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Mass Transfer and Radiation Effects on Unsteady MHD Convective Fluid Flow Embedded In a Porous Medium with Heat Generation and Absorption

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Abstract – The Chief aim of this paper is to investigate the effects of mass transfer and radiation on an unsteady MHD free convective fluid flow embedded in a porous medium with heat generation/absorption. The problem is governed by the system of coupled non-linear partial differential equations whose exact solutions are difficult to obtain. So the Galerkin finite element method has been adopted for its solution. The results obtained are discussed for cooling (Gr>o) and heating (Gr<0) of the plate with the help of graphs and tables to observe the effects by various parameters such as pr Sc, M, Q, K, Gr Gm Nr Kr and Δ. It has been found that when the thermal and solutal Grashof numbers increase, - the thermal and concentration buoyancy effects are increased and the fluid velocity increases. Furthermore, when the Prandtl number (Pr) and Schmidt number (Sc) increase, the thermal and concentration levels decrease which reduces fluid velocity. These results are in good agreements with earlier results.

Keywords – Radiation Heat Flux, Buoyancy Effects, MHD, Heat Generation/ Absorption, Galerkin Finite Element Method.

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1. INTRODUCTION

The analysis of free or natural convection has been of considerable choice for scientists and engineers on account of its wide spread applications in naturally occurring phenomenon and technology.

The representative field of interest in transport processes under conditions of free convection which are significant including design of chemical processing equipment formation and dispersion of fog, distribution of temperature and moisture over agricultural fields and groves of fruits trees, environment pollution. There are also several other situations in which buoyancy forces from thermal and mass diffusion simultaneously play efficient role in the heat transfer mechanism. The evaporation of respiration to control our body temperature, a cooling fluid seeping through a porous medium to maintain surface temperature in high temperature environment and vehicles surface coating with evaporating material to control the surface temperature of high velocity flying objects are some of examples.

In the problem of thermal convection, a situation in which buoyancy forces are generated only by temperature gradient. In many transport processes which occur in nature in addition to temperature, the density difference is caused by chemical composition difference gradient or by materials or phase constitutions.

The phenomenon of convection flow has become a subject of interest among numerous authors and researchers owing to its possible applications to geophysical sciences, astrophysical sciences and in cosmical science. Such flows either arise due to unsteady motion of boundary or boundary temperature. The study of flows through a porous medium based on laminar flow control is one of the most important problems and has many applications in several branches of science. The laminar flow control has become very interesting and important in recent years particularly in field of aeronautical engineering owing to its applications to reduce drag and hence to enhance the vehicle power by a substantial amount. Several techniques that have developed for the purposed of artificially controlling the boundary layer and developments on this subject.

The boundary suction is one of the effective methods of reducing the drag co-efficient which entails large energy losses. The flow through porous media is also used for a keated body to maintain its temperature.. These types of flow have been shown to have great importance in petroleum engineering to study the movement of natural gases, oil and and water purification processes.

Further to study the underground water resources seepage of water in river beds, metal casting, the technologies of paper, textiles and insulating materials, one needs to expore the flow through porous media owing to these applications there has been a considerable growth of interest of researchers towards the subject. During a few years back the flow through porous medium with an arbitrary but smooth plate has been obtained by Yamamoto [1] and Imamura on the basis of Euler's equations and the generalized Darcy's law by taking into account convective acceleration Raptis et.al [2] studied the steady free convective flow of a viscous incompressible fluid through a porous medium bounded by porous isothermal plate. Deka et.al [3] studied the effect of free convection fluid past an infinite vertical plate with constant heat flux. Taneja and Jain [4] solved the hydrodynamic flow in slip flow regime with time dependent suction Das et.al [5] estimated the mass transfer effects on free convection MHD flow of viscous incompressible fluid bounded by an oscillating porous plate in presence of slip regime. Das et.al [6] investigated MHD flow past a vertical porous plate through a porous medium with suction and heat source Kafousiass. et.al [7] have studied unsteady free convective mass transfer flow past vertical plates with suction. Hossain and Begum [8] have discussed unsteady free convection transfer flow past a vertical porous plate.

The present problem is devoted to the study of two dimensional unsteady boundary layer flow of electrically conducting viscous incompressible fluid along a semi-vertical plate under thermal and concentration buoyancy influence with uniform magnetic field acting normally to the field of flow, we assume time dependent suction and differential approximation for radiation. The equations' governing the problem under considerations is solved with finite element procedure of Galerkin. Results of cooling and heating have been discussed by means of different parameters involved in the problem and graphs. It comes to our notice that whenever thermal as well Grashof numbers rises the thermal and concentration buoyancy influences grow rapidly. We observe that in case of Prandtl and Schmidt numbers enhance, the thermal and concentration diminish their levels.

2. MATHEMATICAL FORMULATION OF PROBLEM AND ANALYSIS:

Here the boundary layer in two dimensions flow is the main focus of author the fluid is taken to be viscous in compressible and electrically conducting the flow is along a semi-infinite vertical plate embedded in a porous medium. The flow occurs under the thermal and concentration buoyancy impacts. The time based suction normal to the flow is considered. We choose rectangular reference frame of co-ordinates in order that x^* - axis is along the plate in which the flow of fluid lies. We take y^* - axis normal to it. Further owing to plane surface conditions the flow variables are functions of y^* and t^*. Now a uniform magnetic field comes into existence which is normal to the direction of flow. By the usual Boussinesq's approximation the equations governing the problem can be written as

Momentum Equation

$$\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*} = \frac{\partial^1 u^*}{\partial y^{*2}} + g\beta\,(T^* - T_\infty^*) + g\beta^*\,(C^* - C_\infty^*)$$

$$-\frac{\sigma B_0^2}{\rho} u^* - \frac{\upsilon}{k^*} u^* \qquad (4.2.1)$$

Energy Equation

$$\frac{\partial T^*}{\partial t^*} + v^* \frac{\partial T^*}{\partial y^*} = \upsilon \frac{\partial^2 T^*}{\partial y^{*2}} - \frac{K^1}{\rho_{cp}} \frac{\partial q_r^*}{\partial y^*} + Q^*(T^* - T_\infty^*) \qquad (4.2.2)$$

Concentration Equation

$$\frac{\partial C^*}{\partial t^*} + v^* \frac{\partial C^*}{\partial y^*} = \upsilon \frac{\partial^2 C^*}{\partial y^{*2}} = K_1^{*2} C^* \qquad (4.2.3)$$

Equation of continuity

$$\frac{\partial v^*}{\partial y^*} = 0 \qquad (4.2.4)$$

Where u^*, v^* are the velocity components T^* is the dimension less temperature, q_r^* radiative flux, x^*, y^* are Cartesian co-ordinates, g acceleration due to gravity, β^* co-efficient of volume expansion due to temperature, β^* co-efficient of volume expansion due to concentration, ρ density of fluid, Cp specific heat at constant pressure, υ kinematic viscosity, k^{*2} chemical reaction rate constant, C^* dimension less concentration, C_∞^* species concentration of the fluid, B0 external magnetic field. Roseland approximation for radiative flux vector q_r^* take the form

$$q_r^* = \frac{4\sigma^r}{3K^*} \frac{\partial T^* 4}{\partial y^1} \qquad (4.2.5)$$

Since the temperature differences in flow region is assumed to be small enough and therefore T^{*4} can be expanded in a Taylor series about T_∞^*. After discarding higher order terms it becomes

$$T^{*4} = 4T_\infty^* T^* - 3T_\infty^{*4} \qquad (4.2.6)$$

With the help of (4.2.5) and (4.2.6) the energy equation (4.2.2) can be written as

$$\frac{\partial T^*}{\partial t^*}+v^*\frac{\partial T^*}{\partial y^*}+\frac{K^1}{\rho_{cp}}\frac{\partial^2 T^*}{\partial y^{*2}}+\frac{16}{3}\frac{\sigma^* T_\infty^{*3}}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}}+Q_0(T^*-T_\infty^*) \qquad (4.2.7)$$

Where σ^* and k^* are the Stefan Boltzman constant and mean absorption co-efficient respectively k^1 is the thermal conductivity of fluid.

From equation of continuity (4.2.4) it can be seen that v^* is either a constant or a function of time alone. Hence we assume suction velocity in the form as

$$v^*=-V_0(1+\in Ae^{n^*t^*}) \qquad (4.2.8)$$

Where V_0 is the mean suction velocity, $\in and\ A$ are small such that $\in$A<<1,A is the suction parameter and $\in$ is small reference to parameter ≤ 1 Negative sign before the suction velocity V_0 indicates that it acting towards the plate. It is now convenient to introduce non-dimensional parameters as

$$u=\frac{u^*}{V_0},t=\frac{V_0^2 t^*}{\upsilon},y=\frac{V_0 y^*}{\upsilon},\theta=\frac{T^*-T_\infty^*}{T^*-T_w^*},S_c=\frac{\upsilon}{C^*}$$

$$\varphi=\frac{C^*-C_\infty^*}{C_w^*-C_\infty^*},P_r=\frac{\rho_{Cp}\upsilon}{K},G_r=g\beta^v\left(\frac{T^*-T_\infty^*}{V_0^3}\right) \qquad (4.2.9)$$

$$G_m=g\beta^*\upsilon\left(\frac{C^*-C_\infty^*}{V_0^3}\right),M=\frac{\sigma B_0^2\upsilon}{\rho V_0^2},R=\frac{16\sigma^* T_\infty^{*3}}{3K^* K}$$

$$K_r^2=\frac{K_r^{*2}}{V_0^2},n=\frac{n^*\upsilon}{V_0^2},\lambda=\frac{K^* V_0^2}{\upsilon^2},Q=\frac{Q_0\upsilon}{V_0^2}$$

Substituting (4.2.9) into equations (4.2.1), (4.2.3) and (4.2.7), we obtain non-dimensional governing equations in the following form :

$$\frac{\partial u}{\partial t}-\left(1+\in Ae^{nt}\right)\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+G_r\theta+G_m\theta-(M+\frac{1}{\lambda})u \qquad (4.2.10)$$

$$\frac{\partial\theta}{\partial t}-\left(1+\in Ae^{nt}\right)\frac{\partial\theta}{\partial y}=(\frac{1+R}{P_r})\frac{\partial^2\theta}{\partial y^2}+Q\theta \qquad (4.2.11)$$

$$\frac{\partial\theta}{\partial t}-\left(1+\in Ae^{nt}\right)\frac{\partial\theta}{\partial y}=\frac{1}{Sc}\frac{\partial^2\phi}{\partial y^2}-K_r^2\phi \qquad (4.2.12)$$

Where P_r = Prandtl Number

R = thermal radiation

Q = Heat source Parameter

Sc = Schmidt number

G_r = Free Convection parameter due to temperature

G_m = Free convection parameter due to concentration

M = Magnetic parameter

λ = Permeability of porous medium

K_r^2 = Chemical reaction rate

The corresponding boundary conditions are given by

$$u=1,\theta=1+\epsilon nt,\ \emptyset=1+\epsilon nt \text{ for } y=0 \qquad (4.2.13)$$

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

Hence, the mathematical formulation of the problem is established. The equations (4.2.10), (4.2.11) and (4.2.12) are coupled non-linear systems of partial differential equations whose solutions are obtained under the Initial boundary conditions (4.2.13). Though the solutions in exact form are difficult if possible, so these equations are solved with help of Galerkin finite element method.

3. GALERKIN METHOD OF SOLUTION

Consider the equation (4.2.10) on which Galerkin finite element method is applied over the element (e), $(y_p\leq y\leq y_q)$ is written as

$$\int_{y_p}^{y_q} N(e)^T\left[\frac{\partial^2 u^{(e)}}{\partial y^2}+L_1\frac{\partial u^{(e)}}{\partial y}-\frac{\partial u}{\partial t}-L_2G(e)+G_r\theta+G_m\phi\right]d_y=0 \qquad (4.3.1)$$

Where

$$L_1=1+\in Ae^{nt},L_2=M+\frac{1}{\lambda}$$

Equation (4.3.1) is integrated by parts and finds that

$$\left[N(e)^T\frac{\partial u^{(e)}}{\partial y}\right]_{y_p}^{y_q}-\int_{y_p}^{y_q}\left[\frac{\partial N(e)^T}{\partial y}\frac{\partial u^{(e)}}{\partial y}-N(e)^T\left(L_1\frac{\partial u^{(e)}}{\partial y}+\frac{\partial u^{(e)}}{\partial t}+L_2u^{(e)}-(G_r\theta+G_m^c)\right)\right]dy=0 \qquad (4.3.2)$$

Omitting the first term of equation (4.3.2) we obtain

$$\int_{y_p}^{y_q}\left[\frac{\partial N(e)^T}{\partial y}\ \frac{\partial u^{(e)}}{\partial y}-N(e)^T(L_1\frac{\partial u^{(e)}}{\partial y}+\frac{\partial u^{(e)}}{\partial t}-L_2u^{(e)}-(G_r^\theta+G_m^c)\right]dy=0 \qquad (4.3.3)$$

Consider $u^{(e)}=N^e\varphi[e]$ as the linear piecewise approximate solution

Over the element $(e)(y_p\leq y\leq y_q)$ Where $\varphi^{(e)}=\{u_p\ u_q\}^T$

And

$$N^{(e)}=[N_p,N_q],N_p=\frac{y_q-y}{y_q-y_p},N_q=\frac{y-y_p}{y_q-y_p}$$

are the basic functions. Thus, we obtain,

$$\frac{1}{\ell e}\begin{bmatrix}1&-1\\-1&1\end{bmatrix}\begin{bmatrix}u_p\\u_q\end{bmatrix}-\frac{L_1}{2}\begin{bmatrix}-1&1\\-1&1\end{bmatrix}\begin{bmatrix}u_p\\u_q\end{bmatrix}+\frac{\ell^{(e)}}{6}\begin{bmatrix}2&1\\1&2\end{bmatrix}\begin{bmatrix}\dot{u}_p\\\dot{u}_q\end{bmatrix}+$$

$$L_2 \ell^{(e)} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} u_p \\ u_q \end{bmatrix} = \left(G_r\theta + G_m\varphi\right)\frac{\ell^{(e)}}{2}\begin{bmatrix} 1 \\ 1 \end{bmatrix} \qquad (4.3.4)$$

Where $y_q - y_p = h$ and dot denotes differentiation with respect to 't' we write the element equations for consecutive two elements $y_{s-1} \le y \le y_s$ and $y_s \le y \le y_{s+1}$ assemble three element

Equation, we obtain

$$\frac{1}{\ell^{(e)^2}}\begin{bmatrix} 1 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 1 \end{bmatrix}\begin{bmatrix} u_{s-1} \\ u_s \\ u_{s+1} \end{bmatrix} \frac{L_1}{2}\begin{bmatrix} -1 & 1 & 0 \\ -1 & 0 & 1 \\ 0 & -1 & 1 \end{bmatrix}\begin{bmatrix} u_{s-1} \\ u_s \\ u_{s+1} \end{bmatrix} + \frac{1^{(e)}}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} u_{s-1} \\ u_s \\ u_{s+1} \end{bmatrix}$$

$$+\frac{L_2 1^{(e)}}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} u_{s-1} \\ u_s \\ u_{s+1} \end{bmatrix} = \left(G_r\theta + G_m\varphi\right)\frac{l^{(e)}}{2}\begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \qquad (4.3.5)$$

We now put row corresponding to the node s to zero from equation (4.3.5) the difference schemes with $l^{(e)} = h$ is

$$\frac{l}{l^{(e)^2}}\left[-u_{s-1} + 2u_s - u_{s+1}\right] - \frac{L_1}{2l^e}\left[-u_{s-1} + u_{s+1}\right] + \frac{l^{(e)}}{6}\left[u_{s-1} + 4u_s + u_{s+1}\right] + \frac{L_2 l^{(e)}}{6}\left[u_{s-1} u_s u_{s+1}\right] = (G_r\theta + G_m\phi)$$

i.e.

$$u_{s-1} + 4u_s + u_{s+1} = \frac{1}{h^2}\left(6 - 3L_1h - L_2h^2\right)u_{s-1} - \frac{4}{h^2}\left(3 + L_2h^2\right)u_s + \frac{1}{h^2}\left(6 + 3L_1h - L_2h^2\right)u_{s+1} + 6q(G_r\theta + G_m\phi) \qquad (4.3.6)$$

It is convenient to apply trapezoidal procedure on (4.3.6) the following system of equations in Crank-Nicholson method are found

$$F_1 u_{s-1}^{p+1} + F_2 u_s^{p+1} + F_3 u_{s+1}^{p+1} = F_4 u_{s-1}^p + F_5 u_s^p + F_6 u_{s+1}^p \qquad (4.3.7)$$

By the application of similar procedure to equations (4.2.11) and (4.2.12) we obtain,

$$G_1\theta_{s-1}^{p+1} + G_2\theta_s^{p+1} + G_3\theta_{s-1}^{p+1} = G_4\theta_{s-1}^p + G_5\theta_s^p + G_6\theta_{s+1}^p \qquad (4.3.8)$$

And

$$H_1\phi_{s-1}^{p+1} + H_2\phi_s^{p+1} + H_3\phi_{s+1}^{p+1} = H_4\phi_{s-1}^p + H_5\phi_s^p + F_6\phi_{s-1}^p \qquad (4.3.9)$$

Where

$$F_1 = 1 - 3r + \frac{3}{2}rL_1h + \frac{1}{2}rL_2h^2$$

$$F_2 = 4 + 6r + 2rL_2h^2$$

$$F_3 = 1 - 3r - \frac{3}{2}rL_1h + \frac{1}{2}rL_2h^4$$

$$F_4 = 1 + 3r - \frac{3}{2}rL_1h - \frac{1}{2}rL_2h^2$$

$$F_5 = 4 - 6r - 2rL_2h^2$$

$$F_6 = 1 + 3r + \frac{3}{2}rL_1h - \frac{1}{2}rL_2h^2$$

$$G_1 = 1 - 3rL_3 + \frac{3}{2}rL_1h - \frac{1}{2}Qrh^2$$

$$G_2 = 4 + 6rL_3 - 2rQh^2$$

$$G_3 = 1 - 3rL_3 - \frac{3r}{2}L_1h - \frac{1}{2}Qrh^2$$

$$G_4 = 1 + 3rL_3 - \frac{3}{2}rL_1h + \frac{1}{2}Qrh^2$$

$$G_5 = 4 - 6rL_3 + 2rQh^2$$

$$G_6 = 1 + 3rL_3 + \frac{3}{2}rL_1h - \frac{1}{2}Qrh^2$$

$$H_1 = Sc - 3r + \frac{3}{2}ScL_1rh + \frac{1}{2}rSch^2k_r^2$$

$$H_2 = 4Sc + 6r + 2rSck_r^2h^2$$

$$H_3 = Sc - 3r - \frac{3}{2} + rL_1hSc$$

$$H_4 = Sc + 3r - \frac{3}{2} + rL_1hSc$$

$$H_5 = 4Sc - 6r - 2rh^2k_r^2SC$$

$$H_6 = SC + 6r + \frac{3}{2}L_1rhSC - \frac{1}{2}rk_r^2h^2SC$$

Here $r = \frac{k}{h^2}$, h, q are size of mesh along y direction and the direction of time t respectively Index S refers to space and p refers to time. In equation (4.3.7) to (4.3.9), taking s= 1(1) n and using initial and

Boundary conditions (4.2.13), the following system of equations are found as

$$A_s B_s = B_s, s = 1(1)3 \qquad (4.3.10)$$

Where A_s are of order 'n' matrices, X_s and B_s matrices (column) of n elements. We solve afore said system of equations for velocity, temperature and concentration with the help of 'Thomas Algorithm. Further we obtain the numerical solutions for these equations on the basis of C- program to examine convergence and stability of Galerkin finite element procedure, the same C- program is utilized with slightly changed values h and q. In this situation we observed that there is no significant change in values of u, θ, ϕ. It infers that Galerkin infinite element method is intact stable and convergent.

4. SKIN FRICTION, RATE OF HEAT AND MASS TRANSFER

The skin friction, Nesselt number and Sherwood number are significant physical parameters of boundary layer flows and are given in the following forms

Skin friction co-efficient (C_f) is given as

$$C_f = \left(\frac{\partial u}{\partial y}\right)_{y=0} \qquad (4.4.1)$$

Nesselt number (N_n) as plate is

$$N_n = \left(\frac{\partial \theta}{\partial y}\right)_{y=0} \qquad (4.4.2)$$

Sherwood number (sh) at the plate is

$$Sh = \left(\frac{\partial \varphi}{\partial y}\right)_{y=0} \qquad (4.4.3)$$

5. RESULTS AND DESCUSSION

In this section an attempt has been made to carry out some numerical calculations for dimension less velocity u, temperature θ, Concentration φ, heat and mass transfer co-efficient in terms of Nusselt number (Nu) and Sherwood number (Sh), Co-efficient of skin friction (τ),

For realistic approach we choose values of Schmidt number (S_c) for hydrogen (S_c= 0.22) , for ammonia (S_c= 0.78),for methanol ((S_c= 1.0), for water-vapour (S_c= 0.60) and for propyl benzene at 20^0 C (S_c= 2.62). Further the values

Prandtl number (P_r) chosen for air (P_r=0.71), for electrolytic solution (P_r= 1.0), for waer (P_r=7.0) and for water at 4^0 C (P_r=11.4).

Now figures 4(a),4(b),4(c),5(a),5(b),5(c),6(a), and 6(b) exhibits the influences of material parameters G_r, G_m,λ,M,K_r,A , N_r,Q P_r, S_c , when the plate is cooled under the effect of free-convection currents (G_r,>0). It is noticed that an increase in P_r,S_c ,M and K_r decrease the velocity field u. Again an increase in Nrr,Q,Kr, Gr, Gm leads to increase in velocity field . From figures 5(a), and 5(b) it

is observed that an enhance in suction parameter. A gives a decrease in the velocity field. On comparison of velocity field curves we reach to a conclusion the owing to cooling of the plate velocity rapidly is near the plate and it decreases after attaining a maximum value as y increases.

From figures 6(c) , 7(a) , 7(b) , 7(c) , 8 (a), 8(b) , 8(c) , and 8(d) , , we observe the effects of material parameters Gr, Gm , λ, M, A, K_r , N_r , Q ,S_c , P_r . When the plate is heated by the influence of free- convection currently (G_r<0). After observation it is noticed that an increase in G_r, G_m and P_r, M compels the velocity field to increase. Again it is seen that an increase S_c, Q , N, K_r and λ decrease the velocity field , from Figures 7 (c) and 8 (a) it can be observed that an increase in suction parameter. A gives rise to velocity field.

Fig. 9 (a) describes temperature distribution θ , depicting the influence radiation. It is observed that a decrease in the temperature and temperature boundary layer is noticed as Prandtl number P_r increases. Again an increase in thermal radiation N_r, leads to increase the temperature and temperature boundary layer. The temperature is noticed decreasing exponentially away from the plate; fig. 9(b) displays effect of source parameter Q over the temperature field. It is noticed that an increase in Q increases the temperature field θ Fig. 9(c) describes the impact of Schmidt number S_c and chemical reaction rate K_r on species concentration. It is seen that an increase in the Schmidt number S_c, or chemical reaction rate K_r, decrease the concentration and concentration boundary layer From fig (a) and 9 (c). It is noticed that the suction has a minute or no influence over the temperature and concentration boundary layer.

Table –1 Skin – friction coefficient (π) for cooling of the Plate $(G_r > 0)$

P_r	Sc	Q	N_r	K_r	M	λ	G_r	G_m	τ
0.71	0.22	1.0	0.5	0.5	0.5	1.0	5.0	5.0	5.404040
7.00	0.22	1.0	0.5	0.5	0.5	1.0	5.0	5.0	1.312256
0.71	0.60	1.0	0.5	0.5	0.5	1.0	5.0	5.0	4.525942
0.71	0.22	1.5	0.5	0.5	1.0	1.0	5.0	5.0	8.510313
0.71	0.22	1.0	1.0	0.5	0.5	1.0	5.0	5.0	5.738986
0.71	0.22	1.0	0.5	1.0	0.5	1.0	5.0	5.0	4.956634
0.71	0.22	1.0	0.5	0.5	0.5	1.0	5.0	5.0	4.369522
0.71	0.22	1.0	0.5	0.5	0.5	2.0	5.0	5.0	6.881610
0.71	0.22	1.0	0.5	0.5	0.5	1.0	10.0	5.0	9.514360
0.71	0.22	1.0	0.5	0.5	0.5	1.0	5.0	10.0	7.935074

Table –2 Skin – friction coefficient (τ) for cooling of the Plate $(G_r < 0)$

P_r	Sc	Q	N_r	K_r	M	λ	G_r	G_m	τ
0.71	0.22	1.0	0.5	0.5	0.5	1.0	-5.0	5.0	-2.816585
7.00	0.22	1.0	0.5	0.5	0.5	1.0	-5.0	5.0	1.275202
0.71	0.60	1.0	0.5	0.5	0.5	1.0	-5.0	5.0	-3.694690
0.71	0.22	1.5	0.5	0.5	1.0	1.0	-5.0	5.0	-5.922676
0.71	0.22	1.0	1.0	0.5	0.5	1.0	-5.0	5.0	-3.151528
0.71	0.22	1.0	0.5	1.0	0.5	1.0	-5.0	5.0	-3.263996
0.71	0.22	1.0	0.5	0.5	0.5	1.0	-5.0	5.0	-2.678056
0.71	0.22	1.0	0.5	0.5	0.5	2.0	-5.0	5.0	-2.998256
0.71	0.22	1.0	0.5	0.5	0.5	1.0	-10.0	5.0	-6.926902
0.71	0.22	1.0	0.5	0.5	0.5	1.0	-5.0	10.0	0.287558

Table –3. Heat Transfer coefficient in terms of Nusselt number (Nu)

P_r	Q	N_r	N_u
0.71	1.0	0.5	-0.375516
3.00	1.0	0.5	-1.237810
0.71	2.0	0.5	0.016614
0.71	1.0	1.0	-0.288008

Table –4. Mass Transfer Coefficient in terms of Sherwood number (Sh)

Sc	K_r	S_h
0.22	0.5	-0.443266
0.60	0.5	-0.800992
0.22	1.0	0.558000

Table – 1 presents numerical values of the skin-friction coefficient (τ) for variation in $P_n, Sc, Q, Nr, K_r, A, M, \lambda, G_r$ and G_m for cooling of the plate .

Table – 2 presents numerical values of the skin – friction coefficient (τ) for variation in $P_n, Sc, Q, Nr, K_r, A, M, \lambda, G_r$ and G_m for heating of the plate $(G_r < 0)$. It is observed that, an increase in $P_r M, G_r$ and G_m increase the value of skin – friction coefficient while an increase in Sc, Q, $N_r, K_r and \lambda$ decrease the value of skin-friction coefficient.

Table -3 Displays numerical values of heat transfer coefficient in terms of Nusselt number (Nu) for different values of the Prandtl number P_r heat source parameter Q and thermal radiation N_r respectively. It is found that, an increase in the Prandtl number (P_r) decreases in the value of heat transfer coefficient while an increase in the heat source parameter or thermal radiation leads to increase in the value of heat transfer coefficient.

Table – 4 Exhibits numerical values of mass transfer coefficient in terms of Sherwood number (sh) for different values of Schmidt number Sc and chemical reaction rate constant K_r respectively. It is seen that an increase in the Schmidt number or chemical reaction rate constant decrease the value of mass transfer coefficient.

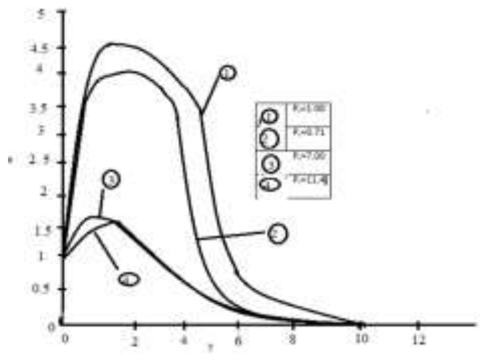

Fig 4(a) Effect of Pr on velocity field if u for cooling of the plate when Gr = 5, Gm = 5, Sc =0.22 . Q = 1.0, Nr=0.5, kr=0.5, M=0.5, λ=1.0, A=0.3, C=0.02, n=0.5, t=1.0

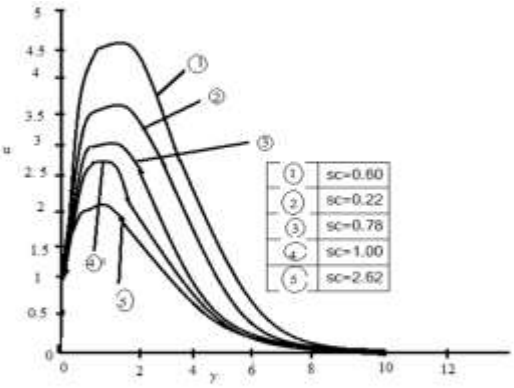

Fig 4(b) Effect of S_c on velocity field u for cooling of the plate when Gr = 5, Gm = 5 Pr =0.71 , Q = 1.0, Nr=0.5, kr=0.5, M=0.5, λ=1.0, A=0.3,ε=0.02,n=0.5,t=1.0

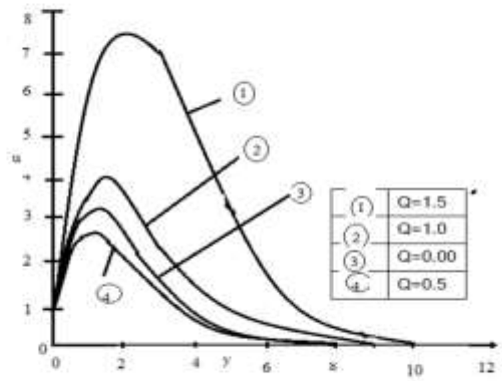

Fig 4(c) Effect of Q on velocity field u for cooling of the plate when Gr = 5, Gm = 5,Pr=0.71, Sc =0.22 , Nr=0.5, kr=0.5, M=0.5, λ=1.0, A=0.3, E=0.02, n=0.5, t=1.0

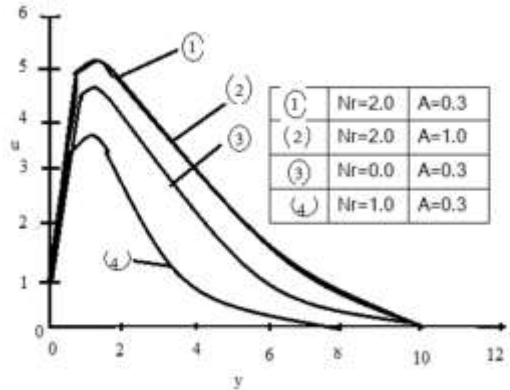

Fig 5(a) Effect of Nr and A on velocity field n for cooling of the plate when Gr = 5, Gm = 5,Sc =0.22,Q = 1.0, kr=0.5, M=0.5, λ=1.0, ε=0.02, n=0.5, t=1.0

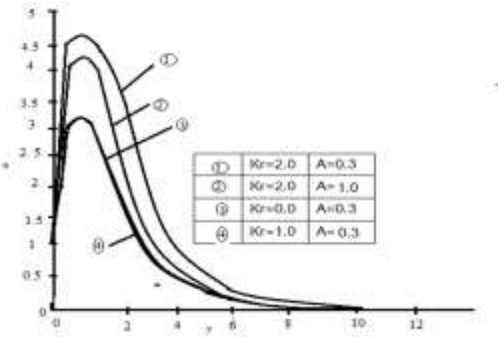

Fig 5(b) Effect of k_r and A on velocity field u for cooling of the plate when Gr=5, Gm = 5, Sc =0.22, Q = 1.0, Nr=0.5, M=0.5,λ=1.0,ε=0.02,n=0.5,t=1.0

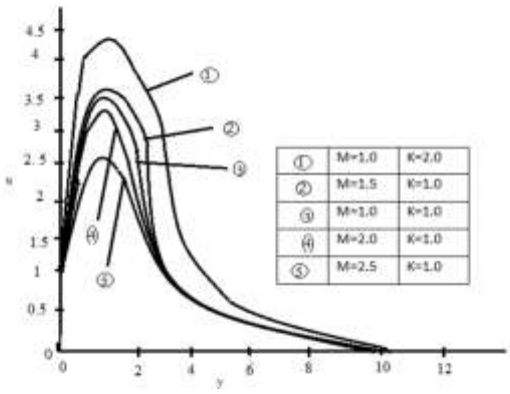

Fig 5(c) Effect of M and λ on velocity field u for cooling of the plate when Gr = 5, Gm = 5, Pr =0.71, Sc=0.22, Q = 1.0, Nr=0.5, kr=0.5, M=0.5,λ=1.0,A=0.3,ε=0.02,n=0.5,t=1.0

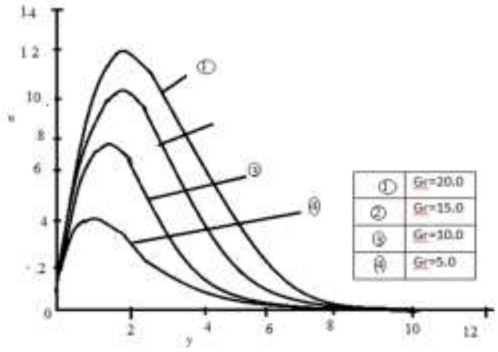

Fig 6(a) Effect of Gr on velocity field u for cooling of the plate when Gm = 5 Pr=0.71, Sc =0.22,Q = 1.0, Nr=0.5, kr=0.5,M=0.5,λ=1.0,A=0.3,ε=0.02,n=0.5,t=1.0

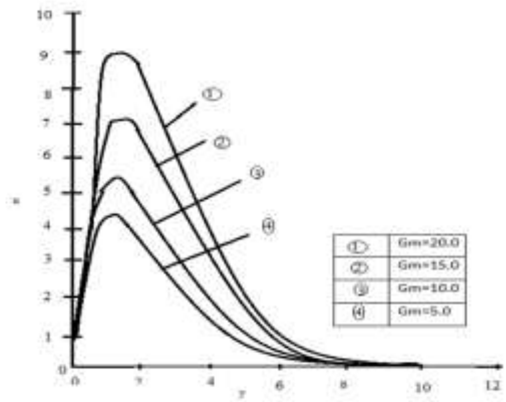

Fig 6(b) Effect of Gm on velocity field u for cooling of the plate when Gr = 5, P_r =0.71, Sc =0.22, Q = 1.0, Nr=0.5, kr=0.5,M=0.5,λ=1.0,A=0.3,ε=0.02, n=0.5,t=1.0

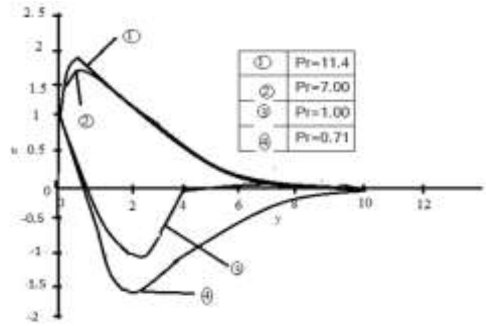

Fig 6(c) Effect of Pr on velocity field u for heating of the plate when Gr =- 5.0,Gm = 5, Sc =0.22 . Q = 1.0, Nr=0.5, kr=0.5, M=0.5,λ=1.0,A=0.3,ε=0.02, n=0.5,t=1.0

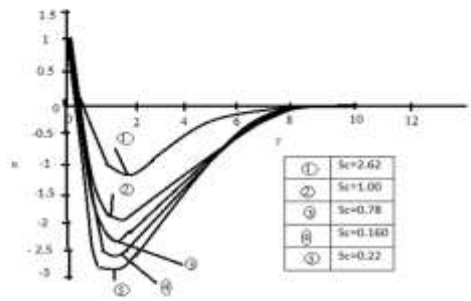

Fig 7(a) Effect of Sc on velocity field u for heating of the plate when Gr =-5.0, Gm = 5,Pr=0.71,Q = 1.0, Nr=0.5, kr=0.5,M=0.5,λ=1.0,A=0.3,ε=0.02, n=0.5,t=1.0

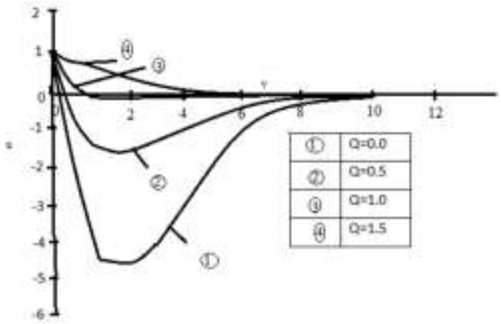

Fig 7(b) Effect of Q on velocity field u for heating of the plate when Gr = -5.0 ,Gm = 5, Pr=0.71, Sc =0.22, Nr=0.5, kr=0.5,M=0.5,λ=1.0,A=0.3,ε=0.02,n=0.5,t=1.0

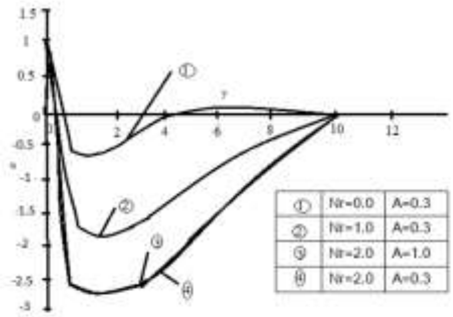

Fig 7(c) Effect of Nr and A on velocity field u for heating of the plate when Gr = -5.0, Gm = 5,Pr=0.71,Sc =0.22, Q = 1.0, kr=0.5,M=0.5,λ=1.0,ε=0.02,n=0.5,t=1.0

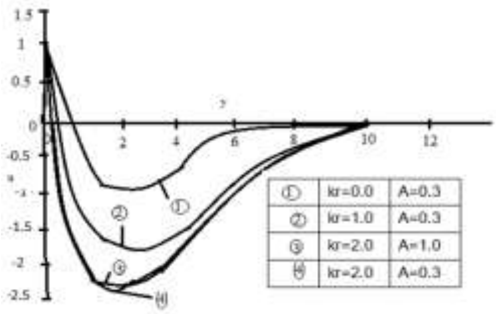

Fig 8(a) Effect of Kr on velocity field u for heating of the plate when Gr = -5.0, Gm = 5,P_r=0.71,Sc =0.22 , Q = 1.0, Nr=0.5, M=0.5,λ=1.0,A=0.3,ε=0.02, n=0.5,t=1.0

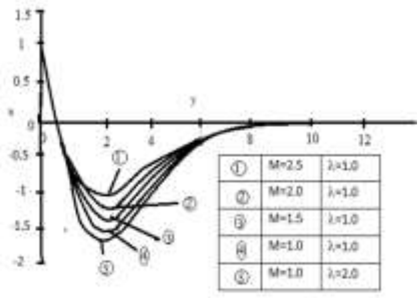

Fig 8(b) Effect of M and λ on velocity field u for heating of the plate when G_r = -5.0, Gm = 5,Pr=0.71, Sc =0.22,Q = 1.0, Nr=0.5, kr=0.5,A=0.3,ε=0.02,n=0.5,t=1.0

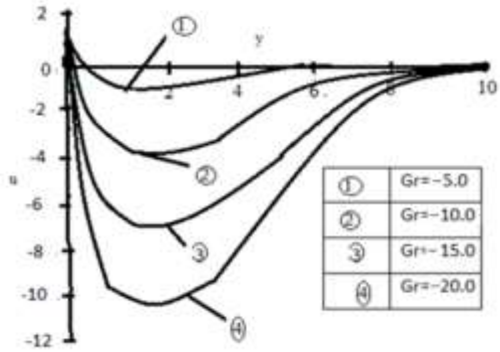

Fig 8(c) Effect of Gr on velocity field u for heating of the plate when Gm = 5,Pr=0.71,Sc =0.22,Q = 1.0, Nr=0.5, K_r=0.5,M=0.5,λ=1.0,A=0.3,ε=0.02,n=0.5,t=1.0

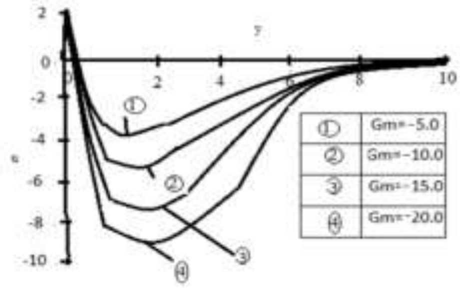

Fig 8(d) Effect of Gm on velocity field u for heating of the plate when Gr =-5,P_r = 0.71, Sc =0.22, Q = 1.0, Nr=0.5, kr=0.5,M=0.5,λ=1.0,A=0.3,ε=0.02,n=0.5,t=1.0

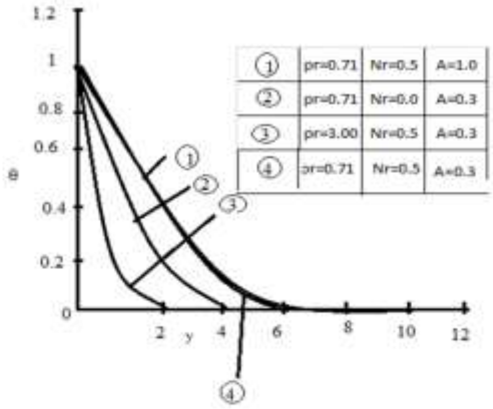

Fig .9(a) – Temperature profiles when Q=1.0.

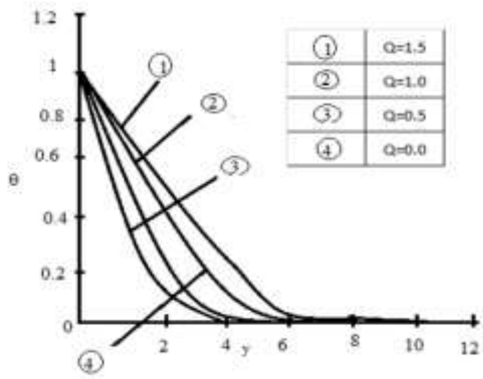

Fig.9 (b) Effect of Q on temperature field θ when P_r=0.71,N_r=0.5,A=0.3.

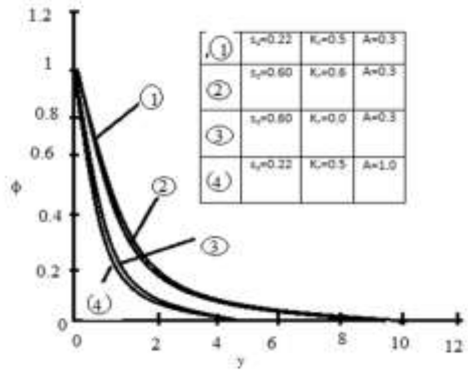

Fig.9(c) Concentration profiles

CONCLUSIONS

Main focus of author on the topic "Mass transfer and radiation effects on unsteady MHD convective fluid in a porous medium with generation and absorption" is to find solution of differential equations under the method known as Galerkin finite element method. The results thus obtained are compared with previous results. It is found that the results obtained are in good agreement with previous results. The results obtained are compared with previous works and found to be in good agreement. It is found that increasing the Prandtl number results in a decrease in the temperature and temperature boundary layer while increasing the thermal radiation leads to a rise in the temperature and temperature boundary layer. An increase in the Schmidt number or chemical reaction rate constant decrease in the concentration and concentrations boundary layer. Also, it has been observed that the suction has a little or no effect on the temperature and concentration. The value of the skin-friction coefficient (τ) decrease as increase in the prandtl number P_r and Schmidt number Sc. The value of the skin-friction coefficient is maximum for cooling of the plate than in case of heating of the plate. Also, it is observed that Nusselt number and Sherwood numbers decrease with increase in the Prandtl number P_r and Schmidt number Sc. These observations are in good agreement with results from literature.

REFERENCES

1. Yamamoto, K. And Iwamura, N. (1976). Flow with convective acceleration through a porous medium. J. Engineering, vol.10, pp. 41-54.

2. Raptis, A. Kafousias, N. And Massalas, C. (1981). Free convective flow through a porous medium bounded by an infinite vertical porous plate with constant heat flux. Reg. Journal Energy Heat Mass Transfer, Vol. 3, pp. 279-283.

3. Deka, R.K, Das, U.N. and soundagakar, V.M. (1997). Convection effects on MHD flow past an infinite vertical plate oscillating with constant heat flux. Indian J. Math 39(3), pp. 195-202.

4. Taneja, R. And Jain, N.C Hydrodynamic flow in slip flow regime with time dependent suction. Ganita 53(1) (2002) pp. 11-22.

5. Das, S.S, Tripathy, U.K., Das, J.K. Sahoo, S.K. Das, B.K. (2008). Mass transfer effects on free convection MHD flow of viscous fluid bounded by an oscillating porous plate in the slip flow regims with heat source. J. Ultra scientists of Phy. SCI. Vol. 20, pp. 169-176.

6. Das, SS, Satpathy, A.K, Das, J.K. Panda, J.P. (2009). Mass transfer effects on MHD flow and heat transfer past a vertical porous plate through a porous medium under oscillatory suction and heat source Int. J. Heat Mass transfer vol. 52 (25-26), pp. 5962-5969.

7. Kafoussias, N.G., Raptis, A. Massala, C. (1985). Free convection flow through a porous medium bounded by an infinite vertical porous plate with constant heat flux. Reg. J. Energy heat Mass Transfer. Vol. 4, pp. 279-283.

8. Hussain, M.A. and Begum, R. A. (1981). Atrophys space science, 145: pp. 115.

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