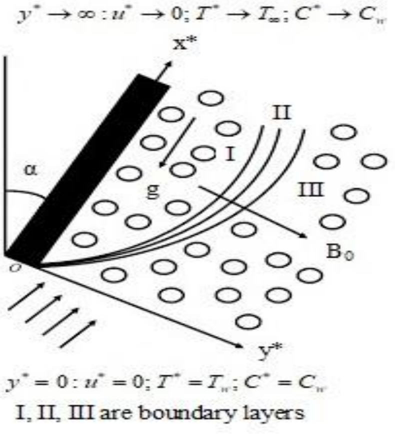

Figure 1: Geometry of the problem

A transverse constant magnetic field is applied, i.e. in the direction of y^* - axis. Since the motion is two dimensional and length of the plate is large therefore all the physical variables are independent of x^*. The governing equations of continuity, momentum, energy and mass for a flow of an electrically conducting fluid are given by the following:

Equation of Continuity:

$$\frac{\partial v^*}{\partial y^*} = 0 \Rightarrow v^* = -v_0 (v_0 > 0) \tag{1}$$

Equation of Motion:

$$v^* \frac{du^*}{dy^*} = \upsilon \frac{d^2u^*}{dy^{*2}} + g\beta\left(T^* - T_\infty\right)\cos\alpha + g\beta^*\left(C^* - C_\infty\right)\cos\alpha - \frac{\sin^2\xi}{\left(1+m^2\right)}\frac{\sigma B_0^2}{\rho}u^* - \frac{\upsilon}{K^*}u^* \tag{2}$$

Equation of Energy:

$$v^* \frac{dT^*}{dy^*} = \frac{k}{\rho C_p}\frac{d^2T^*}{dy^{*2}} + \frac{Q_h}{\rho C_p}(T^* - T_\infty) + \frac{\upsilon}{C_p}\left(\frac{du^*}{dy^*}\right)^2 + \frac{\sin^2\xi}{\left(1+m^2\right)}\frac{\sigma B_0^2}{\rho C_p}u^{*2} \tag{3}$$

Equation of Mass Transfer:

$$v^* \frac{dC^*}{dy^*} = D\frac{d^2C^*}{dy^{*2}} - K_1\left(C^* - C_\infty\right) + D_1\frac{d^2T^*}{dy^{*2}} \tag{4}$$

The boundary conditions are

$$u^* = 0; \quad T^* = T_w; \quad C^* = C_w \quad at \quad y^* = 0 \tag{5}$$

$$u^* \to 0; \quad T^* \to T_\infty; \quad C^* \to C_\infty \quad as \quad y^* \to \infty \tag{6}$$

Introducing following non-dimensional quantities

$$\begin{gathered} y = \frac{y^* v_0}{\upsilon}, u = \frac{u^*}{v_0}, \Pr = \frac{\upsilon\rho C_p}{k}, \theta = \frac{T^* - T_\infty}{T_w - T_\infty}, \phi = \frac{C^* - C_\infty}{C_w - C_\infty}, K^* = \frac{Kv^2}{v_0^2}, \\ \upsilon = \frac{\mu}{\rho}, Sc = \frac{\upsilon}{D}, Gr = \frac{\upsilon g\beta\left(T_w - T_\infty\right)}{v_0^3}, Gm = \frac{\upsilon g\beta^*\left(C_w - C_\infty\right)}{v_0^3}, Ec = \frac{\rho C_p}{C_p\left(T_w - T_\infty\right)}, \\ M^2 = \frac{\sigma B_0^2\upsilon}{\rho v_0^2}, So = \frac{D_1\left(T_w - T_\infty\right)}{\upsilon\left(C_w - C_\infty\right)}, Kr = \frac{\upsilon k_1}{v_0^2}, Q = \frac{Q_h\upsilon}{\rho C_p v_0^2} \end{gathered} \tag{7}$$

In set of equations (2)-(4), we get the governing equations in the dimension form as

$$u'' + u' - H_2 u = -H_3\theta - H_4\phi \tag{8}$$

$$\theta'' + \Pr\theta' + \Pr Q\theta = -\Pr Ec\left(u'\right)^2 - \Pr EcH_1u^2 \tag{9}$$

$$\phi'' + Sc\phi' - ScKr\phi = -SoSc\theta'' \tag{10}$$

The corresponding boundary conditions in dimensionless form are reduced to

$$u = 0, \theta = 1, \phi = 1 \quad at \quad y = 0 \tag{11}$$

$$u \to 0, \theta \to 0, \phi \to 0 \quad as \quad y \to \infty \tag{12}$$

Where $H_1 = \frac{\sin^2\xi}{(1+m^2)}M^2$; $H_2 = H_1 + \frac{1}{K}$; $H_3 = Gr\cos\alpha$ and $H_4 = Gm\cos\alpha$

The physical variables u, θ, ϕ can be expanded in the power of Eckert number (Ec). This can be possible physically as Ec for the flow of an incompressible fluid is always less than unity. It can be interpreted physically as the flow due to the joule dissipation is super imposed on the main flow. Hence we can assume

$$u(y) = u_0(y) + Ec\, u_1(y) + O(Ec^2) \tag{13}$$

$$\theta(y) = \theta_0(y) + Ec\, \theta_1(y) + O(Ec^2) \tag{14}$$

$$\phi(y) = \phi_0(y) + Ec\, \phi_1(y) + O(Ec^2) \tag{15}$$

Using equations (13)-(15) in equations (8)-(10) and equating the coefficient of like powers of Ec, we have

$$u_0'' + u_0' - H_2 u_0 = -H_3\theta_0 - H_4\,\phi_0 \tag{16}$$

$$u_1'' + u_1' - H_2 u_1 = -H_3\theta_1 - H_4\phi_1 \tag{17}$$

$$\theta_0'' + \Pr\theta_0' + \Pr Q\,\theta_0 = 0 \tag{18}$$

$$\theta_1'' + \Pr\theta_1' + \Pr Q\theta_1 = -\Pr u_0'^2 - \Pr H_1 u_0^2 \tag{19}$$

$$\phi_0'' + Sc\phi_0' - ScKr\phi_0 = -ScSo\theta_0'' \tag{20}$$

$$\phi_1'' + \Pr\phi_1' - ScKr\phi_1 = -ScSo\theta_1'' \tag{21}$$

The corresponding boundary conditions are

$$u_0 = 0, u_1 = 0, \theta_0 = 1, \theta_1 = 0, \phi_0 = 1, \phi_1 = 0 \quad at \quad y = 0 \tag{22}$$

$$u_0 \to 0, u_1 \to 0, \theta_0 \to 0, \theta_1 \to 0, \phi_0 \to 0, \phi_1 \to 0 \tag{23}$$

Solving equations (16)-(21) with the help of equations (22)-(23), we obtain

$$u_0(y) = A_5 e^{-m_3 y} + A_3 e^{-m_1 y} + A_4 e^{-m_2 y} \tag{24}$$

$$\begin{aligned} u_1(y) = {} & A_{29}e^{-m_6 y} + A_{21}e^{-m_5 y} + A_{22}e^{-m_4 y} + A_{23}e^{-2m_3 y} + A_{24}e^{-2m_2 y} + A_{25}e^{-2m_1 y} \\ & + A_{26}e^{-(m_3+m_2)y} + A_{27}e^{-(m_1+m_2)y} + A_{28}e^{-(m_3+m_1)y} \end{aligned} \tag{25}$$

$$\theta_0(y) = e^{-m_1 y} \tag{26}$$

$$\theta_1(y) = A_{12}e^{-m_4 y} + A_6 e^{-2m_3 y} + A_7 e^{-2m_2 y} + A_8 e^{-2m_1 y} + A_9 e^{-(m_3+m_2)y} + A_{10}e^{-(m_1+m_2)y} + A_{11}e^{-(m_1+m_3)y} \tag{27}$$

$$\phi_0(y) = A_2 e^{-m_2 y} + A_1 e^{-m_1 y} \tag{28}$$

$$\begin{aligned} \phi_1(y) = {} & A_{20}e^{-m_5 y} + A_{13}e^{-m_4 y} + A_{14}e^{-2m_3 y} + A_{15}e^{-2m_2 y} + A_{16}e^{-2m_1 y} \\ & + A_{17}e^{-(m_2+m_3)y} + A_{18}e^{-(m_2+m_1)y} + A_{19}e^{-(m_1+m_3)y} \end{aligned} \tag{29}$$

Substituting (24)-(29) in equations (13)-(15), we obtain the velocity, temperature and concentration distribution in the boundary layer as follows:

$$u(y) = u_0(y) + Ecu_1(y)$$

$$= \left[A_5 e^{-m_3 y} + A_3 e^{-m_1 y} + A_4 e^{-m_2 y} \right] + Ec \left[\begin{array}{l} A_{29}e^{-m_6 y} + A_{21}e^{-m_5 y} + A_{22}e^{-m_4 y} \\ + A_{23}e^{-(2m_3)y} + A_{24}e^{-(2m_2)y} + A_{25}e^{-(2m_1)y} \\ + A_{26}e^{-(m_2+m_3)y} + A_{27}e^{-(m_2+m_1)y} + A_{28}e^{-(m_1+m_3)y} \end{array} \right] \tag{30}$$

$$\theta(y)=\theta_0(y)+Ec\theta_1(y)$$
$$=\left[e^{-m_1 y}\right]+Ec\begin{bmatrix}A_{12}e^{-m_4 y}+A_6e^{-2m_3 y}+A_7e^{-2m_2 y}+A_8e^{-2m_1 y}+\\ A_9e^{-(m_3+m_2)y}+A_{10}e^{-(m_1+m_2)y}+A_{11}e^{-(m_3+m_1)y}\end{bmatrix} \tag{31}$$

$$\phi(y)=\phi_0(y)+Ec\phi_1(y)$$
$$=\left[A_2e^{-m_2 y}+A_1e^{-m_1 y}\right]+Ec\begin{bmatrix}+A_{20}e^{-m_5 y}+A_{13}e^{-m_5 y}+A_{13}e^{-m_4 y}+A_{14}e^{-2m_3 y}+A_{15}e^{-2m_2 y}+\\ A_{16}e^{-2m_1 y}+A_{17}e^{-(m_3+m_2)y}+A_{18}e^{-(m_1+m_2)y}+A_{19}e^{-(m_3+m_1)y}\end{bmatrix} \tag{32}$$

2.1.Skin-friction

The skin-friction coefficient at the plate is given by

$$Cf=\left(\frac{\partial u}{\partial y}\right)_{y=0}$$
$$=\left[-m_3A_5-m_2A_4-m_1A_3\right]+Ec\begin{bmatrix}-m_6A_{29}-m_5A_{21}-m_4A_{22}-2m_3A_{23}-2m_2A_{24}-\\ 2m_1A_{25}-(m_3+m_2)A_{26}-(m_1+m_2)A_{27}-(m_3+m_1)A_{28}\end{bmatrix} \tag{33}$$

2.2.Rate of heat transfer

Rate of heat transfer in terms of Nusselt number at the plate is given by

$$Nu=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0}$$
$$=\left[m_1\right]+Ec\begin{bmatrix}(m_1+m_2)A_{10}+(m_3+m_2)A_9+(m_3+m_1)A_{11}+\\ m_4A_{12}+2m_3A_6+2m_2A_7+2m_1A_8\end{bmatrix} \tag{34}$$

2.3.Rate of mass transfer

Rate of mass transfer in terms of Sherwood number at the plate is given by

$$Sh=-\left(\frac{\partial\phi}{\partial y}\right)_{y=0}$$
$$=\left[m_2A_2+m_1A_1\right]+Ec\begin{bmatrix}m_5A_{20}+m_4A_{13}+2m_3A_{14}+2m_2A_{15}+2m_1A_{16}+\\ (m_3+m_2)A_{17}+(m_1+m_2)A_{18}+(m_3+m_1)A_{19}\end{bmatrix} \tag{35}$$

3. RESULT ANALYSIS

In the present study, the following default parameter values are adopted for computations: Gr = 2, Gm = 4, K = 0.5, M = 0.5, Pr = 0.71, Ec = 1, Sc = 0.45, S_0 = 0.1, Q = 0.3, α = π/6, m = 0.1, ξ = π/3. All graphs therefore correspond to these values unless specifically indicated in the appropriate graphs. Figs. (2-21) depict the velocity, temperature and concentration distributions respectively. Tables (1–3) represent variation in Skin friction, Nusselt number and Sherwood number. Fig. 2 is prepared to show the influence of Schmidt number Sc on the dimensionless velocity. It is found that there is a decrease with Schmidt number. The effect of inclination of the surface on velocity is shown in Figure 3. From this figure we observe that fluid velocity is decreased for increasing angle α. The fluid has higher velocity when the surface is vertical (α = 0) than when inclined because of the fact that the buoyancy effect decreases due to gravity components (g cosα), as the plate is inclined. Fig. 4 shows the pattern of velocity distribution for different values of magnetic field parameter. It is noticed that velocity decreases with increasing M, which indicates that the magnetic field tends to decelerate flow whereas due to imposition of transverse magnetic field of strength B_0 generates in the electrically-conducting fluid a resistive type of force, called Lorentz force, which acts against the relative motion of the fluid. Variations of heat generation parameter Q on velocity profiles were studied in Fig 5. The results show that the velocity decreases as heat generation parameter Q decreases. The effect of Eckert number is shown in figure 6. Greater viscous dissipative heat causes a rise in the temperature as well as the velocity. The influence of the thermal Grashof number on the velocity is presented in Figure 7. As expected, it is observed that there is a rise in the velocity due to the enhancement of thermo buoyancy force. The thermal Grashof number signifies the relative effect of the thermal buoyancy force to the viscous hydrodynamic force in the boundary layer. Figure 8 presents typical velocity profiles in the boundary layer for various values of the modified Grashof number Gm. As expected, the fluid velocity increases and peak value is distinctive due to increases in the species buoyancy force. The modified Grashof number Gm defines the ratio of the species buoyancy force to the viscous hydrodynamic force. Variations of the permeability parameter on velocity is visualized graphically in Fig. 9. As permeability increases the regime solid fibers progressively decrease. This results in an acceleration in velocity. The effects of Prandtl number Pr on the velocity profile is shown in figure 10. It is seen that the increase in the Prandtl number leads to fall. Figure 11 present the response in the velocity profiles for various values of Soret parameter S_0. It shows that increasing soret significantly increases. Fig. 12 illustrates the effects of chemical reaction parameter Kr on the dimensionless velocity for the fixed values of other parameters. It is observed that the dimensionless velocity slightly decreases with Kr. From Fig. 13 both the velocity enhanced with increasing Hall parameter m. Figure 14 shows the effect of aligned angle over velocity. From these it is observed that the aligned angle does show an influence in the velocity such that flow decreases. The effect of heat generation parameter Q on the temperature is shown in Figure 15. From this figure, we observe that when the value of heat generation parameter increases, the temperature distribution decreases along the boundary layer. The influence of Eckert number Ec on the temperature profiles are displayed in Fig. 16. It is observed that temperature profiles are increases due to the effect of Eckert number. The effects of Prandtl number Pr on the temperature profiles are shown in figures17. It is seen that the increase in the Prandtl number leads to fall in the temperature of the fluid. Figure 18 displays the effects of the Schmidt number Sc on concentration profiles. As the Schmidt number increases, the concentration decreases. The influence of Eckert number Ec on the concentration profiles are displayed in Fig. 19. It is observed that concentration profiles decreases due to the effect of Eckert number. Figure 20 illustrate the influence of Soret S_0 number on the concentration profiles. It is seen that concentration profiles increases and distinctively with the increase of Soret number. Fig. 21 displays the result of the concentration distribution for different values of chemical reaction parameter Kr. It is obvious from the figure that the concentration profiles decreases with the increase of Kr.

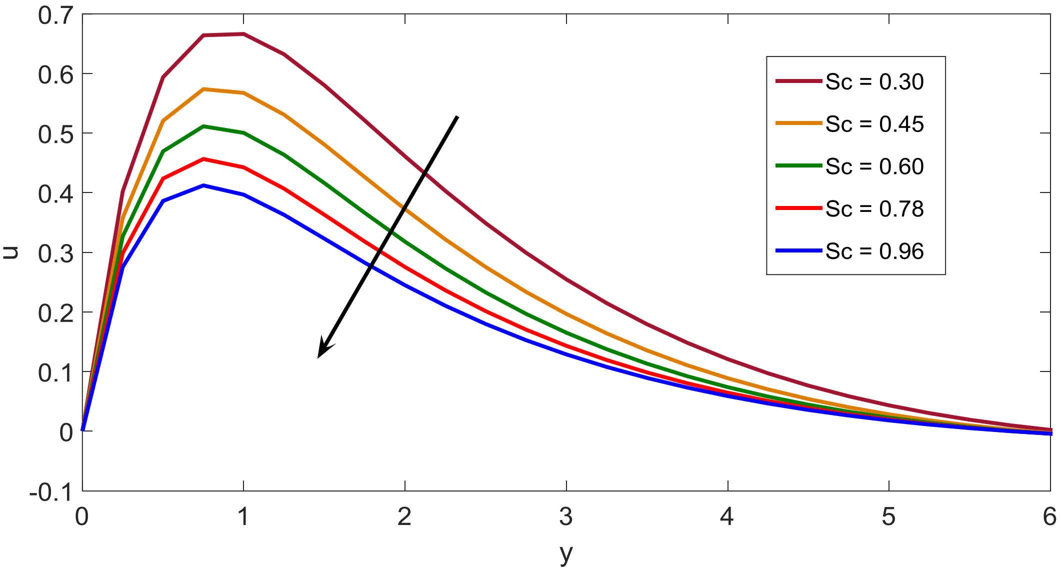

Figure 2: Effect of Sc on velocity profiles

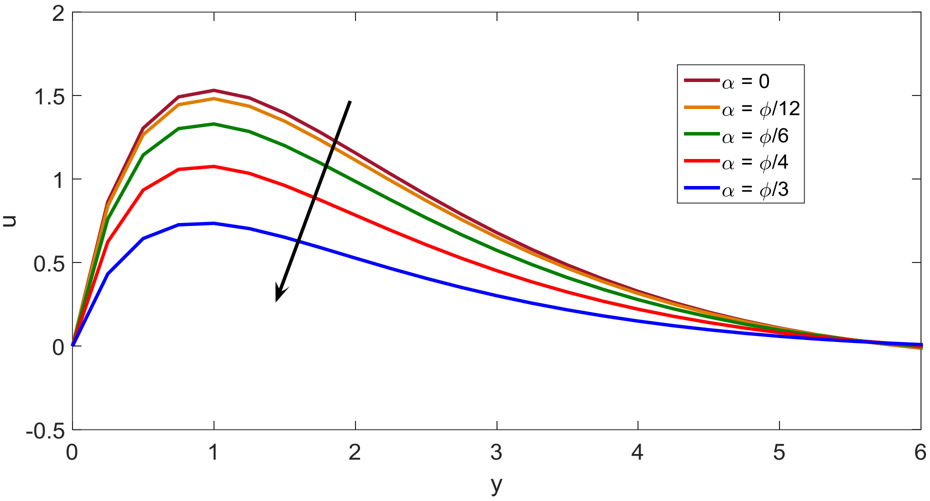

Figure 3: Effect of α on velocity profiles

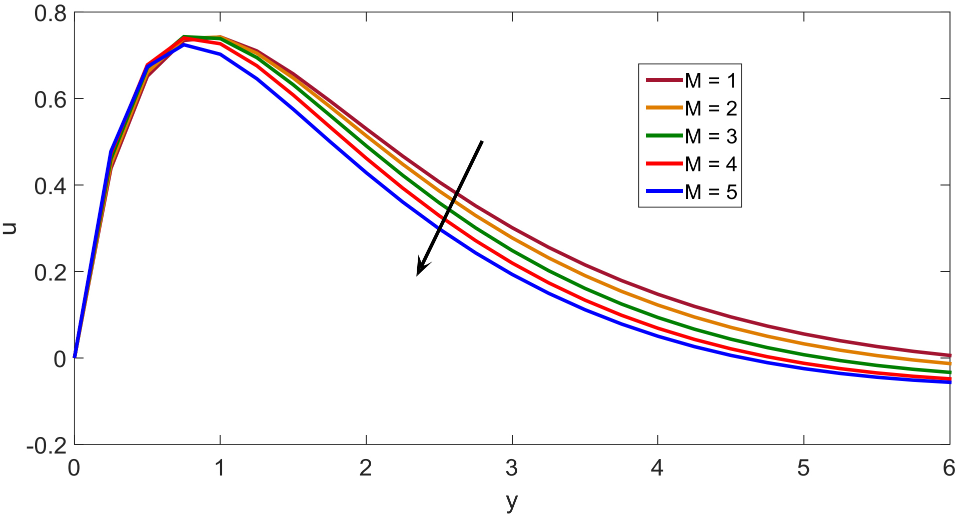

Figure 4: Effect of M on velocity profiles

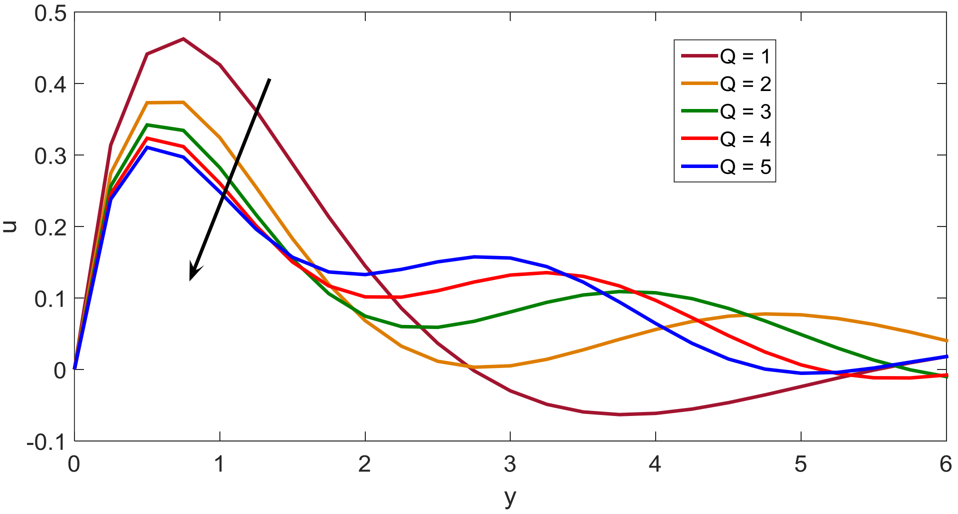

Figure 5: Effect of Q on velocity profiles

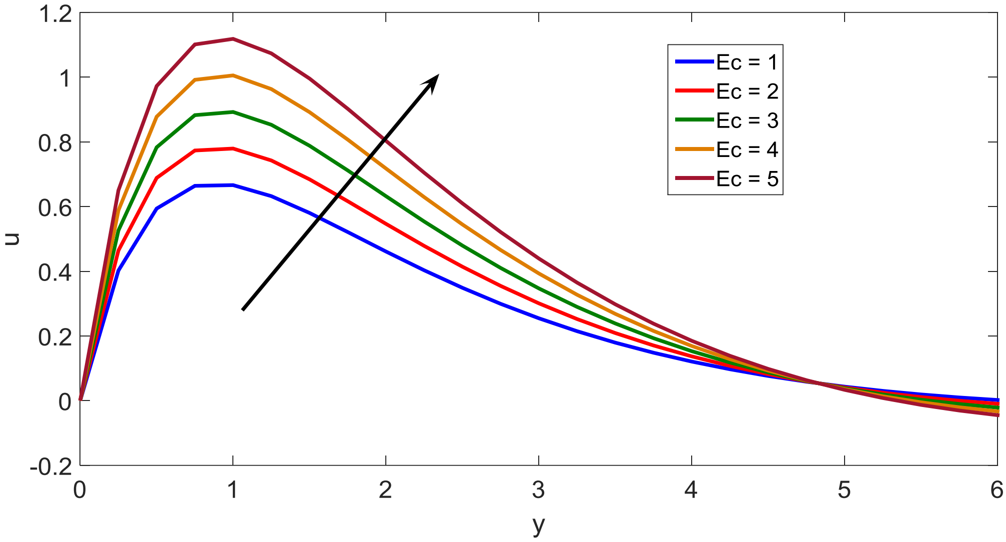

Figure 6: Effect of Ec on velocity profiles

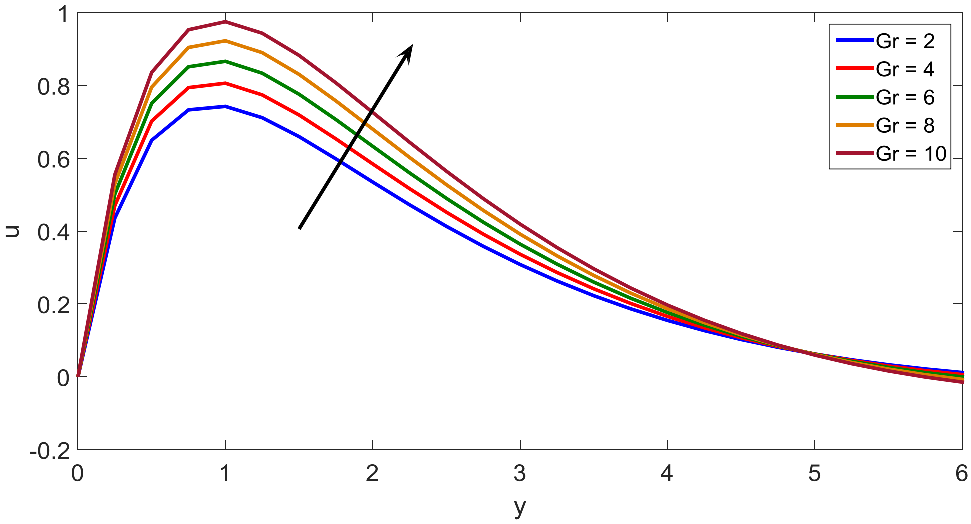

Figure 7: Effect of Gr on velocity profiles

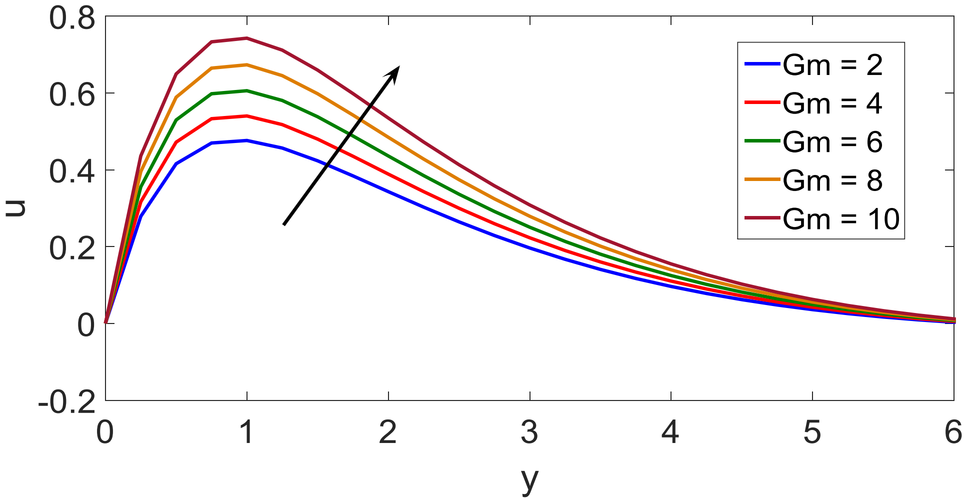

Figure 8: Effect of Gm on velocity profiles

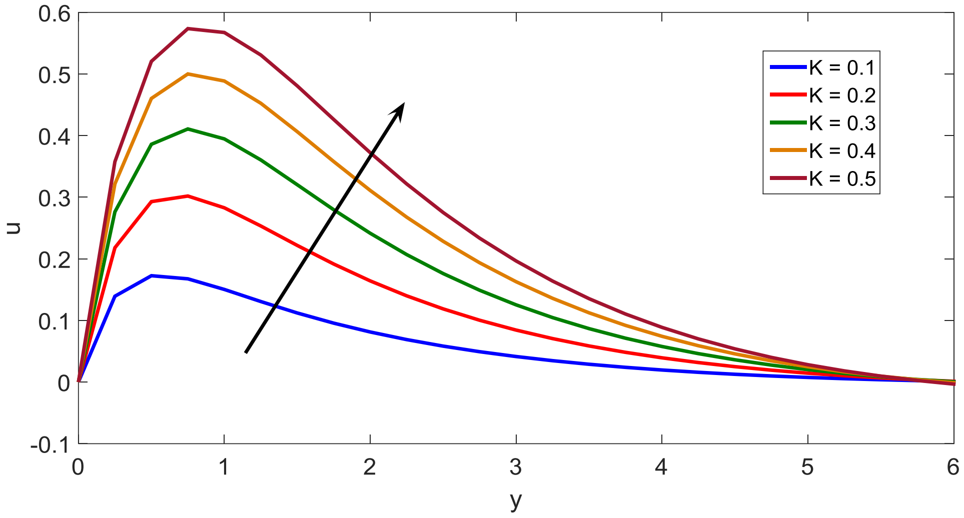

Figure 9: Effect of K on velocity profiles

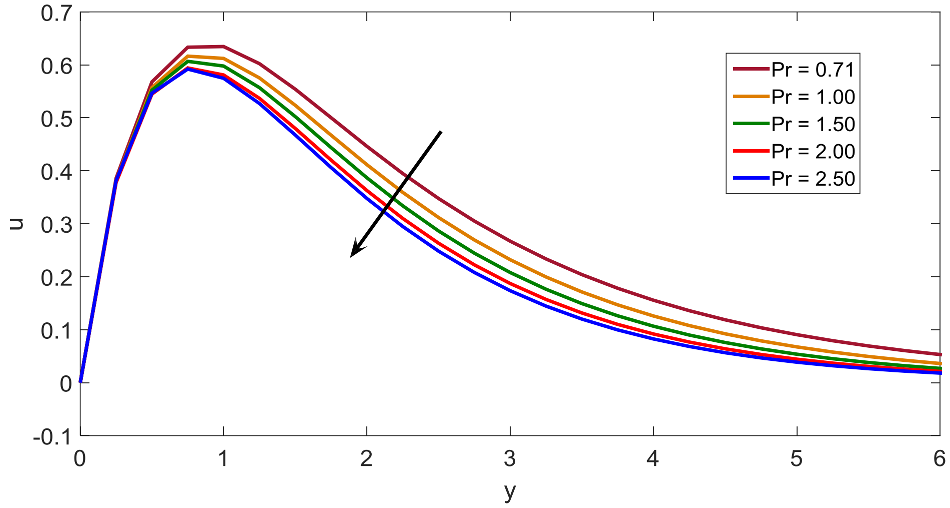

Figure 10: Effect of Pr on velocity profiles

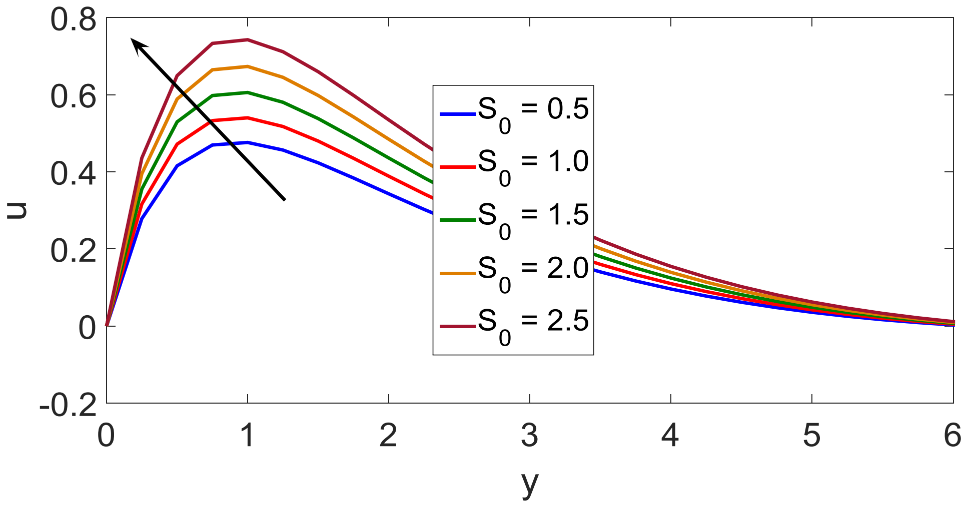

Figure 11: Effect of So on velocity profiles

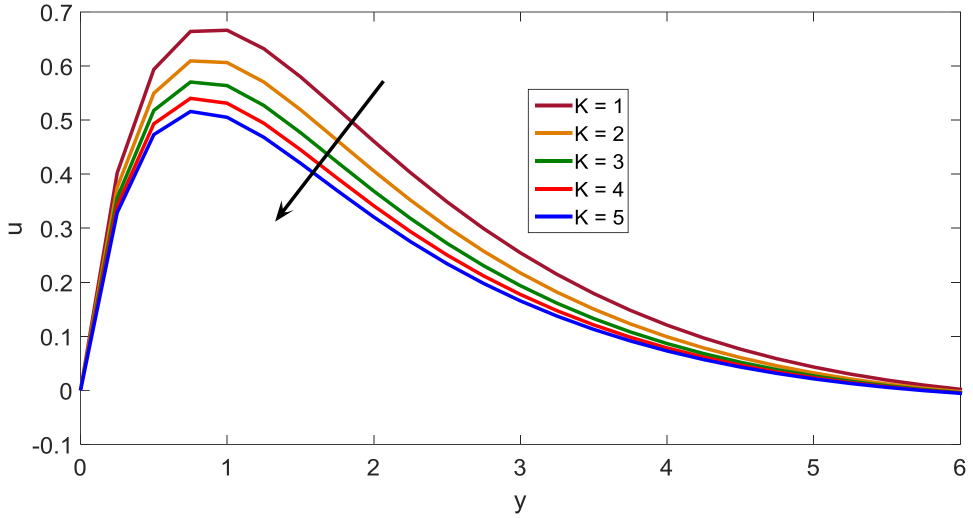

Figure 12: Effect of Kr on velocity profiles

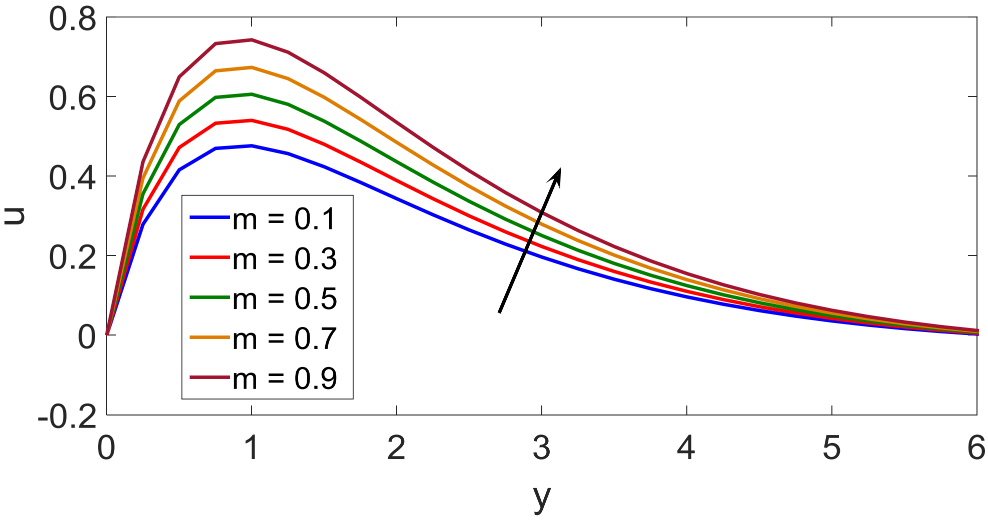

Figure 13: Effect of m on velocity profiles

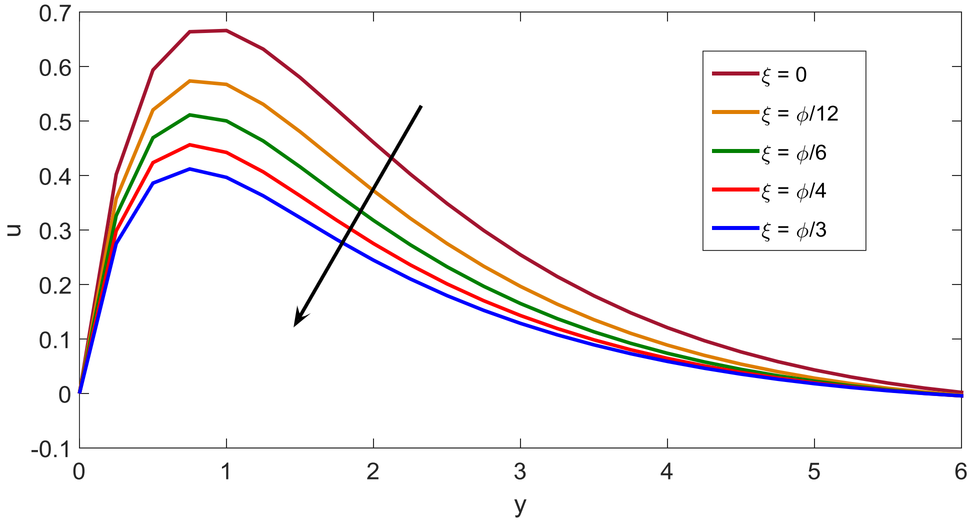

Figure 14: Effect of ξ on velocity profiles

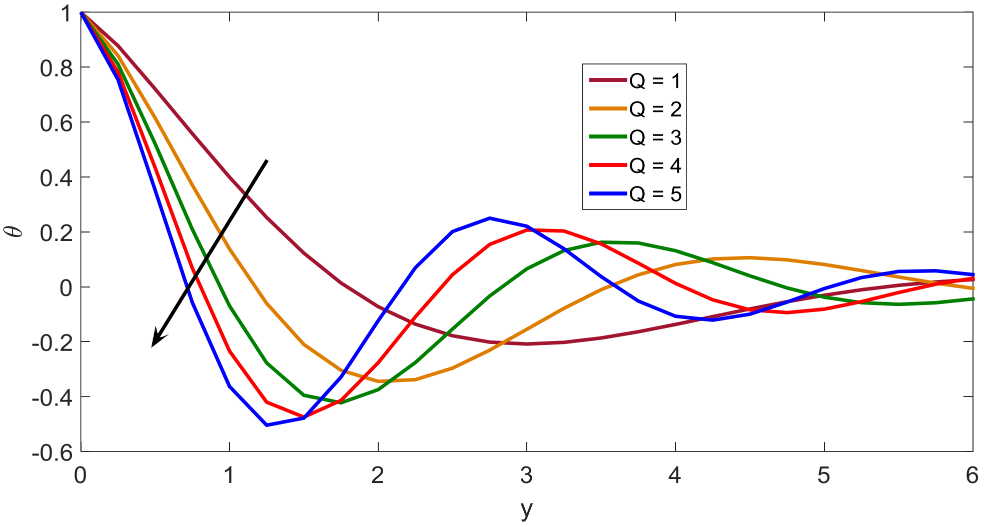

Figure 15: Effect of Q on temperature distribution

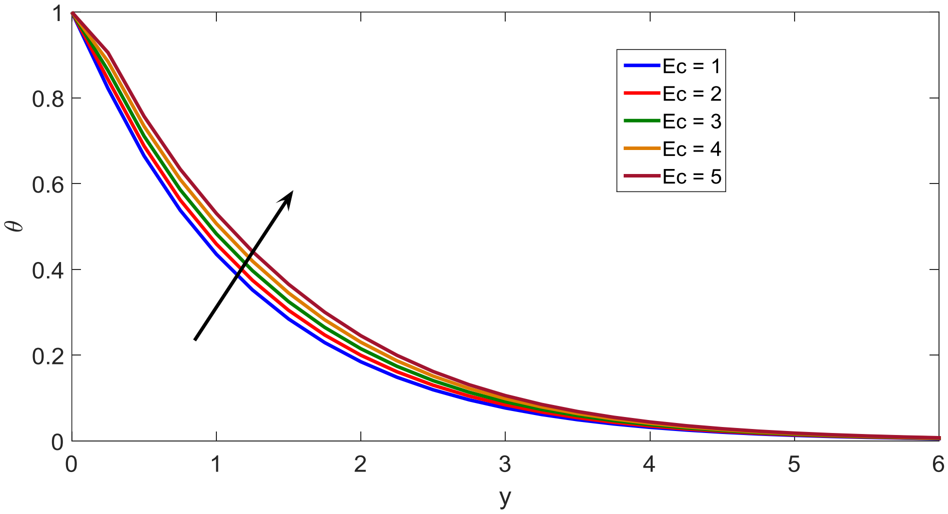

Figure 16: Effect of Ec on temperature distribution

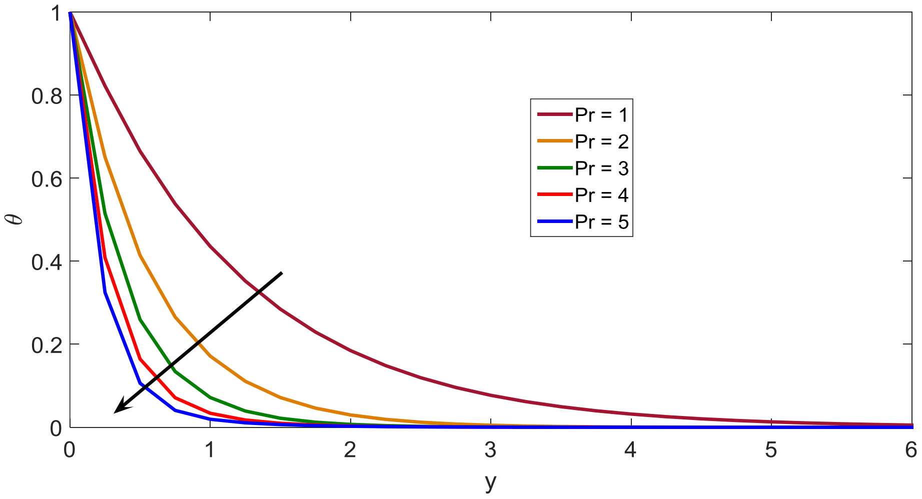

Figure 17: Effect of Pr on temperature distribution

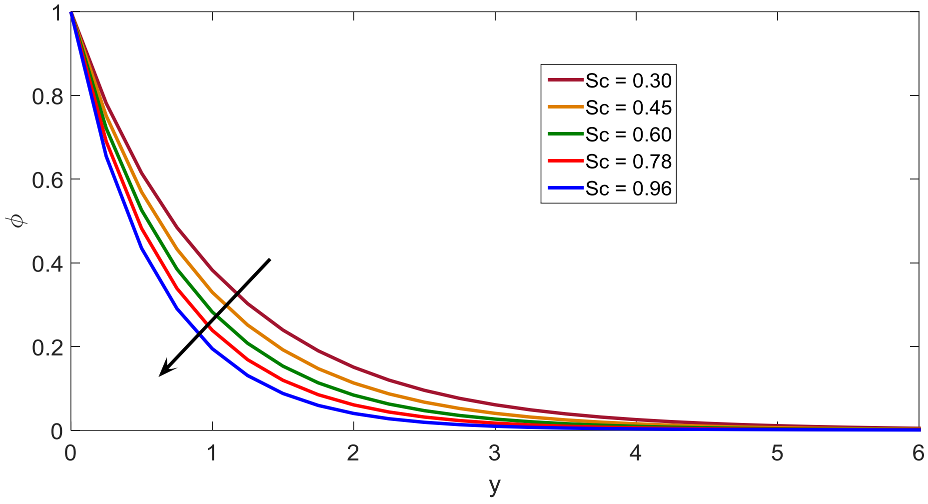

Figure 18: Effect of Sc on concentration distribution

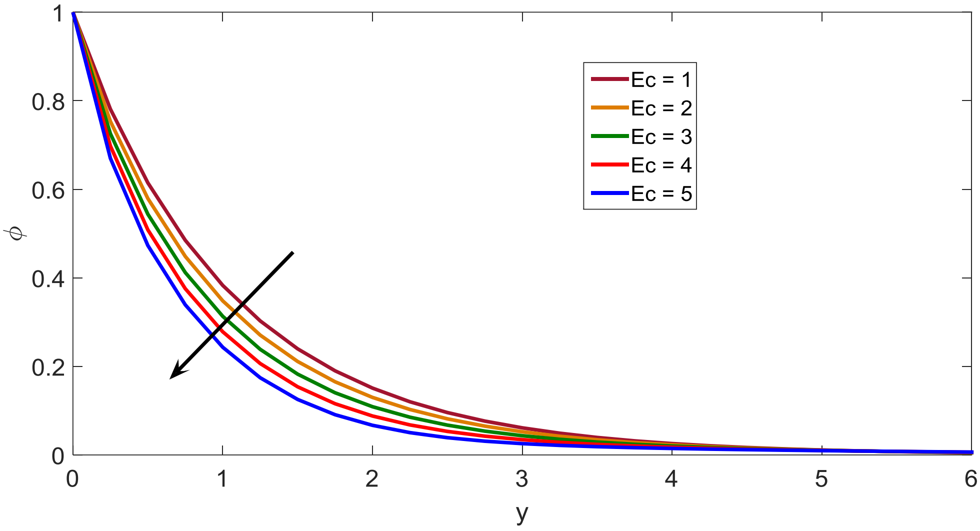

Figure 19: Effect of Ec on concentration distribution

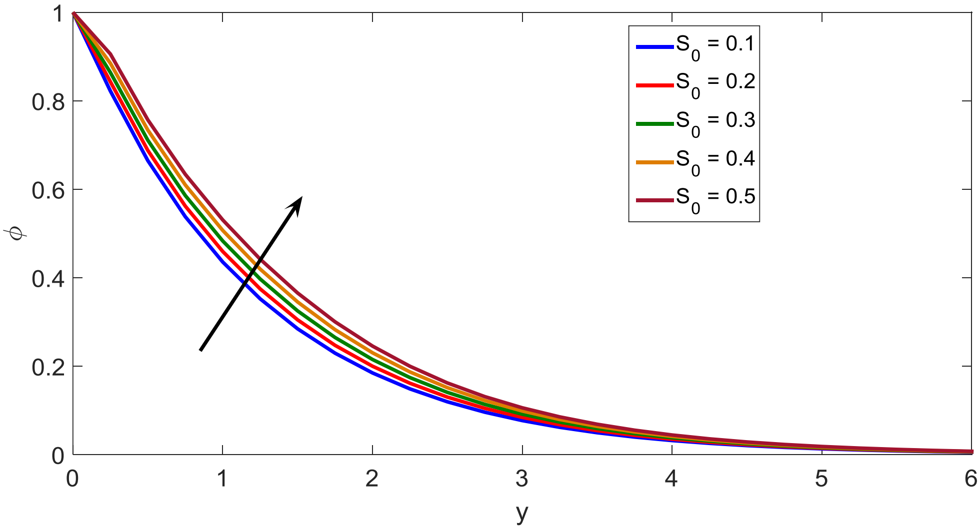

Figure 20: Effect of So on concentration distribution

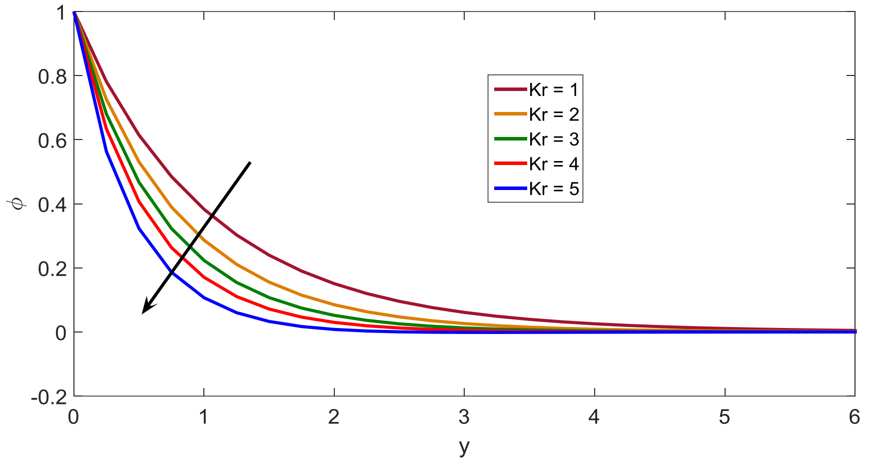

Figure 21: Effect of Kr on concentration distribution

Table 1: Effect of various physical parameters on skin friction

K	M	α	m	ξ	Ec	Pr	Kr	So	Q	τ
0.1 0.2 0.3 0.4										1.7873 2.5681 3.0762 3.3899
	0.1 0.2 0.3 0.4									1.7798 1.7807 1.7823 1.7845
		0 π/6 π/4 π/3								2.0988 1.7873 1.4277 0.9779
			0.2 0.3 0.4 0.5							1.7946 1.8012 1.8066 1.8109
				0 π/6 π/4 π/3						1.7794 1.7821 1.7847 1.7873
					1 2 3 4					1.4441 1.5540 1.6640 1.7739
						0.71 0.81 0.91 1.01				1.8106 1.8073 1.8032 0.8019
							0.1 0.3 0.5 0.7			2.3125 2.0900 1.9863 1.9083
								0.2 0.3 0.4 0.5		1.8340 1.8583 1.8833 1.9092
									1 2 3 4	1.7002 1.6067 1.5445 1.4988

Table 2: Effect of various physical parameters on Nusselt number

Sc	Kr	So	Pr	Ec	Q	M	Nu
0.45							0.4107
0.60							0.4272
0.78							0.4430
0.96							0.4558
	0.1						0.3654
	0.2						0.3742
	0.3						0.3811
	0.4						0.3870
		1					0.3973
		2					0.3814
		3					0.3643
		4					0.3460
			1				0.3811
			2				0.4630
			3				0.5448
			4				0.6269
				0.1			0.3893
				0.2			0.2892
				0.3			0.1891
				0.4			0.0890
					1		0.1749
					2		0.2087
					3		0.2301
					4		0.2444
						1	0.3858
						2	0.3724
						3	0.3524
						4	0.3290

Table 3: Effect of various physical parameters on Sherwood number

Sc	Kr	So	Pr	Ec	Q	Sh
0.45						1.0146
0.60						1.2580
0.78						1.5881
0.96						2.0818
	0.1					0.6449
	0.2					0.4588
	0.3					0.7226
	0.4					0.7789
		0.2				0.8170
		0.3				0.8584
		0.4				0.8941
		0.5				0.9238
			0.70			1.0129
			0.80			1.0306
			0.90			1.0468
			1.00			1.0518
				1		0.7701
				2		0.8326
				3		0.8951
				4		0.9576
					0.2	0.7724
					0.4	0.7664
					0.6	0.7616
					0.8	0.7579

The computed numerical values of skin- friction are presented in table. 1 for different values of Permeability parameter (K), Magnetic field parameter (M), angle of inclination (α), Hall parameter (m), aligned angle (ξ), Eckert number (Ec), Prandtl number (Pr), Chemical reaction parameter (Kr), Soret parameter (So) and Heat generation parameter (Q) respectively. It is interesting to note that, the skin-friction increases with increasing of K, Ec, So, M, m, ξ and Kr . while the skin-friction decreases with increasing of α, Pr and Q. Also, Nusselt number Nu, which measures the rate of heat transfer at the plate y = 0, is shown in table 2 for different values of Schmidt number Sc, Soret parameter So, Chemical reaction parameter Kr, Prandtl number Pr, Eckert number Ec, Heat generation parameter Q and Magnetic field parameter M respectively. It is found that the rate of heat transfer rises with increasing Sc, Kr, Pr and Q. Also Nusselt number decreases as So, M and Ec increases.Sherwood number Sh, which measures the rate of mass transfer at the plate y = 0, is shown in table 3 for different values of Schmidt number Sc, Chemical reaction parameter Kr, Soret parameter So, Prandtl number Pr, Eckert number Ec and Heat generation parameter Q respectively. It is observed that Sherwood number increases with increasing values of Sc, So, Pr and Ec and decreases with increasing values of Kr and Q.

4. CONCLUSION

The novelty of present study is, the influence of the effects of hall current, aligned magnetic, Soret, chemical reaction and heat source on steady MHD mixed convective flow and heat-mass transfer past an inclined plate embedded in porous medium with Ohmic heating and viscous dissipation. From the solutions cited in the previous section and from the results and discussion, the following conclusions are arrived. The dimensionless velocity increases with an increase in Gr or Gc.

- An increase in Prandtl number (Pr) results in the decrease in temperature distribution.
- The dimensionless temperature is increasing according to the increasing values of heat source parameter.
- Soret effect increased the concentration of the fluid while chemical effect decreased.
- The dimensionless concentration of fluid decreases with increase of Schmidt number.
- The velocity, skin friction coefficient and concentration decreases as chemical reaction parameter increases whereas the dimensionless rate of mass transfer increases by it with Gr = 2 and Gm = 4.
- The effect of permeability parameter is to accelerate the velocity and skin friction coefficient with Gr = 2 and Gm = 4.
- The impact of angle of inclination over velocity and skin friction coefficient is significant. The effect of angle of inclination is to decrease the velocity and skin friction coefficient.

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APPLICATION

The results of this study can be applied in many chemical engineering processes such as drying, evaporation, condensation, sublimation and crystal growth as well as deposition of thin films. These processes take place in numerous industrial applications, e.g., polymer production, manufacturing of ceramics or glassware and food processing.

In nature, the presence of pure air or water is rather impossible. It is always possible that some other foreign mass is either present naturally in air, water or foreign masses are mixed with air or water. Simple example is the naturally available water-vapour in nature which causes the flow of air. The flow is also caused by the differences in concentration or material constitution. The presence of foreign mass in air or water causes, many times, some kind of soret and chemical effects combined, For e.g., ammonia, benzene, ethyl alcohol etc., react with air when they come in contact under certain conditions.

APPENDIX:

$$m_1 = m_4 = \frac{1}{2}\left(Pr + \left(\mathrm{Pr}^2 - 4QPr \right)^{\frac{1}{2}} \right);$$

$$m_2 = m_5 = \frac{1}{2}\left(Sc + \left(Sc^2 + 4KrSc \right)^{\frac{1}{2}} \right);$$

$$m_3 = m_6 = \frac{1}{2}\left(1 + \left(1 + 4H_2 \right)^{\frac{1}{2}} \right);$$

$$A_1 = -\frac{ScS_0 m_1^2}{m_1^2 - Scm_1 - KrSc};$$

$$A_2 = 1 - A_1;$$

$$A_3 = -\frac{H_3 + H_4 A_1}{m_1^2 - m_1 - H_2};$$

$$A_4 = -\frac{H_4 A_2}{m_2^2 - m_2 - H_2};$$

$$A_5 = -A_3 - A_4;$$

$$A_6 = -\frac{\mathrm{Pr}\left(m_3^2 + H_1 \right) A_5^2}{4m_3^2 - 2m_3 \mathrm{Pr} - Q\,\mathrm{Pr}};$$

$$A_7 = -\frac{\mathrm{Pr}\left(m_2^2 + H_1 \right) A_4^2}{4m_2^2 - 2m_2 \mathrm{Pr} - Q\,\mathrm{Pr}};$$

$$A_8 = -\frac{\mathrm{Pr}\left(m_1^2 + H_1 \right) A_3^2}{4m_1^2 - 2m_1 \mathrm{Pr} - Q\,\mathrm{Pr}};$$

$$A_9 = -\frac{2\Pr A_4 A_5 \left(m_3 m_2 + H_1\right)}{\left(m_3 + m_2\right)^2 - \Pr\left(m_3 + m_2\right) + Q\Pr};$$

$$A_{10} = -\frac{2\Pr A_4 A_3 \left(m_1 m_2 + H_1\right)}{\left(m_1 + m_2\right)^2 - \Pr\left(m_1 + m_2\right) + Q\Pr};$$

$$A_{11} = -\frac{2\Pr A_3 A_5 \left(m_3 m_1 + H_1\right)}{\left(m_3 + m_1\right)^2 - \Pr\left(m_3 + m_1\right) + Q\Pr};$$

$$A_{12} = -\left(A_6 + A_7 + A_8 + A_9 + A_{10} + A_{11}\right);$$

$$A_{13} = -\frac{ScS_0 m_4^2 A_{12}}{m_4^2 - m_4 Sc - KrSc};$$

$$A_{14} = -\frac{4ScS_0 m_3^2 A_6}{4m_3^2 - 2m_3 Sc - KrSc};$$

$$A_{15} = -\frac{4ScS_0 m_2^2 A_7}{4m_2^2 - 2m_2 Sc - KrSc};$$

$$A_{16} = -\frac{4ScS_0 m_1^2 A_8}{4m_1^2 - 2m_1 Sc - KrSc};$$

$$A_{17} = -\frac{ScS_0 A_9 \left(m_3 + m_2\right)^2}{\left(m_3 + m_2\right)^2 - \left(m_3 + m_2\right)Sc - KrSc};$$

$$A_{18} = -\frac{ScS_0 A_{10} \left(m_1 + m_2\right)^2}{\left(m_1 + m_2\right)^2 - \left(m_1 + m_2\right)Sc - KrSc};$$

$$A_{19} = -\frac{ScS_0 A_{11} \left(m_3 + m_1\right)^2}{\left(m_3 + m_1\right)^2 - \left(m_3 + m_1\right)Sc - KrSc};$$

$$A_{20} = -\left(A_{13} + A_{14} + A_{15} + A_{16} + A_{17} + A_{18} + A_{19}\right);$$

$$A_{29} = -\left(A_{21} + A_{22} + A_{23} + A_{24} + A_{25} + A_{26} + A_{27} + A_{28}\right);$$

$$A_{21} = -\frac{H_4 A_{20}}{m_5^2 - m_5 - H_2};$$

$$A_{22} = -\frac{\left(H_3 A_{12} + H_2 A_{13}\right)}{m_4^2 - m_4 - H_2};$$

$$A_{23} = -\frac{\left(H_3 A_6 + H_4 A_{14}\right)}{4m_3^2 - 2m_3 - H_2};$$

$$A_{24} = -\frac{\left(H_3 A_7 + H_4 A_{15}\right)}{4m_2^2 - 2m_2 - H_2};$$

$$A_{25} = -\frac{\left(H_3 A_8 + H_4 A_{16}\right)}{4m_1^2 - 2m_1 - H_2};$$

$$A_{26} = -\frac{\left(H_3 A_9 + H_4 A_{17}\right)}{\left(m_3 + m_2\right)^2 - \left(m_3 + m_2\right) - H_2};$$

$$A_{27} = -\frac{\left(H_3 A_{10} + H_4 A_{18}\right)}{\left(m_1 + m_2\right)^2 - \left(m_1 + m_2\right) - H_2};$$

$$A_{28} = -\frac{\left(H_3 A_{11} + H_4 A_{19}\right)}{\left(m_3 + m_1\right)^2 - \left(m_3 + m_1\right) - H_2}.$$