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Effects of Radiation and Mass Transfer on an Unsteady MHD Convection Flow in a Porous Medium with Viscous Dissipation - A Finite Element Technique

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ABSTRACT

Finite element method is implemented to study the "Effects of radiation and mass transfer on an unsteady MHD convection flow in a porous medium with viscous dissipation". The numerical solution thus obtained, presented graphically for velocity, temperature and concentration profiles with in the boundary layer and tabulated results for skin-friction coefficient, Nusselt number and Sherwood number are discussed. It is observed that the radiation parameter increases, the velocity and temperature decreases in the boundary layer. Whereas when thermal and solutal Grashof number increases the velocity increases.

Keywords: Radiation, Viscous dissipation, Heat and Mass transfer, Finite Element Method.

1. INTRODUCTION:

Combined buoyancy-generated heat and mass transfer, due to temperature and concentration variations, in fluid-saturated porous media, have several important applications in a variety of engineering processes including heat exchanger devices, petroleum reservoirs, chemical catalytic reactors, solar energy porous water collector systems, ceramic materials[8], migration of moisture through air contained in fibrous insulations and grain storage installations and their dispersion of chemical contaminants through water-saturated soil, superconvecting geothermics [4] etc.

There has been a renewed interest in studying magneto hydrodynamics (MHD) flow and heat transfer in porous and non-porous media due to the effect of magnetic fields on the boundary layer flow control and on the performance of many systems using electrically conducting fluids. In addition, this type of flow finds applications in many engineering problems such as MHD generators, plasma studies, nuclear reactors, and geothermal energy extractions. Kim [9] presented an analysis of an unsteady MHD convection flow past a vertical moving plate embedded in a porous medium in the presence of transverse magnetic field. Helmy [6] presented an unsteady two –dimensional laminar free convection flow of an incompressible, electrically conducting (Newtonian or polar) fluid through a porous medium bounded by infinite vertical plane surface of constant temperature. Singh [10] studied MHD flow of viscous fluid. Recent studies of MHD convection in porous media with various complex effects include those by Beg [2] et al. and Takhar and Ram [11].

Bakier and Gorla [1] investigated the effect of radiation on mixed convection flow over horizontal surfaces embedded in a porous medium. Bestman and Adjepong [3] presented the unsteady hydro magnetic free convection flow with radiative heat transfer in a rotating fluid. Recently Cookey et al [7] have investigated unsteady two dimensional flow radiating and chemically reacting MHD fluid with time dependent suction.

In most of the studies mentioned above, viscous dissipation is neglected. Gebhart has shown the importance of viscous dissipative heat in free convection flow in the case of isothermal and constant heat flux at the plate. Israel Cookey et[5] al had investigated the influence of viscous dissipation and radiation on unsteady MHD free convection flow past an infinite heated vertical plate in the porous medium with time dependent suction. V.Ramachandra Prasad et al [12] studied the radiation and mass transfer effects using regular perturbation method.

The objective of the present work is to analyze the radiation and mass transfer effects on an unsteady two dimensional laminar mixed convective boundary layer flow of a viscous, incompressible, electrically conducting fluid along a vertical moving semi-infinite permeable plate with suction, embedded in a uniform porous medium, in the presence of transverse magnetic field, by taking into account the effect of viscous dissipation. The equation of continuity linear momentum, energy and diffusion which govern the flow fluid are solved by using Finite Element Method. The behavior of velocity, temperature, concentration, skin friction, Nusselt number and Sherwood number has been discussed for variations in the governing parameters.

2. MATHEMATICAL ANALYSIS:

An unsteady two-dimensional hydro magnetic laminar mixed convective boundary layer flow of a viscous, incompressible, electrically conducting and radiating fluid in an optically thin environment, past a semi infinite vertical permeable moving plate embedded in a uniform porous medium, in the presence of thermal and concentration buoyancy effects has been considered. The flow is considered in the direction of x-axis. The x' –axis is taken in the upward direction along the plate and y'- axis normal to it. A uniform magnetic field is applied in the direction perpendicular to the plate. The transverse applied magnetic field and magnetic Reynolds number are assumed to be very small, so that the induced magnetic field is negligible. Also, it is assumed that there is no applied voltage, so that the electric field is absent. The concentration of the diffusing species in the binary mixture is assumed to be very small in comparison with the other chemical species which are present, and hence the Soret and Dufour effects are negligible. Further, due to the semi-infinite plane surface assumption, the flow variables are functions of normal distance y' and t' only. Now, under the usual Boussinesq's approximation, the governing boundary layer equations are:

$$\frac{\partial v'}{\partial y'} = 0 \qquad \text{………… .(1)}$$

$$\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = -\frac{1}{\rho}\frac{\partial p'}{\partial x'} + \nu\frac{\partial^2 u'}{\partial y'^2} + g\beta\left(T' - T'_\infty\right) + g\beta^*\left(C' - C'_\infty\right) - \nu\frac{u'}{K'} - \frac{\sigma B_0^2 u'}{\rho} \qquad \text{……… (2)}$$

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k}{\rho c_p}\left[\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{k}\frac{\partial q'}{\partial y'}\right] + \frac{\nu}{c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 \qquad \text{……….. (3)}$$

$$\frac{\partial^2 q'}{\partial y'^2} - 3\alpha^2 q' - 16\sigma^*\alpha T_\infty'^3\frac{\partial T'}{\partial y'} = 0 \qquad \text{………. (4)}$$

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D\frac{\partial C'}{\partial y'^2} \qquad \text{………… (5)}$$

Where u' and v' are the velocity components in x', y' directions respectively, t'- the time p'- pressure, ρ-the fluid density, g- the acceleration due to gravity, β and β^* -the thermal and concentration expansion coefficients respectively, K'-the permeability of the porous medium, T' – the temperature of the fluid in the boundary layer, v- the kinematic viscosity, σ- the electrically conductivity of the fluid, T'_∞ - the temperature of the fluid far away from the plate, C'- the species concentration in the boundary layer, C'_∞ - the species concentration in the fluid far away from the plate, B_0 – the magnetic induction ,α- the fluid thermal diffusivity k- the thermal conductivity, q' – the radiative heat flux, σ^*- the Stefan-Boltzmann constant and D – the mass diffusivity. The third and fourth terms on the right hand side of the momentum Eqs (2) denote the thermal and concentration buoyancy effects respectively. Also, the second and third terms on right hand side of the energy Eqs (3) represent the radiative heat flux and viscous dissipation respectively.

It is assumed that the permeable plate moves with a constant velocity in the direction of fluid flow and the free stream velocity follows the exponentially increasing small perturbation law. In addition, it is assumed that the temperature and concentration at the wall as well as the suction velocity are exponentially varying with time Eqs (4) is the differential approximation for radiation under fairly broad realistic assumptions. In one space coordinate y, the radiative heat flux q' satisfies this nonlinear differential equation.

The boundary conditions for the velocity, temperature and concentrations fields are:

$$u' = u'_p, \quad T' = T'_\infty + \varepsilon\left(T'_w - T'_\infty\right)e^{n't'}$$

$$C' = C'_\infty + \left(C'_w - C'_\infty\right)e^{n't'} \quad \text{at } y' = 0$$

$$u' = U'_\infty = U_0\left(1 + \varepsilon e^{n't'}\right), \quad T' \to T'_\infty,$$

$$C' \to C'_\infty \text{ as } y' \to \infty \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where u'_p is the plate velocity, T'_w and C'_w- the temperature and concentration of the plate respectively. U'_∞ -the free stream velocity, U_0 and n' the constants. From Eqs (1), it is clear that the suction velocity at the plate is either a constant or function of time only. Hence, the suction velocity normal to the plate is assumed in the form:

$$v' = -V_0\left(1+\varepsilon A e^{n't'}\right) \qquad \text{...... ....(7)}$$

Where A is a real positive constant and ε is small such that ε <<1, A<<1, and V_0 is a non-zero positive constant, the negative sign indicates that the suction is towards the plate.

Outside the boundary layer, Eqs (2) gives:

$$-\frac{1}{\rho}\frac{\partial p'}{\partial x'} = \frac{\partial U'_\infty}{\partial t'} + \frac{\nu}{K'}U'_\infty + \frac{\sigma}{\rho}B_0^2 U'_\infty \qquad \text{............................(8)}$$

Since the medium is optically thin with relatively low density and α<<1, the radiative heat flux given by Eqs (3), in the spirit of Cogley et al. Becomes:

$$\frac{\partial q'}{\partial y'} = 4\alpha^2\left(T' - T'_\infty\right). \qquad \text{..............................(9)}$$

Where $\alpha^2 = \int \delta\lambda \frac{\partial B}{\partial T'}$, Where B in Planck's function,

In order to write the governing equations and the boundary conditions in dimensionless form, the fallowing non-dimensional quantities are introduced.

$$u = \frac{u'}{U_0}, \quad v = \frac{v'}{V_0}, \quad y = \frac{V_0 y'}{\nu}, U_\infty = \frac{U'_\infty}{U_0}$$

$$U_p = \frac{u'_p}{U_0}, \quad t = \frac{t^1 V_0^2}{\nu}, \quad \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \quad C = \frac{C' - C'_\infty}{C'_w - C'_\infty},$$

$$n = \frac{n'\nu}{V_0^2}, K = \frac{K' V_0^2}{\nu^2}, P_r = \frac{\nu\rho c_p}{k}, S_c = \frac{\nu}{D}, M = \frac{\sigma B_0^2 \nu}{\rho V_0^2} \qquad \text{.......... (10)}$$

$$G_r = \frac{g\beta\nu\left(T_w - T_\infty\right)}{U_0 V_0^2}, G_m = \frac{g\beta^*\nu\left(C'_w - C'_\infty\right)}{U_0 V_0^2}, \; E_C = \frac{U_0^2}{c_p(T'_w - T'_\infty)}, \; R^2 = \frac{\alpha^2\left(T'_w - T'_\infty\right)}{\rho c_p k U_0^2}$$

In view of equation (4) and (7-10), eqn (2),(3) and (5) reduce to the following dimensionless form:

$$\frac{\partial u}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial u}{\partial y} = \frac{\partial U_\infty}{\partial t} + \frac{\partial^2 u}{\partial y^2} + G_r\theta + G_m C + N\left(U_\infty - u\right) \qquad \text{....... (11)}$$

$$\frac{\partial \theta}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial \theta}{\partial y} = \frac{1}{p_r}\left[\frac{\partial^2\theta}{\partial y^2} - R^2\right] + E_c\left(\frac{\partial u}{\partial y}\right)^2 \qquad \text{....................... (12)}$$

$$\frac{\partial C}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial C}{\partial y} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} \qquad \text{.............................. (13).}$$

Where N=M+(1/K) and G_r, G_m, P_r, R, E_c and S_c are the thermal Grashof number, solutal Grashof number; Prandtl Number, radiation parameter, Eckert number and Schmidt number, respectively.

The corresponding dimensionless boundary conditions are:

$u=U_p,\ \theta=1+\varepsilon e^{nt},\ c=1+\varepsilon e^{nt}$ at y=0

$U \to U_\infty = 1+\varepsilon e^{nt},\ \theta \to 0,\ C \to 0$ as $y \to \infty$ ……………..(14)

3. SOLUTION OF THE PROBLEM:

The Eqs (11-13) are coupled, non-linear partial differential equations and these cannot be solved in closed form. However, these equations can be reduced to a set of ordinary differential equations, which can be solved by **finite element method**. This can be done by applying **Galerkin finite element method** to eqn (11) over the element (e), $(y_j \le y \le y_k)$

$$\int_{y_j}^{y_k} N^T \left\{ \frac{\partial^2 u}{\partial y^2} + B\frac{\partial u}{\partial y} - \frac{\partial u}{\partial t} - Nu + P \right\} dy = 0$$

Where B= $(1 + \varepsilon A e^{nt})$ and P= $G_r\theta + G_m C + NU_\infty + \varepsilon n e^{nt}$

Integrating the first term in above Eqs by parts one obtains

$$N^T \left\{ \frac{\partial u}{\partial y} \right\}_{y_j}^{y_k} - \int_{y_j}^{y_k} \frac{\partial N^T}{\partial y}\frac{\partial u}{\partial y}\, dy + B\int_{y_j}^{y_k} N^T \frac{\partial u}{\partial y}\, dy - \int_{y_j}^{y_k} N^T \frac{\partial u}{\partial t}\, dy - N\int_{y_j}^{y_k} N^T u\, dy + P\int_{y_j}^{y_k} N^T\, dy = 0$$

Neglecting the first term in above Eqs one gets

$$\int_{y_j}^{y_k} \frac{\partial N^T}{\partial y}\frac{\partial u}{\partial y}\, dy - B\int_{y_j}^{y_k} N^T \frac{\partial u}{\partial y}\, dy + \int_{y_j}^{y_k} N^T \frac{\partial u}{\partial t}\, dy + N\int_{y_j}^{y_k} N^T u\, dy = P\int_{y_j}^{y_k} N^T\, dy$$

Let $u^e = N^e \phi^e$ be the linear piecewise approximation solution over the element $(e)\,(y_j \le y \le y_k)$, where $N^e = [N_j N_k]$, $\phi^e = [u_j u_k]^T$ and $N_j = \frac{y_k - y}{y_k - y_j}$, $N_k = \frac{y - y_j}{y_k - y_j}$ are the basis functions. One obtains:

$$\frac{1}{l}\begin{bmatrix}1 & -1\\ -1 & 1\end{bmatrix}\begin{bmatrix}U_j\\ U_k\end{bmatrix}-\frac{B}{2}\begin{bmatrix}-1 & 1\\ -1 & 1\end{bmatrix}\begin{bmatrix}U_j\\ U_k\end{bmatrix}-\frac{l}{6}\begin{bmatrix}2 & 1\\ 1 & 2\end{bmatrix}\begin{bmatrix}\dot{U}_j\\ \dot{U}_k\end{bmatrix}+\frac{N\,l}{6}\begin{bmatrix}2 & 1\\ 1 & 2\end{bmatrix}\begin{bmatrix}U_j\\ U_k\end{bmatrix}=\frac{P\,l}{2}\begin{bmatrix}1\\ 1\end{bmatrix}$$

Where dot denotes the differentiation w.r.t t. Assembling the element equations for two consecutive elements $y_{i-1} \le y \le y_i$ and $y_i \le y \le y_{i+1}$ following is obtained

$$\frac{1}{l^2}\begin{bmatrix}1 & -1 & 0\\ -1 & 1+1 & -1\\ -1 & 1 & 0\end{bmatrix}\begin{bmatrix}U_{i-1}\\ U_i\\ U_{i+1}\end{bmatrix}+\frac{B}{2l}\begin{bmatrix}-1 & 1 & 0\\ -1 & 0 & 1\\ 0 & -1 & 1\end{bmatrix}\begin{bmatrix}U_{i-1}\\ U_i\\ U_{i+1}\end{bmatrix}+\frac{1}{6}\begin{bmatrix}2 & 1 & 0\\ 1 & 4 & 1\\ 0 & 1 & 2\end{bmatrix}\begin{bmatrix}\dot{U}_{i-1}\\ \dot{U}_i\\ \dot{U}_{i+1}\end{bmatrix}+\frac{N}{6}\begin{bmatrix}2 & 1 & 0\\ 1 & 4 & 1\\ 0 & 1 & 2\end{bmatrix}\begin{bmatrix}\dot{U}_{i-1}\\ \dot{U}_i\\ \dot{U}_{i+1}\end{bmatrix}=\frac{h}{2}\begin{bmatrix}1\\ 2\\ 1\end{bmatrix} \quad \ldots(*)$$

Now put row corresponding to the node i to zero, from Eq. (*) the difference schemes with $l^{(e)}$=h and Applying the trapezoidal rule, following system of equations in Crank-Nicholson method are obtained:

(Nk+3Brh-6r+2)U_{i-1}^{n+1}+ (4NK+12r+8) U_i^{n+1}+ (Nk-3Brh-6r+2) U_{i+1}^{n+1}=

(2-NK-3Brh+6r)U_{i-1}^{n}+ (8-4NK-12r) U_{i-1}^{n}+ (2-NK+3Brh+6r) U_{i-1}^{n}+12PK

Simplifying we get

$$A_1 u_{i-1}^{n+1} + A_2 u_i^{n+1} + A_3 u_{i+1}^{n+!} = A_4 u_{i-1}^{n} + A_5 u_i^{n} + A_6 u_{i+1}^{n} + P^* \qquad \ldots.. \qquad (15)$$

Now from Eqs (12) and (13), following equations are obtained:

$$B_{1b}\theta_{i-1}^{n+1} + B_2\theta_i^{n+1} + B_3\theta_{i+1}^{n+!} = B_4\theta_{i-1}^{n} + B_5\theta_i^{n} + B_6\theta_{i+1}^{n} + Q^* \qquad \ldots\ldots. \qquad (16)$$

$$C_1 C_{i-1}^{n+1} + C_2 C_i^{n+1} + C_3 C_{i+1}^{n+!} = C_4 C_{i-1}^{n} + C_5 C_i^{n} + C_6 C_{i+1}^{n} \qquad \ldots\ldots\ldots \qquad (17)$$

Where

A_1 = Nk+3Brh-6r+2;
A_2 =4NK+12r+8;
A_3 = Nk-3Brh-6r+2;
A_4 = 2-NK-3Brh+6r;
A_5 = 8-4NK-12r;
A_6 = 2-NK+3Brh+6r;

P^{*} = 12PK;

B_1 =2 p_r +3B p_r hr-6r;
B_2 =8 p_r +12r;
B_3 =2 p_r -3B p_r hr-6r;
B_4 =2 p_r -3B p_r hr+6r;
B_5 =8 p_r -12r;
B_6 =2 p_r +3B p_r hr+6r;
Q^{*} =12QK

C_1 =2 S_c +3B S_c hr-6r;
C_2 =8 S_c +12r;
C_3 =2 S_c -3B S_c hr-6r;
C_4 =2 S_c -3B S_c hr+6r;
C_5 =8 S_c -12r;
C_6 =2 S_c +3B S_c hr+6r;

The solutions of above system of equations (15), (16) and (17) are obtained by using Gauss-Seidel method for velocity, temperature and concentration. For various parameters the results are computed and presented graphically.

The **skin-friction**, **Nusselt number** and **Sherwood number** are important physical parameters for this type of boundary layer flow. Knowing the velocity field, the skin-friction at the plate can be obtained, which in non-dimensional form is given by:

$$C_r = \frac{\tau_w^{'}}{\rho U_0 V_0} = \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

Knowing the temperature field, the rate of heat transfer coefficient can be obtained, which in the non-dimensional form, in terms of the Nusselt number, is given by:

$$Nu = -x \frac{\left(\frac{\partial T}{\partial y^{'}}\right)_{y=0}}{T_w^{'} - T_\infty^{'}} \Rightarrow Nu \, \mathrm{Re}_x^{-1} = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0}$$

Knowing the concentration field, the rate of mass transfer coefficient can be obtained, which in the non-dimensional form, in terms of the Sherwood number, is given by:

$$Sh = -x\frac{\left(\frac{\partial C'}{\partial y'}\right)_{y'=0}}{C'_w - C'_\infty} \Rightarrow Sh\,\mathrm{Re}_x^{-1} = -\left(\frac{\partial C}{\partial y}\right)_{y=0}$$

4. RESULTS AND DISCUSSION:

The formation of the problem that accounts for the effects of radiation and viscous dissipation on the flow of an incompressible viscous fluid along a semi-infinite, vertical moving porous plate embedded in a porous medium in the presence of transverse magnetic field was accomplished. Following Cogley et al. approximation for the radiative heat flux in the optically thin environment, the governing equations of the flow field were solved using Finite Element Method, and the expressions for the velocity, temperature, concentration, skin-friction, Nusselt number and Sherwood number were obtained. In order to get a physical insight of the problem, the above physical quantities are computed numerically for different values of the governing parameters viz., thermal Grashof number G_r, the solutal Grashof number G_m, Prandtl number P_r, Schmidt number Sc, the plate velocity U_p , the radiation parameter R and the Eckert number E_c.

Fig 1 shows the typical velocity profiles in the boundary layer for various values of the thermal Grashof number. It is observed that an increase in G_r, leads to a rise in the values of velocity due to enhancement in buoyancy force. Here, the positive valued of G_r correspond to cooling of the plate. In addition, it is observed that the velocity increases rapidly near the wall of the porous plate as Grashof number increases and then decays to the free stream velocity. For the case of different vales of the solutal Grashof number, the velocity profiles in the boundary layer are shown in Fig 2. The velocity distribution attains a distinctive maximum value in the vicinity of the plate and then decreases properly to approach a free stream value. As expected, the fluid velocity distinctive due to increase in the buoyancy force represented by Gm. For different values of the radiation parameter R, the velocity and temperature profiles are shown in Fig 3 and Fig 4, it is noticed that increase in radiation parameter results a decrease in the velocity and temperature within the boundary layer, as well as decreased the thickness of the velocity and temperature boundary layers. Fig 5 shows the effects of Schmidt number on the concentration as the Schmidt number increases, the concentration decreases. This causes the concentration buoyancy effects to decrease yielding a reduction in the fluid velocity. Reductions in the velocity and concentration distributions are accompanied by simultaneous reductions in the velocity and concentration boundary layers. Fig 6 and 7 show the behavior temperature and velocity for different values of Prandtl number. From Fig.6, it is observed that an increase in the Prandtl number results a decrease of the thermal boundary layer thickness and in general lower average temperature with in the boundary layer. From Fig 7 The numerical results show that the effect of increasing values of Prandtl number results in a decreasing velocity The reason is that smaller vales of P_r are equivalent to increase in the thermal conductivity of the fluid and therefore, heat is able to diffuse away from the heated surface more rapidly for higher values of P_r. Hence, in the case of smaller Prandtl numbers as the thermal boundary layer is thicker and the rate of heat transfer is reduced. Fig.8 shows the variation of the velocity distribution across the boundary layer for different values of the plate velocity U_p in the direction of the fluid flow. Although we have different initial plate velocities, the velocity decreases to a constant value for given material parameters. For various values of the magnetic parameter M, the velocity profiles are shown in Fig.9. it is obvious that existence of the magnetic field decreases the velocity. Fig.10 shows the velocity profiles for different values of the permeability parameter. Clearly, as K increases the peak values of the velocity tends to increase.

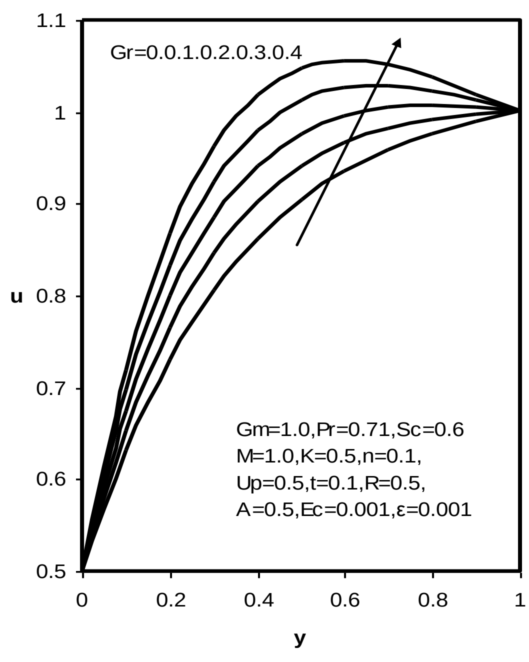

Fig.1-- Effect of G_r on Velocity.

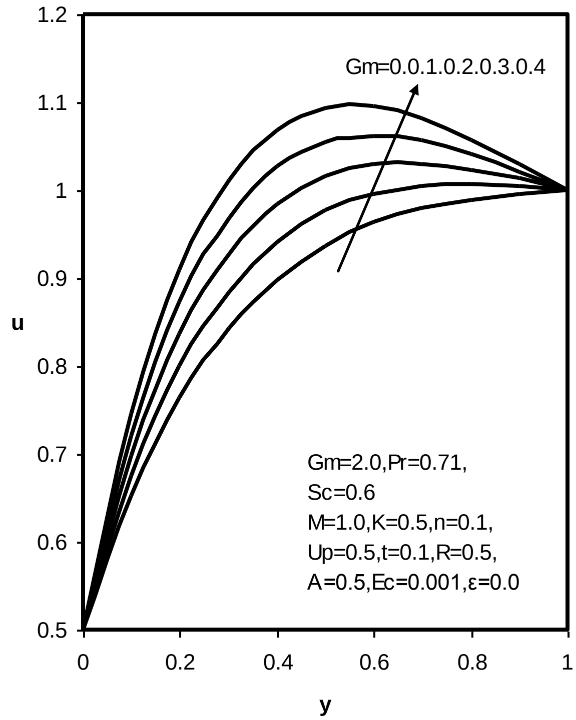

Fig.2. -- Effect of G_m on Velocity.

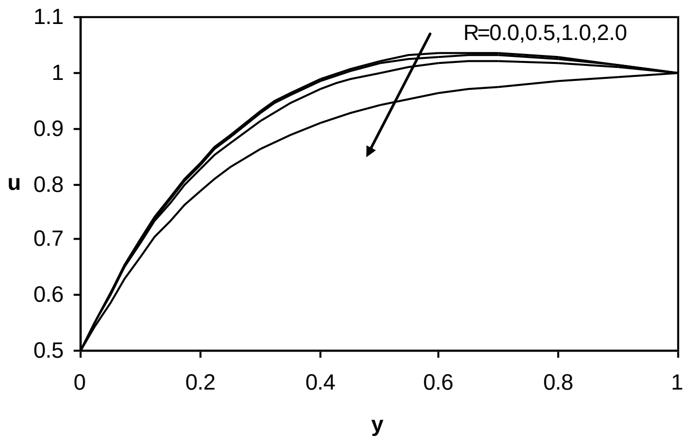

Fig.3-- Effect of radiation on velocity.

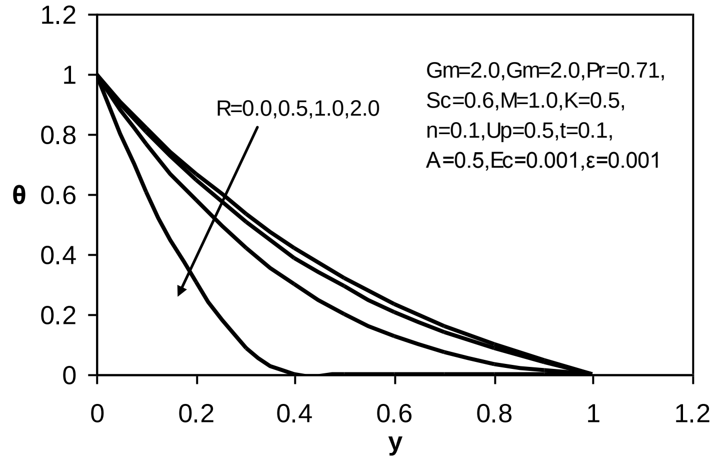

Fig.4-- Effect of radiation on temperature.

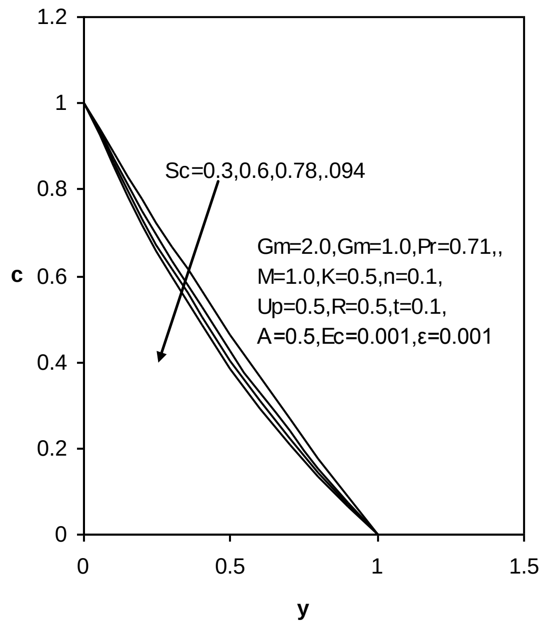

Fig.5—Effect of S_c on Concentration.

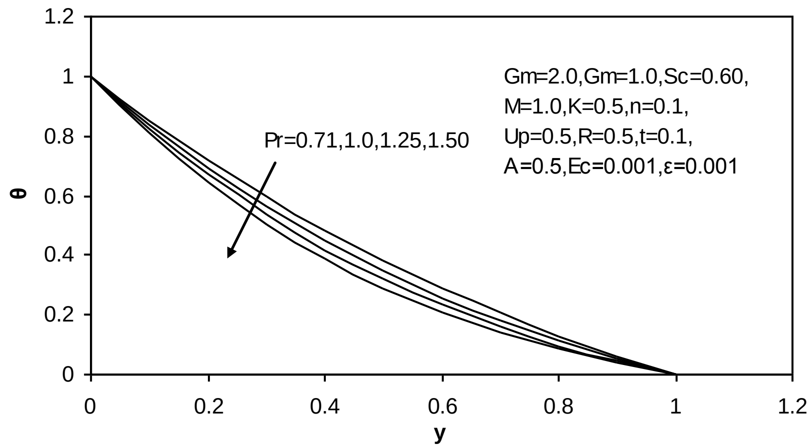

Fig.6 — Effect of P_r of temperature.

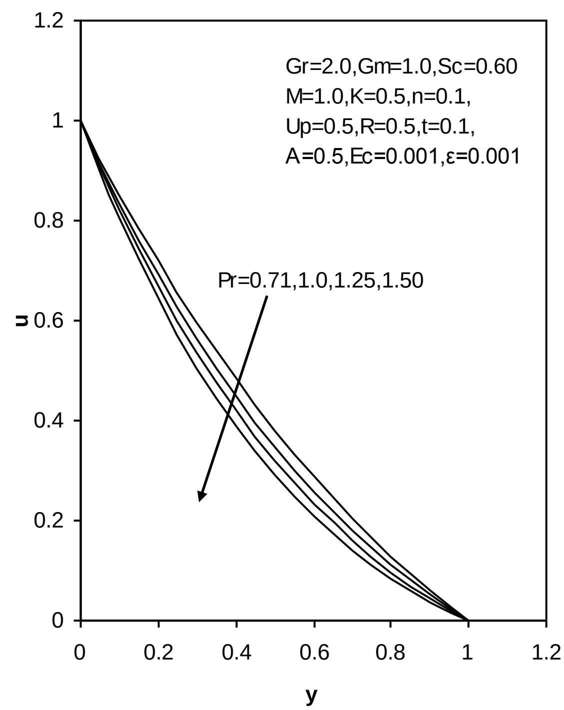

Fig.7.—Effect of P_r on velocity.

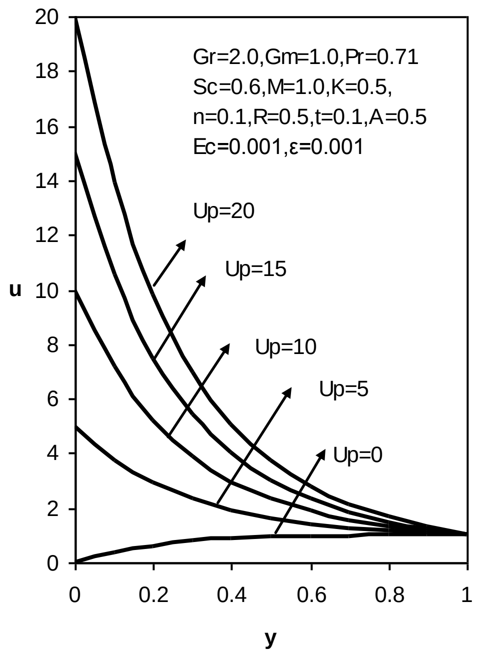

Fig.8. Effect of U_p on velocity.

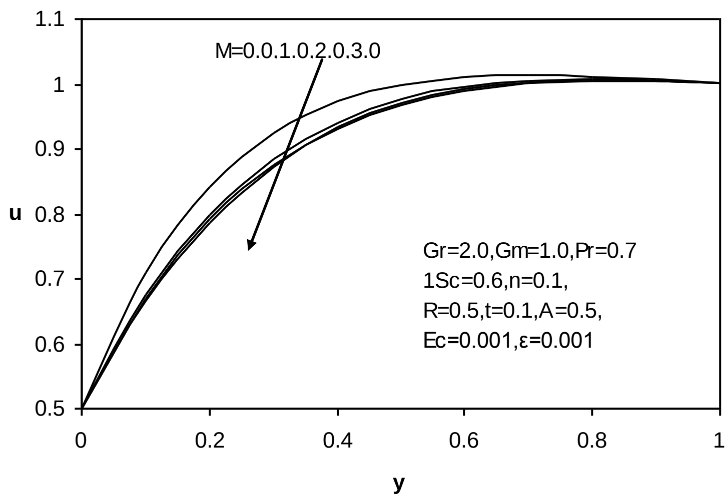

Fig.9.—Effect on M on Velocity.

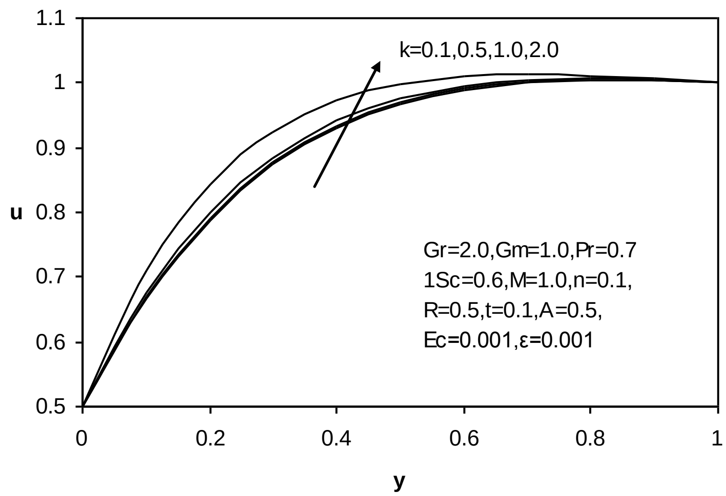

Fig.10.—Effect on permeability (k) on velocity.

Table 1-5 present the effects of the thermal Grashof number, solutal Grashof number, radiation parameter, Schmidt number and Eckert number on the skin-friction C_f , Nusselt number Nu and Sherwood number Sh. From Table 1 and 2, it is observed that as G_r or Gm increases, the skin-friction coefficient increases. However, from Table 3, it can be seen that as the radiation parameter increases, the skin-friction decreases and the Nusselt number increases. From Table 4, it is noticed that an increase in the Schmidt number reduces the skin-friction and increases the Sherwood number. Finally, it is observed from Table 5, that as Eckert number increases the skin-friction increases, and the Nusselt number decreases.

Table.1-- Effects of G_r on C_f

G_r	C_f
0	1.7814
1	1.9199
2	2.0585
3	2.1971
4	2.3356

Table.2-- Effects of G_m on C_f

G_m	C_f
0	1.7547
1	1.9199
2	2.0852
3	2.2504
4	2.4156

Table.3-- Effects of R on C_f and Nu

R	C_f	Nu
0.0	1.9257	1.7939
0.5	1.9199	1.9264
1.0	1.9027	2.3238
1.5	1.8739	3.9134

Table.4. Effect of S_c on C_f and Sh

S_c	C_f	Sh
0.3	1.9268	1.2753
0.6	1.9199	1.4526
0.78	1.9158	1.5646
0.94	1.9120	1.6674

Table.5. Effect of E_c on C_f and Nu

E_c	C_f	Nu
0	1.9268	4.1818
0.01	1.9269	4.1774
0.02	1.9270	4.1730
0.03	1.9271	4.1686

5. CONCLUSION:

The governing equations for unsteady **MHD** convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with radiation was formulated. Viscous dissipation effects were also included in the present work. The plate velocity is maintained at constant value and the flow was subjected to a transverse magnetic field. The resulting partial differential equations were transformed into a set of ordinary differential equations using two-term series and solved using Finite Element Method. Numerical evaluations of the **FEM** results were computed and graphical results were obtained to illustrate the details of the flow and heat and mass transfer characteristics and their dependence on some physical parameters. It is found that when thermal and solutal Grashof numbers were increased, the thermal and concentration buoyancy effects were enhanced and thus, the fluid velocity increased. However, the presence of radiation effects caused reductions in the fluid temperature, when the Schmidt number was increased; the concentration level was decreased resulting in decreased fluid velocity. In addition, it was found that the skin-friction coefficient increased due to increase in thermal and concentration buoyancy effects while it decreased due to increase in either radiation parameter or the Schmidt number. However, the Nusselt number increased as radiation parameter increased and the Sherwood number also increased as Schmidt number increased. Increase in Eckert number leads to an increase skin-friction and decrease in Nusselt number. The results and graphs agree with the previous author's discussion and results [12].

REFERENCES:

1) Bakier A Y & Gorla R S R, Transport in porous media, 23(1996) 357.
2) Beg O A Takhar H S Kumari M & Nath G, Int j Appl mechanics and Engg 6(2001)187.
3) Bestman A R & Adjepong S K, Astrophysics space Sci, 43(1998) 73.
4) Dunn j c & Hardee H C, J Volcanology and geothermal Res 11(1981)189.
5) Gebhart B J, Fluid Mech, 14 (1962) 225.
6) Helmy K a, ZAMM,78(2000)255.
7) Israel-Cookey C Ogulu A & Omubo-Pepple V B, Int J Heat Mass Transfer, 46 (2003) 2305.
8) Kaviany M, Principles of Heat Transfer in Porous Media, (McGraw-Hill, New York), 1992.
9) Kim Y,J, Int J Eng Sce,38(2000)823.
10) Singh K A, Indian j pure and appl phys, 41(2003) 262.
11) Takhar H s & Ram P C, j magneto hydrodynamics and Plasma Res,6(1996) 17.
12) V. Ramachandra Prasad et al., Indian journal of pure and applied physics 46 (2008) 81-92.