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Finite Element Method Application of Effects on an Unsteady MHD Convective Heat and Mass Transfer Flow In a Semi-Infinite Vertical Moving In a Porous Medium with Heat Source and Suction

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Abstract: *The objective of this paper is to analyze the effects of Soret, chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow of a semi-infinite vertical moving in a porous medium with heat source and suction. The plate is assumed to move with a constant velocity in the fluid flow direction. The equations of continuity, momentum, energy and diffusion, which govern the flow field, are solved by using Galerkian finite element method. Numerical solutions of velocity, temperature and concentration profiles are discussed with the help of the graphs for different parameters.*
Keywords: *Vertical plate, MHD, Radiation, FEM, Chemical reaction, Nusselt number, Soret number.*

I. Introduction

The study of magnetohydrodynamics (MHD) flow has received a deal of research interest due to its importance in many engineering applications such as heat- treated materials traveling between a feed roll or materials manufactured by glass and paper production. Various aspects of the problem have been investigated by many authors. Dash and Das [1] analyzed the effect of Hall current MHD free convection flow along an accelerated porous heated plate with mass transfer and internal heat generation. Sattar [2] discussed free convection and mass transfer flow through a porous medium past an infinite vertical plate with time dependent temperature and concentration. Acharya *et.al* [3] studied the effect of chemical and thermal diffusion with Hall current on unsteady hydro magnetic flow near an infinite vertical porous plate. Das *et.al* [4] worked out unsteady free convection and mass transfer boundary layer flow past an accelerated infinite vertical plate with suction. B.Vasu [5] *et.al* analyzed radiation effect and mass transfer on transient free convection flow of a dissipative fluid past semi- infinite vertical plate with uniform heat and mass flux.A.Mythreye and J.P .Promoda [6] presented chemical reaction on unsteady MHD convective heat and mass transfer past a semi - infinite vertical permeable moving plate with heat absorption. D.Srinivasacharya and B.Mallikarjuna [7] studied Soret and Dufour effects on mixed convection along a vertically away surface in porous medium with variable properties.

The study of heat generation or absorption effects in moving fluids is important in view of several physical problems, such as fluids undergoing exothermic or endothermic chemical reaction. Radiation effects on an unsteady MHD convection convective heat and mass transfer flow past a semi - infinite vertical permeable moving plate embedded in porous medium was studied by Ramachandra Prasad *et.al* [8]. F.S.Ibrahim *et.al* [9] studied the effect of the chemical reaction and radiation absorption on the unsteady MHD free conviction flow past a semi infinite vertical permeable moving plate with heat source and suction. Unsteady MHD free convective flow past a moving vertical plate with time dependent suction chemical reaction in a slip flow regime was studied by K.S Balamurugan *et.al* [10]. Md.Abdus Sattar [11] investigated free convection and mass transfer flow through a porous medium past an infinite vertical porous medium past an infinite vertical plate time dependent temperature and concentration. Dual pal and Babul Talukadar [12] investigated perturbation analysis of unsteady MHD convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. G.S.Seth *et.al* [13] investigated MHD natural convection flow with radiative heat transfer past an impulsively moving plate with ramped temperature. Study of effects of radiation and magnetic field on the mixed convection micro polar fluid flow towards a stagnation point on a heated vertical permeable plate using finite element method was studied by G Swapna *et.al* [14]. S.Sivaiah.*et.al* [15] examined the effects of thermal diffusion and radiation on unsteady MHD free convection flow past an infinite heated vertical plate in a porous medium. Tanvir Ahmed and Md.Mahumad [16] investigated a finite difference solution of MHD mixed convection flow with heat generation and chemical reaction. M.K Mazumdar and R.K Deka [17] have analyzed MHD flow past an impulsive started infinite vertical plate in the presence of thermal radiation. Mohmed Abd Ei-Aziz [18] presented unsteady mixed convection heat transfer along a vertical stretching surface with variable viscosity and viscous dissipation.

Elbashbeshy [19] investigated heat and mass transfer along a vertical plate with variable surface temperature and concentration in the presence of magnetic field. Jai Singh [20] studied viscous dissipation and chemical reaction effects on flow past a stretching porous surface in a porous medium.

II. Mathematical Formulation

The x^* - axis is taken in the vertically upward direction along the semi-infinite plate and y^* axis is taken normal to it. Since the motion is two dimensional and length of the plate is large, therefore all the physical variables are independent of x^*. Let u^* and v^* be the components of velocity in x^* and y^* directions, respectively, taken along and perpendicular to the plate.
The governing boundary layer equations are as follows:
Continuity equation:

$$\frac{\partial v^*}{\partial y^*} = 0 \qquad - (1)$$

Momentum equation:

$$\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + \nu \frac{\partial^2 u^*}{\partial y^{*2}} + g\beta\left(T^* - T^*_\infty\right) + g\beta^*\left(C^* - C^*_\infty\right) - \frac{\nu}{K^*}u^* - \frac{\sigma B_0^2}{\rho}u^* \qquad - (2)$$

Energy equation:

$$\frac{\partial T^*}{\partial t^*} + \nu^* \frac{\partial T^*}{\partial y^*} = \frac{1}{\rho C_p}\left[k\frac{\partial T^*}{\partial y^{*2}} - Q_0\left(T^* - T^*_\infty\right)\right] + Q_l^*\left(C^* - C^*_\infty\right) - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*} \qquad - (3)$$

Mass diffusion equation:

$$\frac{\partial C^*}{\partial t^*} + \nu^* \frac{\partial C^*}{\partial y^*} = D\frac{\partial^2 C^*}{\partial t^{*2}} - K_r^*\left(C^* - C^*_\infty\right) + D_T\frac{\partial^2 T^*}{\partial y^{*2}} \qquad - (4)$$

Where g is the gravitational acceleration, ρ is the fluid density, β and β^* are the thermal and concentration expansion coefficients respectively, K^* is the Darcy permeability, B_0 is the magnetic induction, T^* is the thermal temperature inside the thermal boundary layer and C^* is the corresponding concentration, σ is the electric conductivity, C_p is the specific heat at constant pressure, D and D_T are the diffusion coefficient and molecular diffusivity, K_r^* is the chemical reaction parameter, Q_0 is the dimensional heat absorption coefficient, Q_l^* is the coefficient of proportionality of the radiation.
The boundary conditions are:

$$\left.\begin{aligned} &u^* = u_p^*, T^* = T_\infty^* + \varepsilon\left(T_w^* - T_\infty^*\right)e^{n^*t^*}, C^* = C_\infty^* + \varepsilon\left(C_w^* - C_\infty^*\right)e^{n^*t^*} \quad at\ y^* = 0 \\ &u^* = U_\infty^* = U_0 + \varepsilon\left(1 + e^{n^*t^*}\right), \qquad T^* \to T_\infty^*, \quad C^* \to C_\infty^*, \qquad as\ y^* \to \infty \end{aligned}\right\} \qquad - (5)$$

Where u_p^* is the velocity of the fluid, T_w^* and C_w^* are the temperature and concentration of the wall respectively, U_∞^* is the free stream velocity and U_0, n^* are the constants. From equation (1), it is clear that the suction velocity at the plate is either a constant and or a function of time. Hence the suction velocity normal to the plate is assumed in the form:

$$v^* = -v_0\left(1 + \varepsilon A e^{n^*t^*}\right) \qquad - (6)$$

Where A is a real constant, and ε is small such that $\varepsilon << 1, \varepsilon A << 1$ and v_0 is a non-zero positive constant, the negative sign indicates that suction is towards the plate.
Outside the boundary layer, equation (2) gives

$$-\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} = \frac{dU_\infty^*}{dt^*} + \frac{\nu}{K^*}U_\infty^* - \frac{\sigma B_0^2}{\rho}U_\infty^* \qquad - (7)$$

By using the Rosseland diffusion approximation the radioactive heat flux, q_r is given by

$$q_r = -\frac{4\sigma'}{3K_s}\frac{\partial T^{*4}}{\partial y^*} \quad - (8)$$

Where σ' and K_s are the Stefan - Boltzmann constant and the Rosseland mean adsorption coefficient respectively. We assume the temperature difference within the flow is sufficiently small such that T^4 may be expressed as a linear function of temperature.

$$T^4 \approx 4T_\infty^3 T - 3T_\infty^4 \quad - (9)$$

Using (8) and (9), in the last term of equation (3) we obtain

$$\frac{\partial q_r}{\partial y^*} = -\frac{16\sigma' T_\infty^3}{3K_s}\frac{\partial^2 T^*}{\partial y^{*2}} \quad - (10)$$

Introducing the following non- dimensional quantities,

$$\left.\begin{aligned}
&y = \frac{\nu_0 y^*}{\nu}, u = \frac{u^*}{U_0}, \nu = \frac{\nu^*}{\nu_0}, U_\infty = \frac{U_\infty^*}{U_0}, U_p = \frac{Up}{U_0}, \theta = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*}, C = \frac{C^* - C_\infty^*}{C_w^* - C_\infty^*} \\
&Gr = \frac{g\beta v\left(T_w^* - T_\infty^*\right)}{v_0^3}, Gm = \frac{g\beta^* v\left(C_w^* - C_\infty^*\right)}{v_0^3}, Sc = \frac{v}{D}, Q = \frac{vQ_0}{\rho C_p v_0^2}, Q_l = \frac{vQ_l^*}{v_0^2}\frac{\left(C_w^* - C_\infty^*\right)}{\left(T_w^* - T_\infty^*\right)} \\
&n = \frac{vn^*}{v_0^2}, M = \frac{\sigma B_0^2 v}{\rho v_0^2}, K = \frac{K^* v_0^2}{v^2}, Kr = \frac{K_r^* v}{v_0^2}, R = \frac{4\sigma' T_\infty^3}{K_s}, \Pr = \frac{v\rho C_p}{k}, So = \frac{D_T\left(T_w^* - T_\infty^*\right)}{\left(C_w^* - C_\infty^*\right)v}
\end{aligned}\right\} \quad - (11)$$

Where Gr, Gm, Sc, Q, Q_l, Kr, R, $\Pr$ and So are the thermal Grashof number, Solutal Grashof number, Schmidt number, heat absorption parameter, absorption of radiation parameter, Chemical reaction number, and thermal radiation parameter, Prandtl number.

With the help of non- dimensional quantities, equations (2), (3) and (4) becomes

$$\frac{\partial u}{\partial t} - \left(1 + \varepsilon A\, e^{nt}\right)\frac{\partial u}{\partial y} = \frac{\partial U_\infty}{\partial t} + \frac{\partial^2 u}{\partial y^2} + N(U_\infty - u) + Gr\theta + GmC \quad - (12)$$

$$\frac{\partial \theta}{\partial t} - \left(1 + \varepsilon A\, e^{nt}\right)\frac{\partial \theta}{\partial y} = \frac{1}{\Pr}\left(\frac{3 + 4R}{3}\right)\frac{\partial^2 \theta}{\partial y^2} - Q\theta + Q_l C \quad - (13)$$

$$\frac{\partial C}{\partial t} - \left(1 + \varepsilon A\, e^{nt}\right)\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} - KrC + S_0\frac{\partial^2 \theta}{\partial y^2} \quad - (14)$$

Where $N = M + \frac{1}{K}$ is Magnetic field parameter, permeability parameter.

The modified boundary conditions for $t > 0$ are:

$$\left.\begin{aligned}
&u = U_p, \theta = 1 + \varepsilon e^{nt}, C = 1 + \varepsilon e^{nt} \quad at \quad y \to 0 \\
&u = U_\infty = 1 + \varepsilon e^{nt}, \theta \to 0, C \to 0 \quad at \quad y \to \infty
\end{aligned}\right\} \quad - (15)$$

III. Method of Solution

By applying Galerkin finite element method for equation (12) over the element (e), $\left(y_j \le y \le y_k\right)$ is:

$$\int_{y_j}^{y_k}\left\{N^{(e)T}\left[\frac{\partial^2 u^{(e)^T}}{\partial y^2} + B\frac{\partial u^{(e)T}}{\partial y} - \frac{\partial u^{(e)^T}}{\partial t} - Nu^{(e)T} + R_1\right]\right\}dy = 0 \quad - (16)$$

Where $R_1 = n\varepsilon e^{nt} + (Gr)\theta + (Gm)C + NU_\infty$, $B = 1 + \varepsilon Ae^{nt}$, $N = \left(M + \frac{1}{K}\right)$

Integrating the first term in equation (16) by parts, we obtain

$$N^{(e)T}\left\{\frac{\partial u^{(e)^T}}{\partial y}\right\}_{y_j}^{y_k}-\int_{y_j}^{y_k}\left\{\frac{\partial N^{(e)T}}{\partial y}\frac{\partial u^{(e)^T}}{\partial y}-N^{(e)T}\left(\frac{\partial u^{(e)^T}}{\partial t}-B\frac{\partial u^{(e)^T}}{\partial y}+Nu^{(e)^T}-R_1\right)\right\}dy=0 \qquad -(17)$$

Neglecting the first term in equation (17), the following is obtained.

$$\int_{y_j}^{y_k}\left\{\frac{\partial N^{(e)T}}{\partial y}\frac{\partial u^{(e)^T}}{\partial y}+N^{(e)T}\left(\frac{\partial u^{(e)^T}}{\partial t}-B\frac{\partial u^{(e)^T}}{\partial y}+Nu^{(e)^T}-R_1\right)\right\}dy=0$$

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 $N^{(e)}=\begin{bmatrix}N_j & N_k\end{bmatrix}, \phi^{(e)}=\begin{bmatrix}u_j & u_k\end{bmatrix}^T$ 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, u_j and u_k are the velocity components at j^{th} and k^{th} nodes of the typical element $(e), (y_j \le y \le y_k)$.

We obtain the following.

$$\int_{y_j}^{y_k}\left\{\begin{bmatrix}N'_jN'_j & N'_jN'_k\\ N'_jN'_k & N'_kN'_k\end{bmatrix}\begin{bmatrix}u_j\\u_k\end{bmatrix}\right\}dy+\int_{y_j}^{y_k}\left\{\begin{bmatrix}N_jN_j & N_jN_k\\ N_jN_k & N_kN_k\end{bmatrix}\begin{bmatrix}\dot{u}_j\\ \dot{u}_k\end{bmatrix}\right\}dy-B\int_{y_j}^{y_k}\left\{\begin{bmatrix}N_jN'_j & N_jN'_k\\ N'_jN_k & N'_kN_k\end{bmatrix}\begin{bmatrix}u_j\\u_k\end{bmatrix}\right\}dy$$

$$+N\int_{y_j}^{y_k}\left\{\begin{bmatrix}N_jN_j & N_jN_k\\ N_jN_k & N_kN_k\end{bmatrix}\begin{bmatrix}u_j\\u_k\end{bmatrix}\right\}dy=R_1\int_{y_j}^{y_k}\begin{bmatrix}N_j\\N_k\end{bmatrix}dy$$

Simplifying above equation we get,

$$\frac{1}{l^{(e)}}\begin{bmatrix}1 & -1\\-1 & 1\end{bmatrix}\begin{bmatrix}u_j\\u_k\end{bmatrix}+\frac{l^{(e)}}{6}\begin{bmatrix}2 & 1\\1 & 2\end{bmatrix}\begin{bmatrix}\dot{u}_j\\ \dot{u}_k\end{bmatrix}-\frac{B}{2}\begin{bmatrix}-1 & 1\\-1 & 1\end{bmatrix}\begin{bmatrix}u_j\\u_k\end{bmatrix}+\frac{Nl^{(e)}}{6}\begin{bmatrix}2 & 1\\1 & 2\end{bmatrix}\begin{bmatrix}u_j\\u_k\end{bmatrix}=\frac{R_1l^{(e)}}{2}\begin{bmatrix}1\\1\end{bmatrix}$$

Where prime and dot denotes differentiation with respect to y and time t respectively. Assembling the element equations for two consecutive elements $(y_{i-1} \le y \le y_i)$ and $(y_i \le y \le y_{i+1})$ the following is obtained:

$$\frac{1}{l^{(e)^2}}\begin{bmatrix}1 & -1 & 0\\-1 & 2 & -1\\0 & -1 & 1\end{bmatrix}\begin{bmatrix}u_{i-1}\\u_i\\u_{i+1}\end{bmatrix}-\frac{B}{2l^{(e)}}\begin{bmatrix}-1 & 1 & 0\\-1 & 0 & 1\\0 & -1 & 1\end{bmatrix}\begin{bmatrix}u_{i-1}\\u_i\\u_{i+1}\end{bmatrix}+\frac{1}{6}\begin{bmatrix}2 & 1 & 0\\1 & 4 & 1\\0 & 1 & 2\end{bmatrix}\begin{bmatrix}\dot{u}_{i-1}\\ \dot{u}_i\\ \dot{u}_{i+1}\end{bmatrix}+ \qquad -(18)$$

$$\frac{N}{6}\begin{bmatrix}2 & 1 & 0\\1 & 4 & 1\\0 & 1 & 2\end{bmatrix}\begin{bmatrix}u_{i-1}\\u_i\\u_{i+1}\end{bmatrix}=\frac{R_1}{2}\begin{bmatrix}1\\2\\1\end{bmatrix}$$

Now equate row corresponding to the node i to zero, from equation (18) the difference schemes with $l^{(e)}=h$ is as follows.

$$\frac{1}{h^2}\left[-u_{i-1}+2u_i-u_{i+1}\right]-\frac{B}{2h}\left[-u_{i-1}+u_{i+1}\right]+\frac{1}{6}\left[\dot{u}_{i-1}+4\dot{u}_i+\dot{u}_{i+1}\right]+$$

$$\frac{N}{6}\left[u_{i-1}+4u_i+u_{i+1}\right]=R_1 \qquad -(19)$$

Applying Crank – Nicholson method to the equation (19), we obtain following system of equations:

$$A_1u_{i-1}^{n+1}+A_2u_i^{n+1}+A_3u_{i+1}^{n+1}=A_4u_{i-1}^{n}+A_5u_i^{n}+A_6u_{i+1}^{n}+R^* \qquad -(20)$$

Where
$$A_1 = 2-6r+3Brh+Nk \qquad A_4 = 2+6r-3Brh-Nk$$
$$A_2 = 8+12r+4Nk, \qquad A_5 = 8-12r-4Nk$$
$$A_3 = 2-6r-3Brh+Nk \qquad A_6 = 2+6r+3Brh-Nk$$
$$R^* = 12R_1k = 12k(n\varepsilon e^{nt} + (Gr)\theta_i^n + (Gm)C_i^n + NU_\infty),$$

From equations (13) and (14), the following equations are obtained:

$$B_1\theta_{i-1}^{n+1} + B_2\theta_i^{n+1} + B_3\theta_{i+1}^{n+1} = B_4\theta_{i-1}^n + B_5\theta_i^n + B_6\theta_{i+1}^n + P^{**} \qquad - (21)$$

$$C_1C_{i-1}^{n+1} + C_2C_i^{n+1} + C_3C_{i+1}^{n+1} = C_4C_{i-1}^n + C_5C_i^n + C_6C_{i+1}^n + R^{***} \qquad - (22)$$

Where
$$B_1 = 2P_1 - 6r + 3P_1Brh + kP_1Q \qquad B_4 = 2P_1 + 6r - 3P_1Brh - kP_1Q$$
$$B_2 = 8P_1 + 4kP_1Q + 12r \qquad B_5 = 8P_1 - 4kP_1Q - 12r$$
$$B_3 = 2P_1 - 6r - 3P_1Brh + kP_1Q \qquad B_6 = 2P_1 + 6r + 3P_1Brh - kP_1Q$$
$$C_1 = 2Sc - 6r + 3rBh.Sc + kScKr \qquad C_4 = 2Sc + 6r - 3rBh.Sc - kScKr$$
$$C_2 = 8Sc + 12r + 4kScKr \qquad C_5 = 8Sc - 12r - 4kScKr$$
$$C_3 = 2Sc - 6r - 3rBh.Sc + kScKr \qquad C_6 = 2Sc + 6r + 3rBh.Sc - kScKr$$
$$R^{**} = 12R_2k = 12kP_1Q_lC_i^n \qquad R^{***} = 12ScS_0\frac{\partial^2\theta_i}{\partial y_i^{\,2}}$$

Here, $r = \frac{k}{h^2}$ and h , k are mesh size along the y direction and the time direction respectively. Index i refers to the space, and n refers to the time. In the Equations (21) – (22), taking $i = 1,\ldots,n$ and using boundary conditions (15), the following system of equations is obtained:

$$A_iX_i = B_i, \qquad i = 1,\ldots n \qquad - (23)$$

Where A_i 's are matrix of order n and X_i, B_i 's column matrices having n components. The solutions of above systems of equations are obtained by using the Thomas algorithm for velocity, temperature and concentration. Also the numerical solutions are obtained by executing the C-program with the smaller values of h and k . No significant change was observed in u, θ and C , then the Galerkin finite element method is stable and convergent.

The skin friction, Nusselt number and Sherwood number are important physical parameters for this type of boundary later flow.

Knowing the velocity, temperature and concentration fields, the Skin-friction at the plate, this in the non-dimensional form is given by $\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0}$

The rate of heat transfer coefficient can be obtained, which in the non- dimensional form in terms of the Nusselt number is given by $N_u = -\left(\frac{\partial T}{\partial y}\right)_{y=0}$

The rate of mass transfer coefficient can be obtained, which in the non- dimensional form in terms of the Sherwood number is given by $S_b = -\left(\frac{\partial C}{\partial y}\right)_{y=0}$

IV. Results and Discussion

Numerical results are computed for various physical parameters which are presented with the help of graphs. The results obtained are used to illustrate the influence of the thermal Grashof number(Gr), Solutal Grashof number(Gm), Magnetic field parameter(M), Schmidt number(Sc),Chemical reaction parameter(Kr), heat absorption parameter(Q), absorptions of radiation parameter(Q_l), thermal radiation parameter (R) and Soret number(So), Prandtl number($\Pr$). The effects of the above parameters on velocity, temperature and concentration profiles are presented graphically through figures 1-19.

The velocity profiles are plotted in figure 1 for various values of M, it is clear from the figure that the existence of the magnetic field is to decrease the velocity in the momentum boundary layer because the application of the transverse magnetic field is a resisting type of force known as Lorentz force, which acts against flow, if the magnetic field is applied in the direction normal to the flow. Figure 2 shows that the velocity decreases with an increase in Kr. It is clear from the figure 3 that the boundary layer thickness will decreases with an increase in the heat absorption parameter Q. Figures 4 and 12 show that an increase in the Prandtl number give raise to a decrease in the velocity as well as the temperature, the reason is that smaller values of Pr are equivalent to increasing the thermal conductivities, and therefore heat is able to diffuse away from the heated plate more rapidly than for higher values of Pr. Figure 5 shows the effect of Gr on velocity, it is observed that an increase in Gr leads to an increase in the values of velocity due to enhancement in the buoyancy force. Here, the positive values of Gr correspond to cooling of the plate. Figure 6 depicts velocity profile in the boundary layer for the various values of Solutal Grashof number Gm, the fluid velocity increases and peak value is more distinctive due to an increase in the species buoyancy force. The velocity distribution attains a distinctive maximum value in the region of the plate and then decreases properly to approach a free stream value. We observe from the figure 7 that at very low values of the Schmidt number (e.g. Sc =1), there is an increase in the peak velocity near the plate, where as for higher values of Schmidt number (e.g. Sc =4), the peak shifts closer to the plate. Figure 8 shows the velocity profile for different values of permeability parameter K, clearly, as K increases the peak values of velocity tends to increase.

Figure 9 shows the velocity profiles for different values of the radiation parameter R , as R increases the peak values of the velocity tends to increase. Figure 10 shows that the velocity profile for different values of absorptions of radiation parameter (Q_l), we observe that an increase in the value of absorptions of radiation parameter (Q_l) there is an increase in the buoyancy force, which accelerates the flow rate.

Figure 11 and 16 depict the velocity and concentration profiles for different values of the Soret number (S_0). We observe that an increase in the Soret number S_0 results to an increase in velocity and concentration within the boundary layer. Figure13 displays the temperature decrease with an increase in the heat source parameter Q because as heat is absorbed, the buoyancy force decreases the temperature profiles. Figure14 shows the temperature profile for different values of radiation parameter R, clearly, as R increases the temperature profile increases. It is seen from figure 15 that the effect of absorption of radiation is to increase temperature in the boundary layer as the radiated heat is absorbed by fluid which in turn increases the temperature of the fluid very close to the porous boundary layer and its effect diminishes far away from the boundary layer. The effect of increasing the value of Schmidt number (Sc) is as shown in figure17. As the Schmidt number (Sc) increases, the concentration profile decreases. Figure18 displays the effect of the chemical reaction Kr on concentration, we observe that concentration profile decreases with an increase in Kr. Figure 19 shows the temperature profile for different values of Soret number S_0, clearly, as S_0 increases the temperature profile increases.

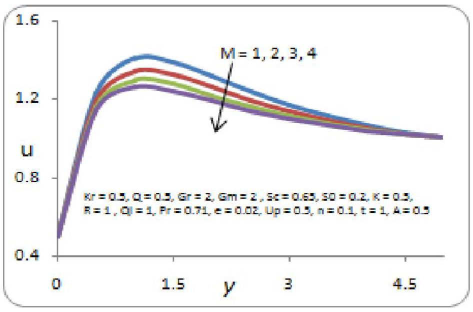

Fig.1. Effect of M on velocity profile

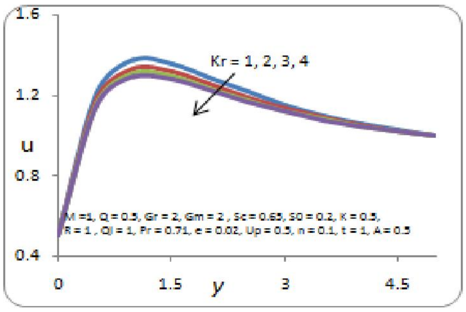

Fig.2.Effect of Kr on velocity profile.

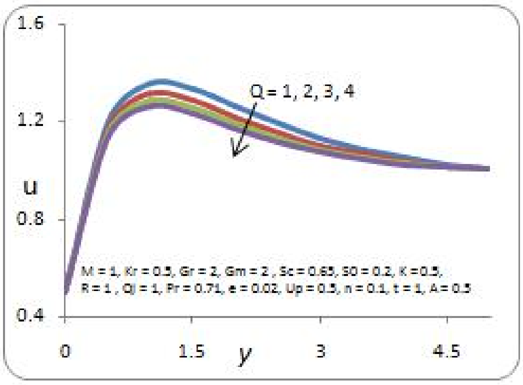

Fig.3. Effect of Q on velocity profile

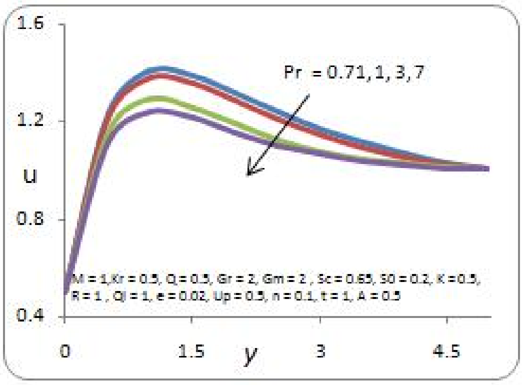

Fig.4. Effect of Pr on velocity profile

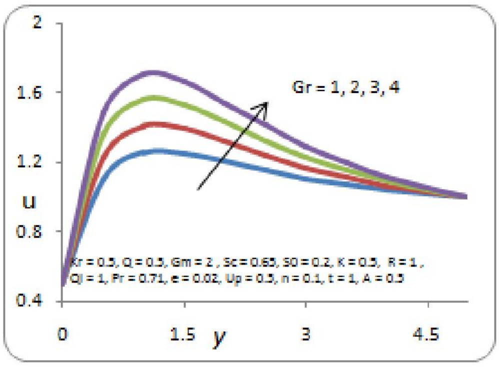

Fig.5. Effect of Gr on velocity profile

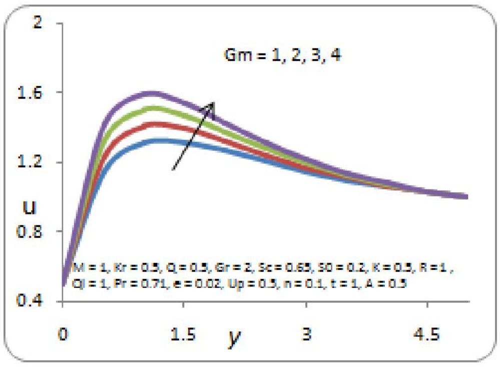

Fig.6. Effect of Gm on velocity profile

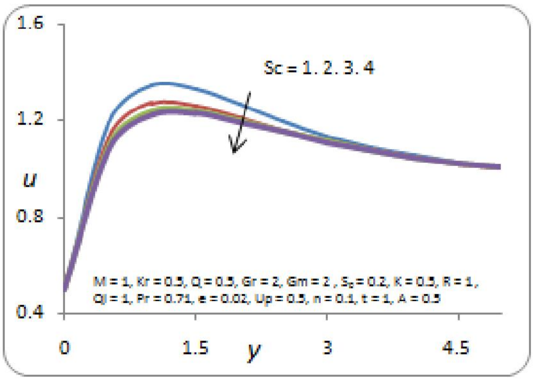

Fig. 7. Effect of Sc on velocity profile

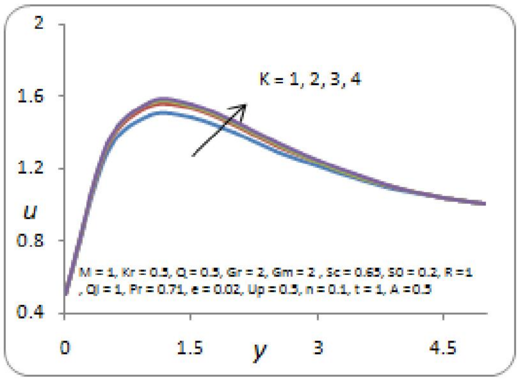

Fig.8. Effect of K on velocity profile

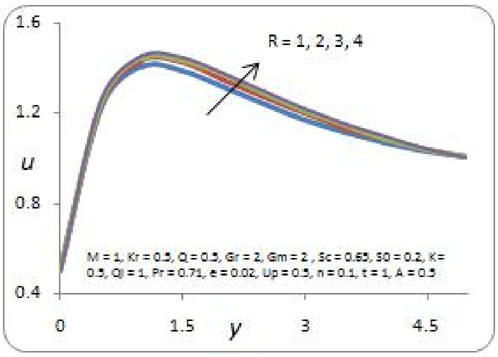

Fig. 9. Effect of R on velocity profile

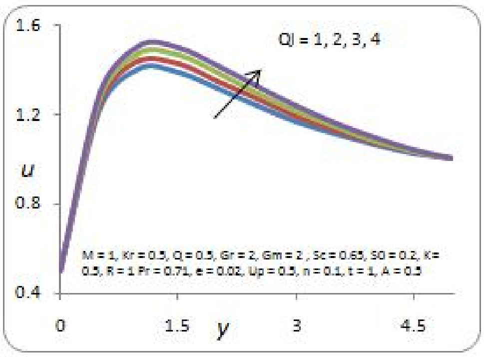

Fig.10. Effect of Ql on velocity profile

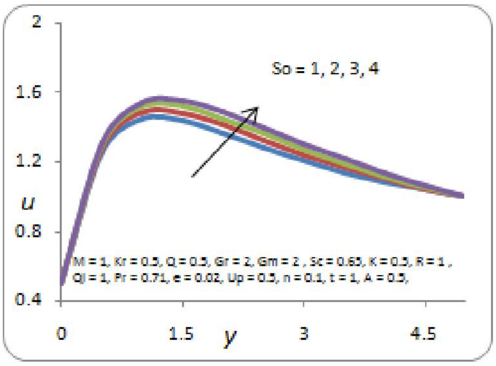

Fig11. Effect of So on velocity profile

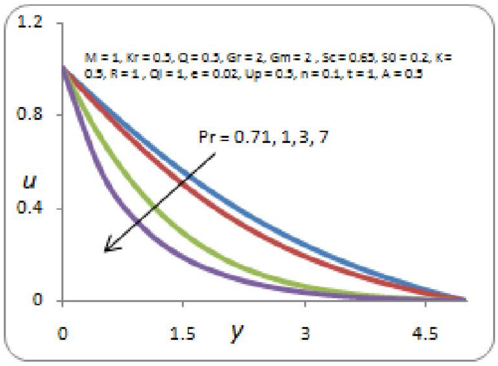

Fig. 12. Effect of Pr on Temperature profile

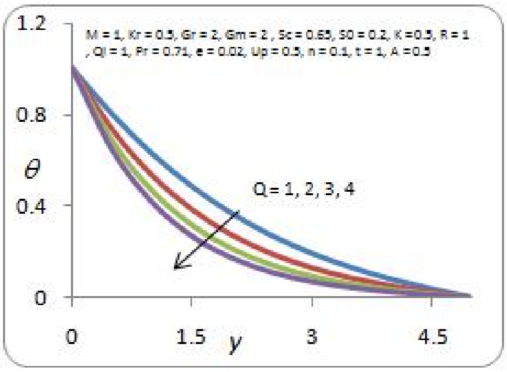

Fig.13. Effect of Q on Temperature profile

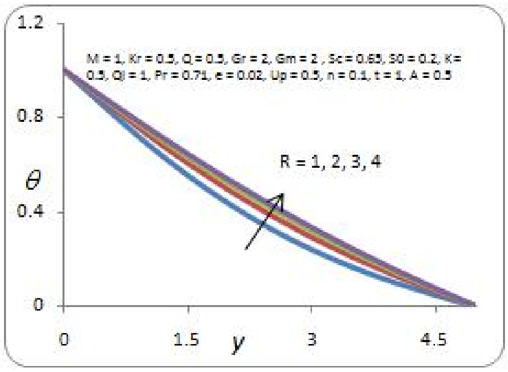

Fig. 14. Effect of R on Temperature profile

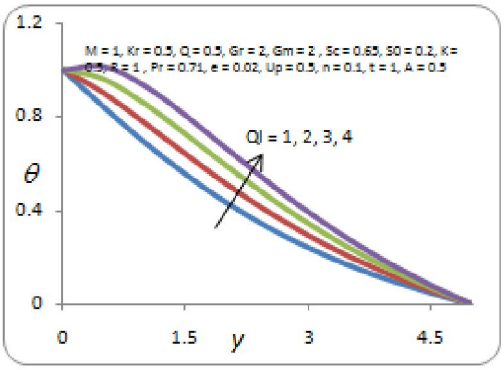

Fig.15. Effect of Ql on Temperature profile

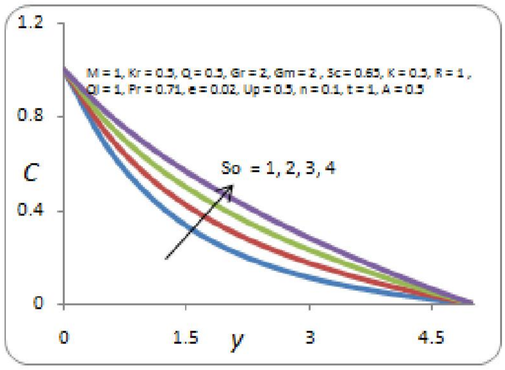

Fig. 16. Effect of So on Concentration profile

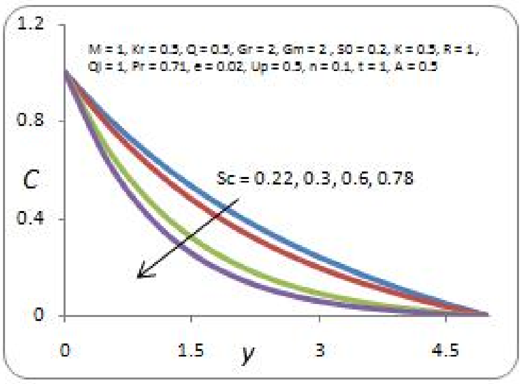

Fig.17. Effect of Sc on Concentration profile

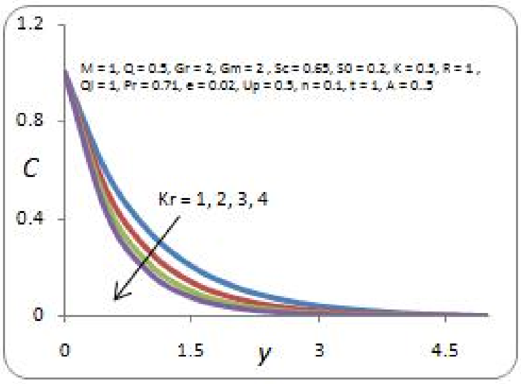

Fig. 18.Effect of Kr on Concentration profile

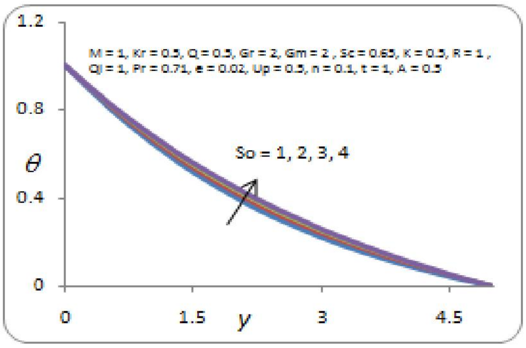

Fig. 18.Effect of So on Temperature profile

V. Conclusions

In this paper we investigated the effects of Soret, chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow a semi - vertical moving in a porous medium with heat source. Numerical calculations are carried out for various values of the dimensionless parameters. A finite element method has been employed to evaluate and solve for velocity, temperature, concentration, skin friction, Sherwood number and Nusselt number. The conclusions of the study are as follows:

- The velocity increases with the Solutal Grashof number, thermal Grashof number and permeability parameter.
- The velocity decreases with an increase in magnetic field, Prandtl number and Chemical reaction parameter.
- The temperature decreases with an increase in the heat source parameter, Prandtl number and Schmidt number.
- The temperature increases with an increase in radiation parameter.
- An increase in the Soret number leads to an increase in velocity and concentration.
- The concentration decreases with an increase in chemical reaction.

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