

Heat and Mass transfer Flow on Magneto Hydro Dynamic Convective flow through Porous medium between Infinite vertical plate with Soret and Joules dissipation

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Abstract: In the present paper, we have deliberated the combined impact of magneto hydro dynamic mixed convective two-dimensional flow of viscous fluid which is of electrically conducting and incompressible through porous medium past between unbounded vertical plate taking Soret and Joules dissipations into account. The dimensionless equations are examined by using perturbation technique. The impacts of the dimensionless parameters, warmth, velocity and concentration distributions are examined with the aids of graphs. Also, the consequences of the pertinent parameters at the skin-friction coefficient and rates of heat and mass transfer in phrases of the Nusselt and Sherwood numbers are computationally discussed.

Keywords: Vertical plate, porous medium, heat and mass transfer, Soret and Joules dissipations, magnetic field, skin-friction, Nusselt number, Sherwood numbers.

1. Introduction

MHD is presently bear a phase of great growth and differentiation of subject matter. The attention at the present problem achieves by their importance in liquid materials, electrolytes and ionized gases. with their varied importance, these types of flows have been examined by various persons among them are Raju and Varma [1], Srinivas and Muthuraj [2] and Orthan and Ahmet [3]. Reddy et al. [4] examined Thermo-diffusion and chemical effects by concurrent thermal and mass diffusion in Magneto Hydro Dynamic mixed convection flow by holmic warming. Magneto Hydro Dynamic mixed convection by Soret and Dufour impacts over permeable channel was studied by Makinde [5]. The considerable focus of our discussion is the impact on mixed convection flow of the extension of a second fluid. The consequence of Soret impact on the flow of an electrically conducting fluid past on a vertical plate in the existence of varied physical parameters has been examined by Satya Narayana et al. [6]. Veera Krishna et al. [6-10] discussed some MHD flows through porous channels. Motivated from, the above studies in the current paper, we have deliberated the joint effects of Magneto Hydro Dynamic mixed convective multi-dimensional flow of an incompressible viscous fluid of electrically conducting fluid through porous medium an unbounded vertical plate taking Soret and Joules dissipations into account.

2. Formulation and Solution of the Problem:

We take the joint convention flow of viscous fluid which is of electrically conducting and incompressible. The x -axis is considered as upward direction parallel to the plate and z -axis is perpendicular to the plate as shown in the figure 1. A uniform magnetic field is applied, along the direction normal to x -axis. All the substantial variables are independent of the variable x because the movement is 2-dimensional, plate length is unbounded. Between the fluid and species, a first order homogeneous chemical reaction is taken in to account, it says the species concentration is directly proportional to the rate of chemical reaction. For the continuity, momentum, energy and mass for a flow of an electrically conducting viscous fluid the governing equations are taken as

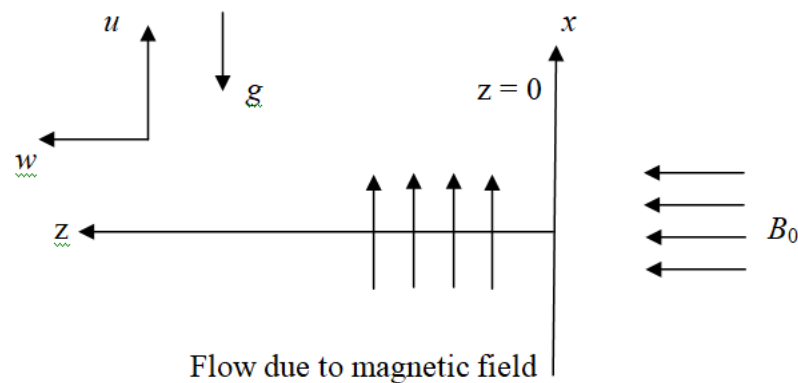


Fig 1: Physical Configuration of the Problem

$$\frac{\partial w}{\partial z} = 0 \Rightarrow -w_0 \quad (w_0 \geq 0) \quad (1)$$

$$w \frac{\partial u}{\partial v} = \nu \frac{\partial^2 u}{\partial z^2} - \frac{\sigma B_0^2}{\rho} u - \frac{\nu}{k} u + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) \quad (2)$$

$$w \frac{\partial w}{\partial z} = \nu \frac{\partial^2 w}{\partial z^2} - \frac{\sigma B_0^2}{\rho} w - \frac{\nu}{k} w \quad (3)$$

$$w \frac{dT}{dz} = \frac{k_1}{\rho C_p} \frac{d^2 T}{dz^2} + \frac{\nu}{C_p} \left(\frac{du}{dz} \right)^2 + \frac{\sigma B_0^2}{\rho C_p} (u^2 + w^2) + \frac{Q_0}{\rho C_p} (T - T_\infty) \quad (4)$$

$$w \frac{dC}{dz} = D \frac{d^2 C}{dz^2} + D_1 \frac{d^2 T}{dz^2} - k_2 (C - C_\infty) \quad (5)$$

The boundary conditions for the velocity, temperature and concentration fields are

$$u = 0; \quad w = 0 \quad T = T_w \quad C = C_w \quad \text{at } z = 0$$

$$u = (0); \quad w = (0); \quad T \rightarrow T_\infty; \quad C \rightarrow C_\infty \quad \text{at } z \rightarrow \infty \quad (6)$$

Combining equations (2) and (3), let $q = u + iw$ we obtain

$$w \frac{\partial q}{\partial v} = \nu \frac{\partial^2 q}{\partial z^2} - \frac{\sigma B_0^2}{\rho} q - \frac{\nu}{k} q + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) \quad (7)$$

Introducing following non-dimensional quantities

$$y = \frac{y^* v_0}{\nu}, \quad u = \frac{u^*}{v_0}, \quad \text{Pr} = \frac{\nu \rho C_p}{k}, \quad \theta = \frac{T^* - T_\infty}{T_w - T_\infty}, \quad \phi = \frac{C^* - C_\infty}{C_w - C_\infty}, \quad \text{Gr} = \frac{\nu g \beta (T_w - T_\infty)}{v_0^3},$$

$$\begin{aligned} Gr &= \frac{\nu g \beta^* (C_w - C_\infty)}{\nu_0^3}, Ec = \frac{\nu_0^2}{C_p (T_w - T_\infty)}, M^2 = \frac{\sigma B_0^2 \nu}{\rho \nu_0^2}, K = \frac{\nu}{k \nu_0^2}, \nu = \frac{\mu}{\rho}, \\ Sc &= \frac{\nu}{D}, So = \frac{D_1 (T_w - T_\infty)}{\nu (C_w - C_\infty)}, Kr = \frac{\nu k_1}{\nu_0^2}, Q = \frac{Q_0 \nu}{\rho C_p \nu_0^2}. \end{aligned} \quad (8)$$

Here $Gr, Gm, Pr, Sc, So, Ec, M, K$ and Kc are the Grashoff number, mass of Grashoff number, Prandtl number, Schmidt number, Soret number, Eckert number, Magnet parameter, Permeability parameter and Chemical reaction parameter respectively for the equations form (2) - (4), the non-dimensional form of governing equations are:

$$q'' + q' - \left(M^2 + \frac{1}{K} \right) u = -Gr\theta - Gm\phi \quad (9)$$

$$\theta'' + Pr\theta' + PrEc(u')^2 + PrEcM^2(u^2 + w^2) + PrQ\theta = 0 \quad (10)$$

$$\phi'' + Sc\phi' - ScKr\phi + SoSc\theta'' = 0 \quad (11)$$

The corresponding boundary conditions in dimensionless form are reduced to

$$\begin{aligned} q=0; \quad \theta=1; \quad \phi=1 \quad \text{at } z=0 \\ q \rightarrow 0; \quad \theta \rightarrow 0; \quad \phi \rightarrow 0 \quad \text{at } z \rightarrow \infty \end{aligned} \quad (12)$$

In the index of the Eckert number Ec the substantial variables q, θ and ϕ are to be expanded. It is substantially hold as Ec is always less the unity for the incompressible fluid flow. The joules dissipation is overlying on the original fluid flow so this is to be disrupted substantially. Hence, we consider

$$\left. \begin{aligned} q(y) &= q_0(y) + Ecq_1(y) + O(Ec^2) \\ \theta(y) &= \theta_0(y) + Ec\theta_1(y) + O(Ec^2) \\ \phi(y) &= \phi_0(y) + Ec\phi_1(y) + O(Ec^2) \end{aligned} \right\} \quad (13)$$

Substituting equation (13) into equations (9)-(11) .by comparing the Ec coefficients of equal powers, to get the zeros order, first order differential equations and boundary conditions.

Solving these equations, we obtain temperature, concentration and velocity distribution in the boundary layer.

Skin function, Nusselt number and Sherwood number:

The non-dimensional Skin friction coefficient at the plate, the rate of heat transfer in terms Nusselt number and Sherwood number are given by

$$C_f = \left(\frac{\partial u}{\partial z} \right)_{z=0}, \quad Nu = \left(\frac{\partial \theta}{\partial z} \right)_{z=0}, \quad Sh = \left(\frac{\partial \phi}{\partial z} \right)_{z=0}$$

3. Results and Discussion:

From the Fig.2, we observer by increasing the intensity of the magnetic field M , the significance of the velocity segments u and v decreases, it is because of the this is due to the evidence that the initiation of a translation magnetic field, perpendicular to the direction of the fluid flow, it has habitually generated the drag knowns like Lorentz force it resists the fluid flow. The response velocity is going to decrease by increasing Hartmann number M . Fig.3, it is observed by increasing the permeability parameter K the significance the velocity segments u and w growing up. It is observed the permeability parameter decrease the fluid flow velocity throughout the fluid region. The consequent velocity is also increases with enhancing permeability parameter K .

In Fig.4 it is showing that the impacts of Grashoff number Gr over the velocity elements u and w for the constant values of another parameters. And is noticed that non dimensional velocity grown up with it is

observed that the dimensionless velocity increases with rising Grashoff number Gr . In Fig.5 it is shown that the effects of heat generating parameter Q over the non-dimensional velocity elements u and w for the constant values of the parameters. It is observed that the two non-dimensional velocity elements u and v rising together with Q . In Fig 6 we study the influence of the Prandtl number Pr over the non-dimensional warmth to the constant values of another parameters. The warmth decreases by rising Prandtl number Pr . Fig.7 shows the consequence of the non-dimensional absorption to different values of parameter Kc (chemical reaction). This is noticeable when raising the value of Kc the decrease is to be noticed in the concentration profiles. It indicates that buoyancy impacts are considerable over the plate. From the tables 1 to 3 we observe the change in skin friction parameter, the amount of heat exchange (Nusselt number) and the amount of mass transmission (Sherwood number) to the different parameters of interest. We see that the Skin friction coefficient decreases by enhancing Reaction coefficient Kc , Pr (Prandtl number), M (Hartmann number) and Sc (Schmidt number); same as it increases permeability coefficient K , thermal coefficient, Gr (Grashoff number), Gm (mass Grashoff number), Q (Heat generation parameter) and So (Soret parameter) (showed in table 1).

The significance of the Nusselt number (Nu) enhances by rising Prandtl number (Pr) and reduces by enhancing Heat generation parameter coefficient (Q) (showed in table 2). Likewise, the significant of the Sherwood parameter (Sh) enhances by rising Schmidt parameter (Sc) or Chemical reaction parameter (Kc) and decreases by enhancing Soret number (So). For the effectiveness of our effort, in the absence of heat source and porous medium we compare our results with the we have compared our results with the actual outcomes of Reddy et al. [4]. Our result shows to be in excellent agreement with the existing results (see Table .4).

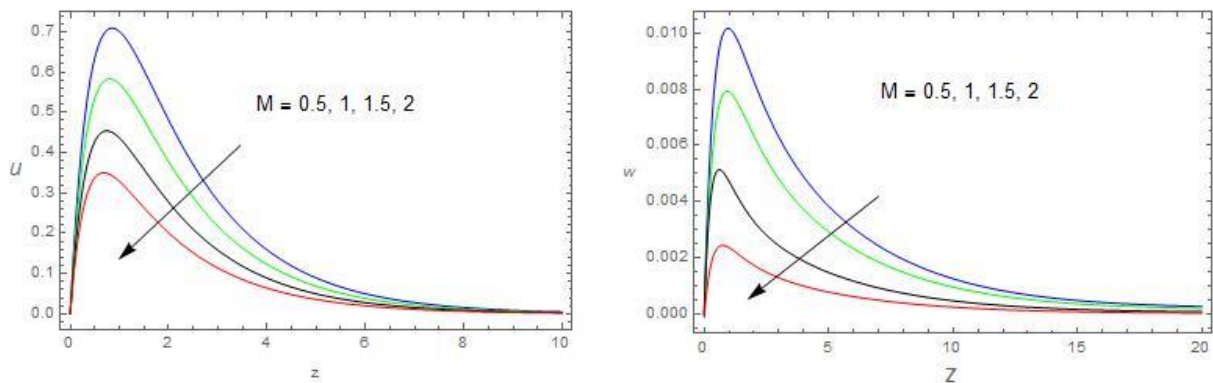


Fig 2: The velocity profiles for u and w against M

$$K=0.5, Pr=0.71, Gr=3, Gm=1, Q=0.1, Kc=1, Sc=0.22, So = 0.5$$

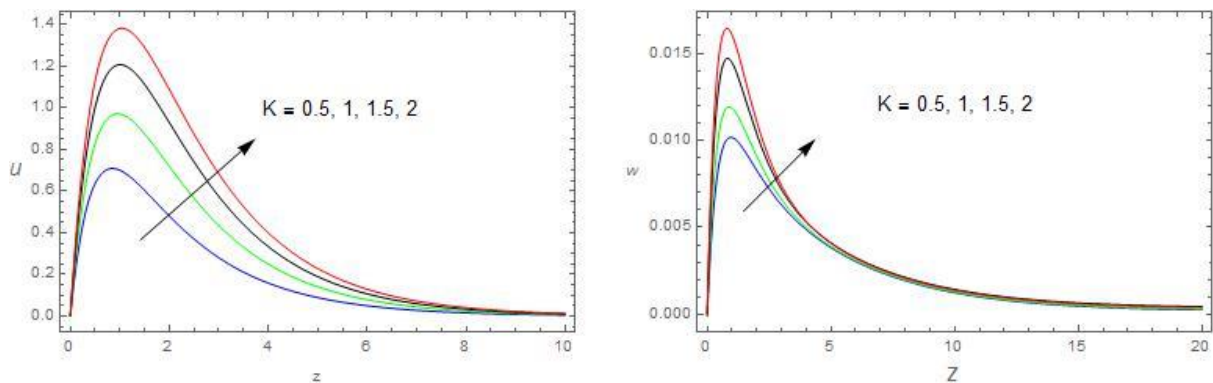


Fig 3: The velocity profiles for u and w against K

$$M = 0.5, Pr = 0.71, Gr = 3, Gm = 1, Q = 0.1, Kc = 1, Sc = 0.22, So = 0.5$$

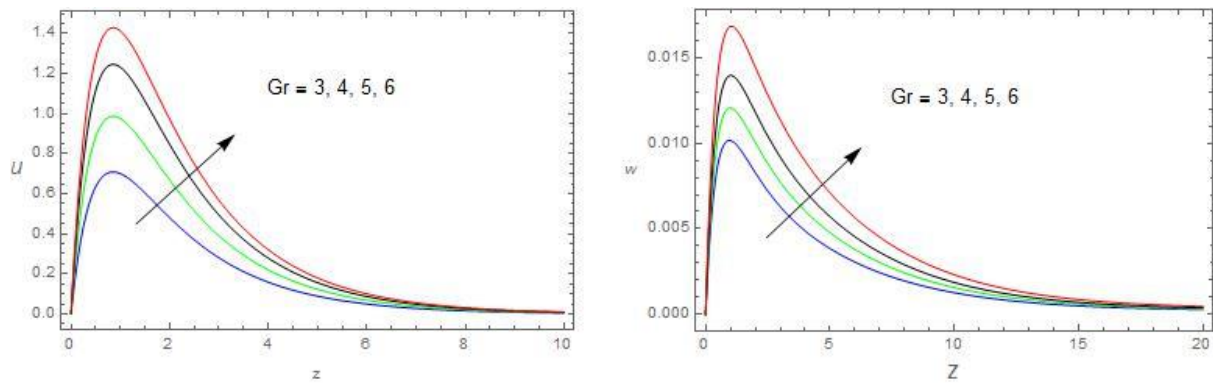


Fig 4: The velocity profiles for u and w against Gr

$$M = 0.5, K = 0.5, Pr = 0.71, Gm = 1, Q = 0.1, Kc = 1, Sc = 0.22, So = 0.5$$

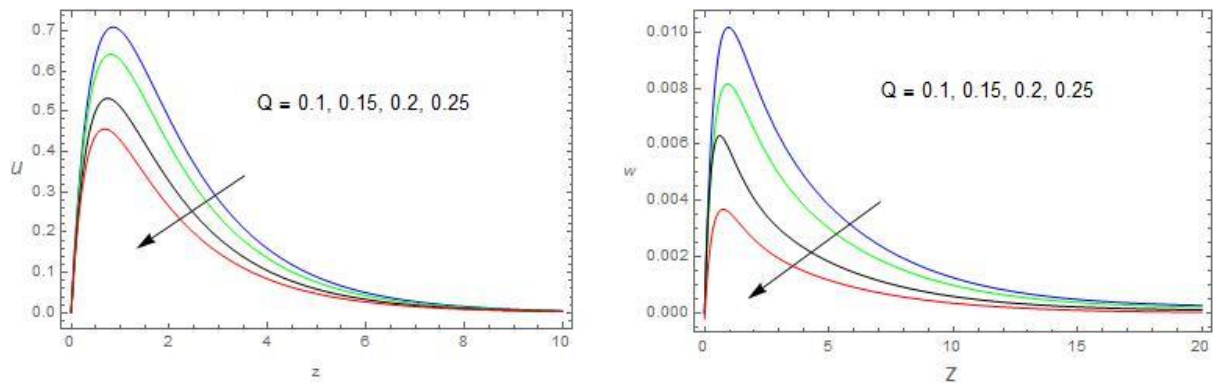


Fig 5: The velocity profiles for u and w against Q

$$M=0.5, K=0.5, Pr=0.71, Gr=3, Gm=1, Kc=1, Sc=0.22, So=0.5$$

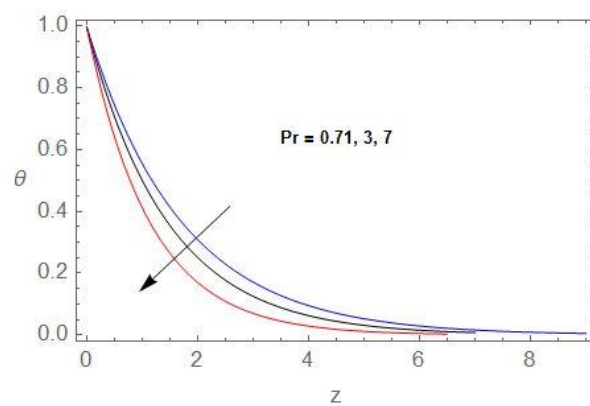


Fig 6: The temperature profile for θ against Pr with $Q = 0.1$

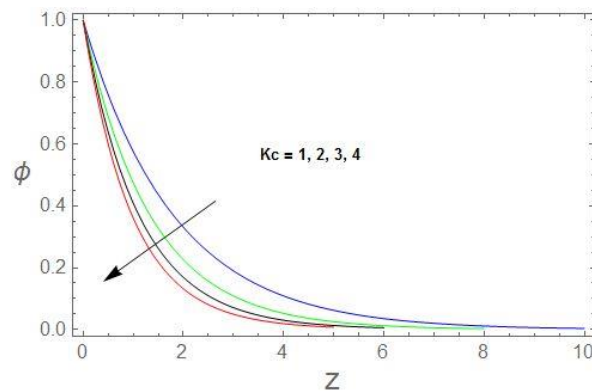


Fig 7: The Concentration profile for ϕ against Kc with $So = 0.5$, $Sc = 0.22$

Table 1: Shear stress ($Ec=0.01$)

M	K	Pr	Gr	Gm	Kc	Q	Sc	So	$ \tau $
0.5	0.5	0.71	3	1	1	0.1	0.22	0.5	2.41279
1									2.10318
1.5									1.82170
	1								3.08254
	1.5								3.47849
		3							1.39572
		7							1.02851
			4						3.01694
			5						3.62411
				2					3.02759
				3					3.64290
					2				2.34754
					3				2.30599
						0.5			2.68722
						0.8			2.81238
							0.3		2.37349
							0.6		2.27696
								1	2.42702
								1.5	2.44124

Table 2: Nusselt number

($M=0.5, K=0.5, Gr=3, Gm=1, Kc=1, So=0.5, Sc=0.22, Ec=0.01$)

Pr	Q	Nu
0.71	0.1	-0.579521
3		-3.009720
7		-6.910550
	0.2	-0.342134
	0.3	-0.133423

Table 3: Sherwood number
($M=0.5, K=0.5, Pr=0.71, Gr=3, Gm=1, Q=0.1, Kc=1, Ec=0.01$)

So	Sc	Kc	Sh
0.5	0.22	1	-0.553031
1			-0.514333
1.5			-0.475675
	0.3		-0.667466
	0.6		-1.033987
		2	-0.750102
		3	-0.901226

Table 4: Comparison of results with Reddy et al. [25]
for ($K=\infty, Gr=3, Gm=1, Pr=0.71, Q=0, Ec=0.01$)

M	Kc	So	Sc	<i>Reddy et al. [25]</i>			<i>Present work</i>		
				Cf	Nu	Sh	Cf	Nu	Sh
0.5	1	0.5	0.22	4.70415	-0.65747	-0.54588	4.70417	-0.65742	-0.54587
1				3.15452	-0.68073	-0.54341	3.15455	-0.68077	-0.54344
1.5				2.30347	-0.69218	-0.54326	2.30346	-0.69216	-0.54328
	2			4.41999	-0.66541	-0.74314	4.41997	-0.66540	-0.74313
	3			4.26892	-0.66922	-0.89451	4.26891	-0.66925	-0.89457
		1		4.77844	-0.65518	-0.50049	4.77841	-0.65516	-0.50042
		1.5		4.85268	-0.65281	-0.45540	4.85266	-0.65284	-0.45544
			0.3	4.52842	-0.66246	-0.65738	4.5285	-0.66245	-0.65739
			0.6	4.19354	-0.67098	-1.01922	4.19356	-0.67099	-1.01921

4. Conclusions

1. When enhancing the Hartmann number, the resultant velocity reduces.
2. By enhancing the heat source parameter, the velocity and non-dimensional temperature rises.
3. By enhancing the magnetic field parameter or permeability parameter the Sc (skin friction coefficient) reduces, this indicates the opposite effect the case of Grashoff Gm and mass Grashoff Gr numbers.
4. By enhancing the Prandtl number the Nusselt number rises.

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