# A STUDY ON UNSTEADY MHD FREE CONVECTION AND MASS TRANSFER FLOW PAST A VERTICAL POROUS PLATE

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**Abstract:** We investigate the Unsteady MHD free Convection and Mass transfer Boundary layer flow past a semi-infinite vertical Porous plate immersed in a Porous medium with heat Source is studied. The Plate moves with a uniform Velocity in the direction of the fluid flow while the free Stream Velocity is considered to follow the exponentially increasing Small Perturbation law. Usual Similarity transformations are introduced to solve the Momentum, Energy and Concentration Equations. To Obtain the Solutions of the Problem, the ordinary differential equations are Solved by Using Perturbation technique depending upon the physical parameters including the Radiation Parameter (R), the Magnetic Parameter (M), the Prandtl number (Pr), the Grashof number for heat transfer (Gr) the modified Grashof number for Mass transfer (Gc), the Schmidt number (Sc), the Soret number, the permeability parameter (K) and the heat Source (Q). The resulting Equations are solved and the solutions for the Velocity, temperature and Concentration fields are presented graphically. For the different Values of the flow parameters involved in the problem, the numerical Calculations for the Nusselt number, Sherwood number and Skin Frictions are discussed graphically.

**Key Words:** MHD, Heat and Mass Transfer, Porous plate, Perturbation Law, Heat Source, Soret number, Free Convection.

**Introduction:** The study of unsteady MHD free convection flow with mass transfer along a vertical porous plate is receiving considerable attention of many researchers because of its various applications. Permeable porous plate are used in the filtration processes and also for a heated body to keep its temperature constant and to make the heat insulation of the surface more effective .Sometimes along with the free convection currents caused by differences in concentration or material constitution. This type of flow has applications in many branches of science and engineering. The study of such flow under the influence of magnetic field has attracted the investigators in view of its various applications in MHD generators, plasma studies, nuclear reactors, geothermal energy extractions and boundary layer control in the field of aerodynamics. Moreover, considerable interest has been shown in radiation interaction with convection for heat and mass transfer in fluids. This is due to the significant role of thermal radiation in the surface heat transfer when convection heat trasnsfer is small, particularly in free convection problems involving absorbing –emitting fluids.

Some of them have studied the problem of free convection flow with mass transfer. Singh et al have studied MHD free convection flow past an accelerated vertical porous plate by finite difference method. Free convection and mass transfer flow through porous medium bounded by an infinite vertical limiting surface with constant suction have been analyzed by Raptis et al. Unsteady free convection interaction with thermal radiation in boundary layer flow past a vertical porous plate has been discussed by Sattar et al. Das et al have studied numerical solution of mass transfer effects on Unsteady flow past an accelerated vertical porous plate with suction. Das et al have studied mass transfer effects on MHD flow and heat transfer past a vertical porous plate through porous medium under oscillatory suction and heat source .Applied magnetic field on transient convective flow in a vertical channel has been discussed by Jah .Kim has investigated the problem of unsteady MHD convective has transfer past a semi-infinite vertical porous moving plate with variable suction. Soundalgekar et al have analyzed the transient free convection flow of a viscous dissipative fluid past a semi-infinite vertical plate. Mohameda et al have analyzed finite element analysis of hydromagnetic flow and heat transfer of a heat generation fluid over a surface embedded in a non-darcian porous medium in the presence of chemical reaction. The Soret effect on free convective unsteady MHD flow over a vertical plate with heat source has been analyzed by Bhavana et al.Abd El –Naby et al employedimplict finite difference methods to study the effects of radiation on MHD unsteady free convection flow past a semi-infinite vertical porous plate but did not take into account the viscous dissipation. Alam and Rahman have examined Dufour and Soret effects on mixed convection flow past a vertical porous flat plate with variable suction embedded in a porous medium for hydrogen-air mixture as the non chemical reacting fluid pair.Anwa.et.al examined the combined effects of Soret and Dufour diffusion and porous impedance on laminar magneto – hydrodynamic mixed convection heat and mass transfer of an electrically-conducting, Newtonian, Boussinesq fluid from a vertical stretching surface in a Darcian porous medium under uniform transverse magnetic field. Hady et al. studied the problem of free convection flow along vertical surface embedded in electrically conducting fluid saturated porous media in the presence of internal heat generation or absorption effect. Makinde have discussed free convection flow with thermal radiation and mass transfer past a moving vertical porous plate.

**Formulation of the Problem:** Consider a two dimensional unsteady f low of a laminar, incompressible, viscous, electrically conducting and heat generation fluid past a semi-infinite vertical moving plate embedded in a uniform porous medium and subjected to a uniform transverse magnetic field in the presence of a pressure gradient has been considered with free convection, thermal diffusion and thermal radiation effects taking in to an account. According to the coordinate system the $x^*$ -axis is taken along the porous plate in the upward direction and $y$-$^*$axis normal to it. The fluid is assumed to be gray, absorbing–emitting but not scattering medium. The radiative heat flux in the $x$*-direction is considered negligible in comparison with that in the $y$*-direction. It is assumed that there is no applied voltage of which implies the absence of an electric field. The transversely applied magnetic field and magnetic Reynolds number are very small and the induced magnetic field is negligible. Viscous and Darcy resistance terms are taken into account the constant permeability porous medium. The MHD term is derived from an order of magnitude analysis of the Navier-stokes equation. The fluid properties are considered to be constants except that the influence of density variation with temperature and concentration has been assumed in the body-force term. Due to the semi-infinite plate surface assumption, the flow variable are functions of $y$* and $t$* only. The governing equation for this observation is based on the balances of mass, linear momentum, energy and concentration species.

**Continuity Equation**:

$$\frac{\partial v^*}{\partial y^*} = 0 \tag{1}$$

**Momentum Equation**:

$$\rho\left(\frac{\partial u^*}{\partial t^*} + \gamma^* \frac{\partial u^*}{\partial y^*}\right) = \frac{\partial p^*}{\partial x^*} + \mu \frac{\partial^2 u^*}{\partial y^{*^2}} - \rho\beta - \frac{\mu}{K^*} u^* - \sigma B_0^2 u^* \tag{2}$$

**Energy Equation**:

$$\frac{\partial T^*}{\partial t^*} + \gamma^* \frac{\partial T^*}{\partial y^*} = \frac{k}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*^2}} - \frac{1}{\rho C_p}\frac{\partial {q_r}^*}{\partial y^*} - \frac{Q_0}{\rho C_p}(T^* - T_\infty^*) \tag{3}$$

**Species Concentration**:

$$\frac{\partial C^*}{\partial t^*} + \gamma^* \frac{\partial C^*}{\partial y^*} = D_m \frac{\partial^2 C^*}{\partial y^{*^2}} + D_T \frac{\partial^2 T^*}{\partial y^{*^2}} \tag{4}$$

The boundary conditions are

$$u^* = u_p^*, T^* = T_w^* + \varepsilon(T_w^* - T_\infty^*)e^{n^* t^*}, C^* = C_w^* + \varepsilon(C_w^* - C_\infty^*)e^{n^* t^*} \text{ at } y^* = 0 \tag{5}$$

$$u^* \to U_\infty^* = U_0(1 + \varepsilon e^{n^* t^*}), T^* \to T_\infty^*, C^* \to C_\infty^* \text{ at } y^* \to \infty \tag{6}$$

$$v^* = -v_0(1+\varepsilon e^{n^* t^*}) \tag{7}$$

We introduce the following quantities as

$$u^* = uU_0, v^* = vV_0, T^* = T_\infty^* + \theta(T_w^* - T_\infty^*), C^* = C_w^* + C(C_w^* - C_\infty^*), U_\infty^* = U_\infty U_0$$

$$u_p^* = U_p U_0, K^* = \frac{Kv^2}{V_0^2}, y^* = \frac{yv}{V_0}, Gc = \frac{vg\beta*(C_w^* - C_\infty^*)}{V_0^2 U_0}, Gr = \frac{vg\beta*(T_w^* - T_\infty^*)}{V_0^2 U_0} \tag{8}$$

$$\Pr = v\rho C_p, M = \frac{\sigma B_0^2 v}{\rho V_0^2}, Q = \frac{vQ_0}{\rho V_0^2 C_p}, R = \frac{4\sigma^* T_\infty^{*^3}(T_w^* - T_\infty^*)}{k_1^* k}$$

The non dimensional forms of equations are

$$\frac{\partial v}{\partial y} = 0 \tag{9}$$

$$\frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y} = \frac{\partial U\infty}{\partial t} + \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC + N(U_\infty - u) \tag{10}$$

$$\frac{\partial \theta}{\partial t} + v\frac{\partial \theta}{\partial y} = \frac{1}{\Pr}(1+\frac{4R}{3})\frac{\partial^2 \theta}{\partial y^2} - Q\theta \tag{11}$$

$$\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + S_0\frac{\partial^2 \theta}{\partial y^2} \tag{12}$$

The Corresponding initial boundary Conditions are

$$u = U_p, \theta = 1+\varepsilon e^{nt}, C = 1+\varepsilon e^{nt} \text{ at y=o} \tag{13}$$

$$u \to U_\infty \to 1+\varepsilon e^{nt}, \theta \to 0, C \to 0 \text{ as } y \to \infty$$

For perturbation technique to solve equation s.we consider as the following forms

$$u = u_0(y) + \varepsilon e^{nt} u_1(y) + O(\varepsilon^2) \tag{14}$$

$$\theta = \theta_0(y) + \varepsilon e^{nt}\theta_1(y) + O(\varepsilon^2)$$

$$C = C_0(y) + \varepsilon e^{nt} C_1(y) + O(\varepsilon^2)$$

By substituting the above equations we get

$$u_0'' + u_0' - Nu_0 = -N - Gr\theta_0 - GcC_0 \tag{15}$$

$$u_1'' + u_1' - (N+n)u_1 = -(N+n) - Au_0' - Gr\theta_1 - GcC_1 \tag{16}$$

$$(3+4R)\theta_0'' + 3\Pr\theta_0' - 3Q\Pr\theta_0 = 0 \tag{17}$$

$$(3+4R)\theta_1'' + 3\Pr\theta_0' - (3n+Q)\Pr\theta_1 = -3A\Pr\theta_0' \tag{18}$$

$$C_0'' + ScC_0' = -S_0 Sc\theta_0'' \tag{19}$$

$$C_1'' + ScC_1' - nScC_1 = -AScC_0^1 - S_0 Sc\theta_0'' \tag{20}$$

Then the Corresponding boundary conditions can be written as

$$\left.\begin{array}{l} u = U_0, v = -1, \theta = 1, \phi = 1, \quad at\ y = 0 \\ u \to 0, v \to -1, \theta \to 0, \phi \to 0, at\ y \to \infty \end{array}\right\} \tag{21}$$

The Solutions of the equations are

$$u_0 = 1 + A_1 e^{m_2 y} + A_2 e^{m_6 y} + A_3 e^{m_2 y} + A_4 e^{m_{10} y} \tag{22}$$

$$u_1 = 1 + A_6 e^{m_{10}y} + A_7 e^{m_2 y} + A_8 e^{my} + A_9 e^{m_2 y} + A_{10} e^{m_4 y} + A_{11} e^{m_2 y} + A_{12} e^{m_8 y} + A_{13} e^{m_6 y} + A_{14} e^{m_2 y} + A_{15} e^{m_2 y} + A_{16} e^{m_4 y} + A_{17} e^{m_{12} y}$$

$$\theta_0 = e^{m_2 y} \tag{24}$$

$$\theta_1 = D_1 e^{m_2 y} + D_2 e^{m_4 y} \tag{25}$$

$$C_0 = B_1 e^{m_2 y} + B_2 e^{m_6 y} \tag{26}$$

$$C_1 = B_3 e^{m_6 y} + B_4 e^{m_2 y} + B_5 e^{m_8 y} + D_3 e^{m_2 y} + D_4 e^{m_4 y} \tag{27}$$

$$u(y,t) = 1 + A_1 e^{m_2 y} + A_2 e^{m_6 y} + A_3 e^{m_2 y} + A_4 e^{m_{10} y} + \varepsilon e^{nt}(1 + A_6 e^{m_{10} y} + A_7 e^{m_2 y} + A_8 e^{my} + A_9 e^{m_2 y} + A_{10} e^{m_4 y}$$
$$+ A_{11} e^{m_2 y} + A_{12} e^{m_8 y} + A_{13} e^{m_6 y} + A_{14} e^{m_2 y} + A_{15} e^{m_2 y} + A_{16} e^{m_4 y} + A_{17} e^{m_{12} y}$$

$$\theta(y,t) = e^{m_2 y} + \varepsilon e^{nt}\left(D_1 e^{m_2 y} + D_2 e^{m_4 y}\right)$$

$$C(y,t) = B_1 e^{m_2 y} + B_2 e^{m_6 y} + \varepsilon e^{nt}(B_3 e^{m_6 y} + B_4 e^{m_2 y} + B_5 e^{m_8 y} + D_3 e^{m_2 y} + D_4 e^{m_4 y})$$

$$A_3 = \frac{-GcB_1}{m_2^2 + m_2 - N}$$

$$A_4 = (U_p - 1 - A_1 - A_2 - A_3)$$

$$m_2 = \frac{-1 + \sqrt{1 + 4Q}\beta_1}{2\beta_1} \qquad A_6 = \frac{-AA_4 m_{10}}{m_{10}^2 + m_{10} - (N+n)}$$

$$m_4 = \frac{-1 + \sqrt{1 + 4(n+Q)\beta_1}}{2\beta_1} \qquad A_7 = \frac{-AA_1 m_2}{m_2^2 + m_2 - (N+n)}$$

$$A_8 = \frac{-AA_2 m_6}{m_6^2 + m_6 - (N+n)}$$

$$m_6 = -Sc \qquad A_9 = \frac{-AA_3 m_6}{m_2^2 + m_2 - (N+n)}$$

$$m_8 = \frac{-Sc + \sqrt{(Sc^2) + 4nSc}}{2} \qquad A_{10} = \frac{-GrD_2}{m_4^2 + m_4 - (N+n)}$$

$$m_{10} = \frac{-1 + \sqrt{1 + 4N}}{2} \qquad A_{11} = \frac{-GrD_1}{m_2^2 + m_2 - (N+n)}$$

$$m_{12} = \frac{-1 + \sqrt{1 + 4(n+N)}}{2} \qquad A_{12} = \frac{-GcB_5}{m_4^2 + m_4 - (N+n)}$$

$$\beta_1 = \frac{(3+4R)}{3\Pr} \qquad A_{13} = \frac{-GcB_3}{m_6^2 + m_6 - (N+n)}$$

$$D_1 = \frac{-Am_2}{\beta_1 m_2^2 + m_2 - (n+Q)} \qquad A_{14} = \frac{-GcB_4}{D^2 + D - (N+n)}$$

$$D_2 = (1 - D_1)$$

$$D_3 = \frac{-ScS_0 m_2^2 D_1}{m_2^2 + Scm_2 - nSc} \qquad A_{15} = \frac{-GcD_3}{m_2^2 + m_2 - (N+n)}$$

$$D_4 = \frac{-ScS_0 m_4^2 D_2}{m_4^2 + Scm_4 - nSc} \qquad A_{16} = \frac{-GcD_4}{m_4^2 + m_4 - (N+n)}$$

$$B_1 = \frac{-ScS_0 m_2}{m_2 + Sc}$$

$$B_2 = (1 - B_1)$$

$$B_3 = \frac{-AScm_6 B_2}{m_6^2 + Scm_6 - nSc}$$

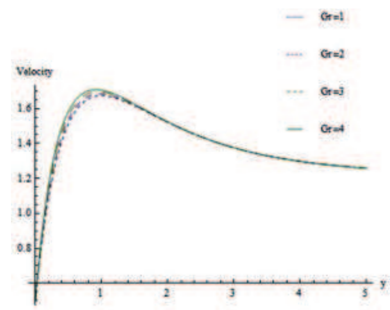
$$B_4 = \frac{-AScm_2 B_1}{m_2^2 + Scm_2 - nSc}$$

$$B_5 = (1 - B_3 - B_4 - D_3 - D_4)$$

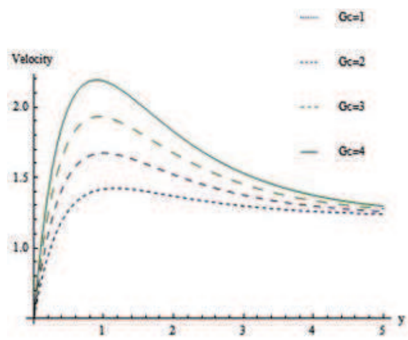
$$A_1 = \frac{-Gr}{m_2^2 + m_2 - N}$$

$$A_2 = \frac{-GcB_2}{m_6^2 + m_6 - N}$$

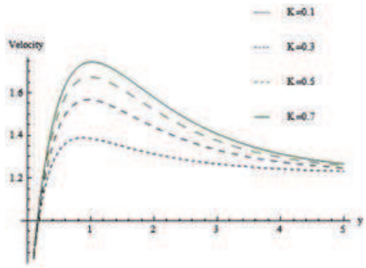
**Results and Discussions:** This enables us to carry out the numerical computation for the velocity, temperature, concentration, Nusselt number and Sherwood number across the boundary layer for various values of the flow parameters. Fig(1) shows that the increasing in Gr leads to increase in the values of velocity. The velocity attains at the highest value of y=1.0. Fig(2) shows that an increasing in Gc leads to increase in the value of velocity. At y=1.2 the velocity is maximum for Gc=4.0.Fig(3) shows that the velocity for different values of the permeability(K).It is clear that the peak value of the velocity tends to increases as permeability (K) increases. At y=1.25 is the velocity highest. Fig(4),shows that the effect of increasing values of M results in decreasing velocity distribution across the boundary layer. At y=1.0(approximately)the velocity is highest. Fig(5) exhibit the velocity profiles across the boundary layer for different values of Prandtl number(pr).It shows that the effect of increasing values of prandtl number (pr) results in decreasing the velocity. Fig(6) the effects of Soret number on the velocity profiles .We see that the velocity profile increase with an increasing of So from which we conclude that the fluid velocity rises due to greater thermal diffusion. Fig(7) it shows that the effect of increasing values of Sc parameters results in decreasing velocity distribution across the boundary layer. Fig(8) and Fig the effect of heat source parameter(Q) on the velocity and concentration profiles. Fig(9) we observe that the temperature profiles decreases for an increasing value of R, with an increasing in the thermal boundary layer thickness.Fig(10) shows the temperature profiles for decreases with an increasing of heat source parameters(Q).It for different values of prandtl number(Pr).It shows that profiles of thermal boundary layer thickness and constant temperature distribution across the boundary layer thickness and constant temperature distribution across the boundary layer. Fig represents the effects of radiation parameter on concentration profiles.



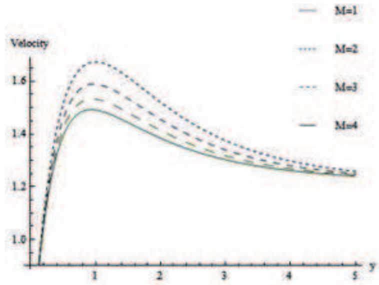

Fig(1): The Velocity Profile for different values of Gr



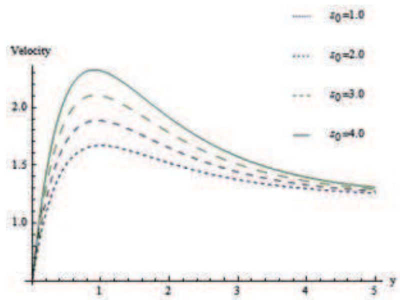

Fig(2):The Velocity Profile for different values of Gc



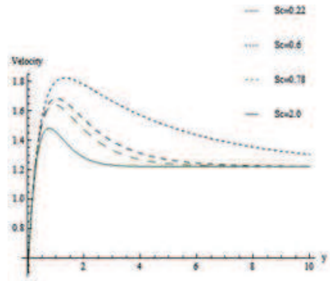

Fig(3):Velocity profile for different values of K



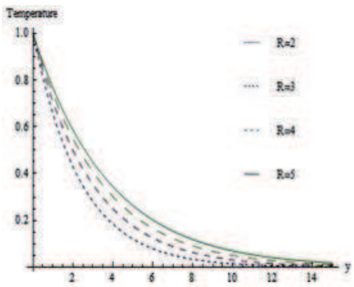

Fig(4):Velocity profile for different values of M



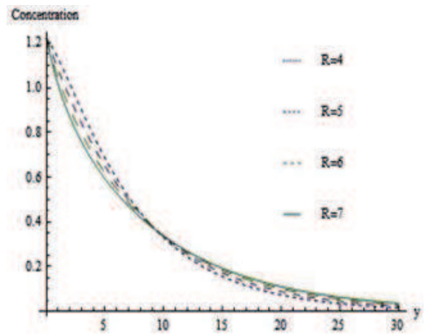

Fig(5):Velocity Profile for different values of Soret



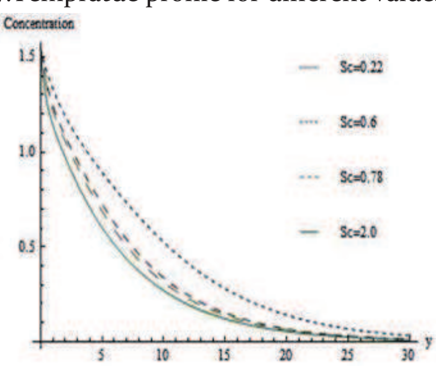

Fig(6):Velocity Profile for differenValueof S



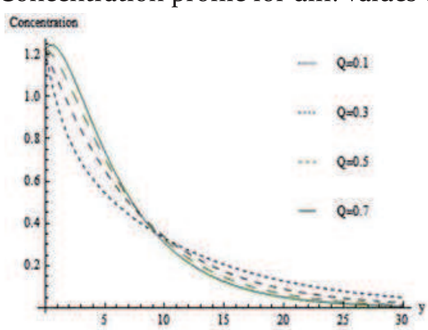

Fig(7):Tempratue profile for different values of R




Fig(8):Concentration profile for diff. values of R




Fig(9):Concentration profile for diff. values of Sc




Fig(10):Concentration profile for different values Q

**Conclusions:** In the present research work , the boundary layer equations become non –dimensional by using non-dimensional quantities. The non-dimensional equations are solved by using perturbation technique. The following conclusions are set out through the overall observations.

1.) Velocity increases with an increase of Grashof number(Gr),modified Grashof number for mass transfer(Gc),Permeability(K) and Soret number(So).Whereas velocity decreases with an increase of Prandtl number(Pr),magnatic field parameter(M) and Schmidth number(Sc).There is no effect of heat source parameter(Q) on velocity profiles.

2.) The temperature and skin friction increase with an increasing value of radiation parameter(R) also temperature decreases with the increase value Prandtl number(Pr) and,heat source parameter(Q).

3.) The Nusselt number (Nu) decreases with an increasing value of radiation parameter (R) and the Sherwood number increase with an value of Soret number.

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