Diffusion-Thermo and Radiation Absorption Effects on Unsteady MHD Convective Flow Past A Semi-Infinite Moving Plate

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Abstract—*This paper focuses on unsteady, two-dimensional ,laminar ,boundary layer flow of a viscous incompressible electrically conducting and heat absorbing fluid along a semi-infinite vertical permeable moving plate in the presence of Diffusion-thermo and radiation absorption effects .The plate is assumed to move with a constant velocity in fluid flow direction. A uniform transverse magnetic acts perpendicular to the porous surface, the dimensionless equations are solved analytically using perturbation technique. The effects of the various fluid flow parameters on velocity, temperature and concentration fields within the boundary layer have been analysed with the help of graphs. The local skin-friction coefficient and the rates of heat and mass transfer coefficients are also derived and discussed through tables.*

Keywords— *Chemical reaction, Diffusion-thermo effect, Heat absorption, MHD, Radiation absorption.*

I. INTRODUCTION

The range of free convective flows that occur in nature and in engineering practice is very large and has been extensively considered by many researchers [1, 2]. When heat and mass transfer occur simultaneously between the fluxes, the driving potentials are of more intricate nature. An energy flux can be generated not only by temperature gradients but by composition gradients. The energy flux caused by a called Dufour or Diffusion-thermo effect. Generally the thermal diffusion and the diffusion- thermo effects are of smaller- order magnitude than the effects prescribed by Fourier's laws and are often neglected in heat and mass transfer processes. However, there are exceptions. The thermal- diffusion effect, for instance, has been utilized for isotope separation and in mixture between gases with very light molecular weight (Hydrogen-Helium) and of medium molecular weight (Nitrogen- air) the diffusion-thermo effect was found to be of a magnitude such that it cannot be neglected.

Postelnicu [10] studied simultaneously heat and mass transfer by natural convection from a vertical plate embedded in electrically conducting fluid saturated porous medium, using Darcy- Boussinesq model including Soret and Dufour effects. Chamka [13] studied the convective heat and mass transfer past a semi-infinite vertical permeable moving plate. Dulal pal[8] studied the MHD convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction.

The interaction of buoyancy with thermal radiation has in increased greatly during the last decade due to its importance in many practical applications. The thermal radiation effect is important under many isothermal and non-isothermal situations. If the entire system involving the polymer extrusion process is placed in a thermally controlled environment, then thermal radiation could be important. The knowledge of radiation heat transfer in the system can perhaps, lead to a desired product with sought characteristics.

The uses of magnetic field to control the flow and heat transfer processes in fluids near different types of boundaries are now well known. This has led to considerable interest in the study of boundary layer, the inclusion of ohmic heating effect is extremely important. Hossain [3] examined the effect of ohmic heating on MHD free convective heat transfer for a Newtonian fluid.

Convection in porous media has gained significant attention in recent years because of its importance in engineering applications such as geothermal systems, solid matrix heat exchangers, thermal insulations, oil extraction and store of nuclear waste materials. Convection in porous media can also be applied to underground coal gasification, ground water hydrology, iron blast furnaces, wall cooled catalytic reactors, cooling of nuclear reactors, solar power collectors, energy efficient drying processes, cooling of nuclear fuel in shipping flasks, cooling of electronic equipments and natural convection in earth's crust. Reviews of the applications related to convective flows in porous media can be found in Nield and Bejan [4]. The fundamental problem of flow through porous media has been studied extensively over the years both theoretically and experimentally [5, 6].

The combined effects of heat and mass transfer with chemical reaction are of great importance to engineers and scientists because of its almost universal occurrence in many branches of science and engineering, and hence received of considerable amount of attention in recent years. The study of chemical reaction with heat transfer in porous medium has important engineering applications e.g., tubular reactors, oxidation of solid materials and synthesis of ceramic materials. There are two types of reactions such as (i) homogeneous reaction and (ii) heterogeneous reaction. A homogeneous reaction occurs uniformly throughout the given phase, whereas heterogeneous reaction takes place in a restricted region or within the boundary of a phase. The effect of a chemical reaction depends on whether the reaction is heterogeneous. A chemical reaction is said to be first-order, if the rate of reaction is directly proportional to concentration itself. In many industrial processes involving flow and mass transfer over a flat surface, such as the polymer production and manufacturing of ceramics or glassware, the diffusing species can be generated or absorbed due to some kind of chemical reaction with the ambient fluid, which can greatly affect the flow and hence the properties and quality of the final product. These processes take place in numerous industrial applications such as the polymer production and the manufacturing of ceramics or glassware. Thus we are particularly interested in cases in which diffusion of the species and chemical reactions occur at roughly the same speed in analyzing the mass transfer phenomenon. Das et al. [7] have studied the effect of homogeneous first-order chemical reaction on the flow past an impulsively started infinite vertical plate with uniform heat flux and mass transfer.

The objective of this paper is consider unsteady simultaneous convective heat and mass transfer flow along a vertical permeable plate embedded in a fluid-saturated porous medium in the presence of mass blowing or suction, diffusion-thermo and radiation absorption effects, magnetic field effects and absorption effects. Most of previous works assumed that the semi-infinite plate is rest. In the present work, it is assumed that the plate is embedded in a uniform porous medium and moves with a constant velocity in the flow direction in the presence of a transverse magnetic field. Muthucumarsamy and Ganesan [11] investigated the diffusion and first-order chemical reaction on an impulsively started infinite vertical plate with variable temperature. Abo-Eldahab and Elgendy [9] presented radiation effect on convective heat transfer in an electrically conducting fluid at stretching surface with variable viscosity and uniform free stream. Recently Kim [12] discussed unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction.

II. FORMULATION OF THE PROBLEM

We consider unsteady two-dimensional flow of an incompressible, viscous, electrically conducting and heat-absorbing fluid past a semi-infinite vertical permeable plate embedded in a uniform porous medium which is subject to slip boundary condition at the interface of porous medium which is subject to slip boundary at the interface of porous and fluid layers. A uniform transverse magnetic field of strength B_0 is applied in the presence of radiation and concentration buoyancy effects in the direction of y^*-axis. The transversely applied magnetic field and magnetic Reynolds number are assumed to be very small so that induced magnetic field and Hall Effect are negligible. It is assumed that there is no applied voltage which implies the absence of electric field. Since the motion is two dimensional and the length of the plate is large enough so all the physical variables are independent of x^*. The wall is maintained at constant temperature T_w and concentration C_w, higher than the ambient temperature T_∞ and concentrationC_∞, respectively. Also, it is assumed that there exists a homogeneous first-order chemical reaction with rate constant R between the diffusing species and the fluid. It is assumed that the porous medium is homogeneous and present everywhere in local thermodynamic equilibrium. Rest of properties of the fluid and the porous medium are assumed to be constant. In the above assumptions the governing equations as follows:

Continuity Equation:

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

Momentum Equation:

$$\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + \nu \frac{\partial^2 u^*}{\partial {y^*}^2} - \frac{\sigma B_0^2}{\rho} u^* + g\beta_T (T - T_\infty) + g\beta_c (C - C_\infty) - \frac{\nu}{K^*} u^* \tag{2}$$

Energy Equation:

$$\frac{\partial T}{\partial t^*}+v^*\frac{\partial T}{\partial y^*}=\alpha\frac{\partial^2 T}{\partial {y^*}^2}-\frac{Q_0}{\rho C_p}(T-T_\infty)+\frac{Q_1^*}{\rho C_p}(C-C_\infty)+\frac{D_m}{C_s}\frac{K_T}{\rho C_p}\frac{\partial^2 C}{\partial {y^*}^2} \quad (3)$$

Mass Diffusion Equation:

$$\frac{\partial C}{\partial t^*}+v^*\frac{\partial C}{\partial y^*}=D\frac{\partial^2 C}{\partial {\eta^*}^2}-K_1(C-C_\infty) \quad (4)$$

Where x^* and y^* are the dimensional distances along to the plate. u^* and v^* are the components of dimensional velocities along x^* and y^* directions. g is the gravitational acceleration, T^* is the dimensional temperature of the fluid near the plate,T_∞ is the stream dimensional temperature, C^* is the dimensional concentration, C_∞ is is the stream dimensional concentration. β_T and β_C are the thermal and concentration expansion coefficients, respectively. p^* is the pressure ,C_p is the specific heat of constant pressure, B_0 is the magnetic field coefficient, μ is viscosity of the fluid, q_r^* is the radiative heat flux, ρ is the density, K is the thermal conductivity, σ is the density magnetic permeability of the fluid, $\nu=\frac{\mu}{\rho}$ is the kinematic viscosity, D is the molecular diffusivity, Q_0 is the dimensional heat absorption coefficient,Q_1^* is the coefficient of proportionality of the absorption of the radiation and R is the chemical reaction. The fourth and fifth terms of RHS of the momentum Eq. (2) denote the thermal and concentration buoyancy effects, respectively. The second and third term on the RHS of Eq. (3) denote the inclusion of the effect of thermal radiation and heat absorption effects, respectively.

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

$$u^*=U_\infty^*=U_0\left(1+\varepsilon e^{n^*t^*}\right), T\to T_\infty,\ C\to C_\infty\ \ as\ \ y\to\infty \quad (6)$$

Where $U_p, C_w\ and\ T_w$ are the wall dimensional velocity, concentration and temperature, respectively. $U_\infty^*, C_\infty, and\ T_\infty$ are the free stream dimensional velocity, concentration and temperature, respectively$U_0\ and\ n^*$are constants.

It is clear from Eq.(1) that the suction velocity at the plate surface is a function of time only. Assuming that it takes the following exponential form:

$$v^*=-V_0(1+\varepsilon A e^{n^*t^*}) \quad (7)$$

Where A is a real positive constant, ε and εA are small less than unity, and V_0 is a scale of suction velocity which has non-zero positive constant. Outside the boundary layer, Eq. (2) gives

$$-\frac{1}{\rho}\frac{dp^*}{dx^*}=\frac{dU_\infty^*}{dt^*}+\frac{\sigma}{\rho}B_0^2U_\infty^*+\frac{\nu}{K^*}U_\infty^* \quad (8)$$

Introducing the non-dimensional quantities

$$u=\frac{u^*}{U_0},\ v=\frac{v^*}{V_0},\ \eta=\frac{v_0 y^*}{\nu},\ U_\infty=\frac{U_\infty^*}{U_0},\ t=\frac{V_0^2 t^*}{\nu},$$

$$\theta=\frac{T-T_\infty}{T_w-T_\infty},\ ,\ C=\frac{C-C_\infty}{C_w-C_\infty},\ n=\frac{n^*\nu}{V_0^2},\ U_p=\frac{u_p^*}{U_0}$$

$$Gr_T=\frac{\rho g\nu(T_w-T_\infty)\beta_T}{U_0V_0^2},\ Gr_c=\frac{\rho g\nu(C_w-C_\infty)\beta_C}{U_0V_0^2},$$

$$M=\frac{\sigma\nu B_0^2}{\rho V_0^2},\ \ Pr=\frac{\nu C_p}{K}=\frac{\nu}{\alpha},\ \ \emptyset=\frac{Q_0\nu}{\rho C_p V_0^2},$$

$$Q_1=\frac{Q_1^*\nu^2(C_w-C_\infty)}{V_0^2(T_w-T_\infty)},\ \ Sc=\frac{\nu}{D},\ \ \gamma=\frac{K_1\nu}{V_0^2},$$

$$Du=\frac{D_mK_T}{C_sK}\frac{(C_w-C_\infty)}{(T_w-T_\infty)},\ K=\frac{V_0^2K^*}{\nu^2} \quad (9)$$

In the view of the above non-dimensional variables, the basic field of Eqs. (2)-(4) can be expressed in non-dimensional form as

$$\frac{\partial u}{\partial t}-(1+\varepsilon Ae^{nt})\frac{\partial u}{\partial\eta}=\frac{dU_\infty}{dt}+\frac{\partial^2 u}{\partial\eta^2}+Gr_T\theta+Gr_cC+N(U_\infty-u) \quad (10)$$

$$\frac{\partial\theta}{\partial t}-(1+\varepsilon Ae^{nt})\frac{\partial\theta}{\partial\eta}=\frac{1}{Pr}\frac{\partial^2\theta}{\partial\eta^2}+Q_1C-\emptyset\theta+\frac{D_u}{Pr}\left(\frac{\partial^2 C}{\partial\eta^2}\right) \quad (11)$$

$$\frac{\partial C}{\partial t}-(1+\varepsilon Ae^{nt})\frac{\partial C}{\partial\eta}=\frac{1}{Sc}\frac{\partial^2 C}{\partial c^2}-\gamma C \quad (12)$$

Where, $N=\left(M+\frac{1}{K}\right)$

The corresponding boundary conditions (5) and (6) in dimensionless form are

$$u=U_p, \theta=1+\varepsilon e^{nt}, C=1+\varepsilon e^{nt}\ at\ \eta=0 \quad (13)$$

$$u\to U_\infty=(1+\varepsilon e^{nt}),\ \theta\to 0, C\to 0\ as\ \eta\to\infty \quad (14)$$

III. METHOD OF SOLUTION

$$u=f_0(\eta)+\varepsilon e^{nt}f_1(\eta)+O(\varepsilon^2) \quad (15)$$

$$\theta=g_0(\eta)+\varepsilon e^{nt}g_1(\eta)+O(\varepsilon^2) \quad (16)$$

$$C=h_0(\eta)+\varepsilon e^{nt}h_1(\eta)+O(\varepsilon^2) \quad (17)$$

Substituting (15)-(17) into Eqs.(10)-(12) and equating the harmonic and non-harmonic terms, and neglecting the higher order $O(\varepsilon^2), and$ simplifying to get the following pairs of equations for f_0, g_0, h_0 and f_1, g_1, h_1.

$$f_0''+f_0'-Nf_0=-N-Gr_Tg_0-Gr_ch_0 \quad (18)$$

$$f_1'' + f_1' - (N+n)f_1 = -(N+n) - Af_0' - Gr_T g_1 - Gr_c h_1 \quad (19)$$

$$g_0'' + Prg_0' - \Pr\emptyset g_0 = -PrQ_1 h_0 - Duh_0'' \quad (20)$$

$$g_1'' + Prg_1' - \Pr(\emptyset + n)g_1 = -PrQ_1 h_1 - Duh_1'' - PrAg_0' \quad (21)$$

$$h_0'' + Sch_0' - Sc\gamma h_0 = 0 \quad (22)$$

$$h_1'' + Sch_1' - Sc(\gamma + n)h_1 = -ASch_0' \quad (23)$$

Where the prime denotes ordinary differentiation with respect to y. The corresponding boundary conditions are $f_0 = U_p,\ f_1 = 0,\ g_0 = 1, g_1 = 1, h_0 = 1,$

$$h_1 = 1 \quad at\ \eta = 0 \quad (24)$$

$$f_0 = 1,\ f_1 = 1, g_0 \to 0,\ g_1 \to 0, h_0 \to 0, h_1 \to 0 \ \text{ as } \eta \to \infty. \quad (25)$$

Without going into the details, the solutions of Eqs. (18)-(23) with the help of boundary conditions (24) and (25),we get

$$f_0 = 1 + B_4 e^{-m_6\eta} - A_3 e^{-m_2\eta} - A_2 e^{-P_1\eta} \quad (26)$$

$$f_1 = 1 + B_5 e^{-m_3\eta} + A_4 e^{-m_6\eta} - A_{10} e^{-m_2\eta} - B_1 e^{-P_1\eta} - B_2 e^{-m_5\eta} - B_3 e^{-m_4\eta} \quad (27)$$

$$g_0 = (1 - A_1)e^{-m_2\eta} + A_1 e^{-P_1\eta}, \quad (28)$$

$$g_1 = A_9 e^{-m_5\eta} + A_6 e^{-P_1\eta} + A_7 e^{-m_2\eta} + A_8 e^{-m_4\eta} \quad (29)$$

$$h_{0=} e^{-P_1\eta} \quad (30)$$

$$h_1 = (1 - A_5)e^{-m_4\eta} + A_5 e^{-P_1\eta} \quad (31)$$

$$u(y,t) = (1 + B_4 e^{-m_6\eta} - A_3 e^{-m_2 y} - A_2 e^{-P_1\eta}) + \varepsilon e^{nt}(1 + B_5 e^{-m_3\eta} + A_4 e^{-m_6\eta} - A_{10} e^{-m_2\eta} - B_1 e^{-P_1\eta} - B_2 e^{-m_5\eta} - B_3 e^{-m_4\eta}) \quad (32)$$

$$\theta(y,t) = (1 - A_1)e^{-m_2\eta} + A_1 e^{-P_1\eta} + \varepsilon e^{nt}(A_9 e^{-m_5\eta} + A_6 e^{-P_1\eta} + A_7 e^{-m_2\eta} + A_8 e^{-m_4\eta}) \quad (33)$$

$$C(y,t) = e^{-P_1\eta} + \varepsilon e^{nt}((1 - A_5)e^{-m_4\eta} + A_5 e^{-P_1\eta}) \quad (34)$$

The Skin-friction coefficient, the Nusselt number and the Sherwood number are important physical parameters for this type of boundary layer flow which are defined and determined as follows:

$$C_{fx} = \frac{\tau_w^*}{\rho U_0 V_0} = \left(\frac{\partial u}{\partial \eta}\right)_{at\ \eta=0} \backslash$$

$$C_{fx} = -B_4 m_6 + A_3 m_2 + A_2 P_1 + \varepsilon e^{nt}(-B_5 m_3 - A_4 m_6 + A_{10} m_2 + B_1 P_1 + B_2 m_5 + B_3 m_4) \quad (35)$$

$$Nu_x = x\frac{\left(\frac{\partial T}{\partial y^*}\right)_{at\ \eta=0}}{(T_w - T_\infty)} \Rightarrow Nu_x/Re_x = \left(\frac{\partial \theta}{\partial \eta}\right)_{at\ \eta=0}$$

$$Nu_x/Re_x = (-m_2(1 - A_1) - A_1 P_1) + \varepsilon e^{nt}(-m_5 A_9 - P_1 A_6 - m_2 A_7 - m_4 A_8) \quad (36)$$

$$Sh_x = x\frac{\left(\frac{\partial C}{\partial \eta^*}\right)_{at\ \eta=0}}{(C_w - C_\infty)} \Rightarrow Sh_x/Re_x = \left(\frac{\partial C}{\partial \eta}\right)_{at\ \eta=0} = -P_1 + \varepsilon e^{nt}(-m_4(1 - A_5) - A_5 P_1) \quad (37)$$

Where $Re_x = \frac{V_0 x}{\nu}$ is the local Reynolds number.

IV. GRAPHS

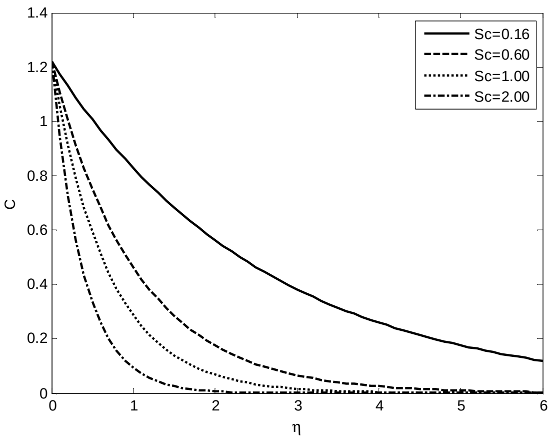

Fig.1 Effects of Sc on Concentration profiles with $\gamma = 0.5, A = 0.5, \varepsilon = 0.2, n = 0.1, t = 1$

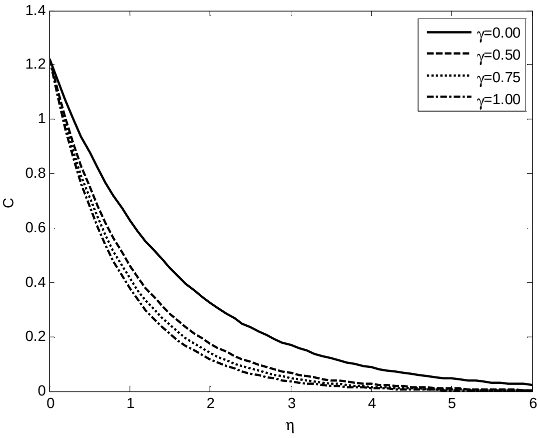

Fig.2 Effects of γ *on Concentration profiles with* $\gamma = 0.5, A = 0.5, \varepsilon = 0.2, n = 0.1, t = 1$

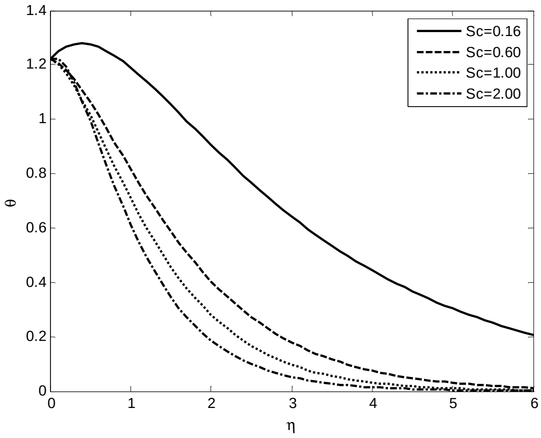

Fig.4 Effects of Sc *on temperature profiles with* $\varepsilon = 0.2, n = 0.1, \emptyset = 1, Pr = 0.7, A = 0.5, Gr_T = 4,$ $Gr_C = 2, t = 1, Q_1 = 2, Du = 2, \gamma = 0.5$

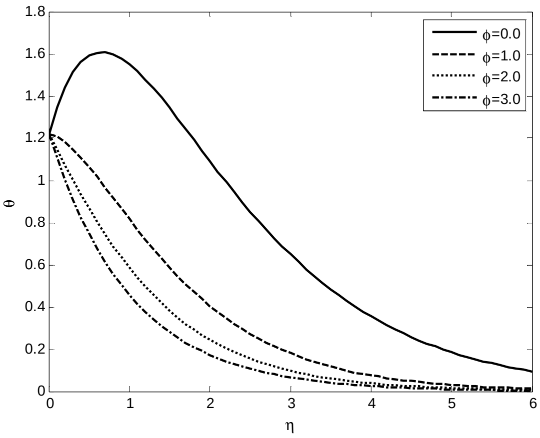

Fig.3 Effects of $\emptyset$ *on temperature profiles with* $Sc = 0.60, Pr = 0.7, \gamma = 0.5, A = 0.5, \varepsilon = 0.2, n = 0.1$ $, t = 1, Gr_T = 4, Gr_C = 2, Q_1 = 2, Du = 0.5$

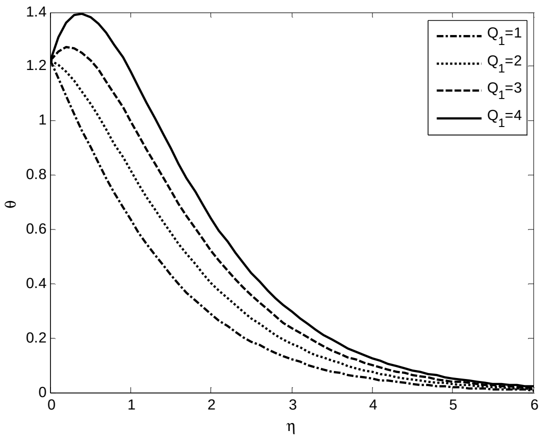

Fig.5 Effects of Q_1 *on temperature profiles with* $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Pr = 0.7, A = 0.5,$ $Gr_T = 4, Gr_C = 2, t = 1, Du = 0.5, \gamma = 0.5$

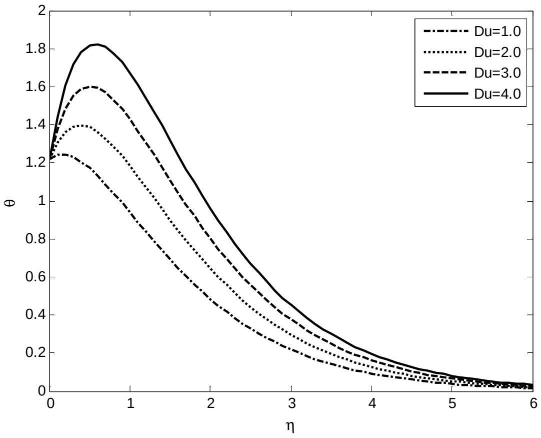

Fig.6 Effects of Du on temperature profiles with $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Pr = 0.7, A = 0.5, Gr_T = 4, Gr_C = 2, t = 1, Q_1 = 2, \gamma = 0.5$

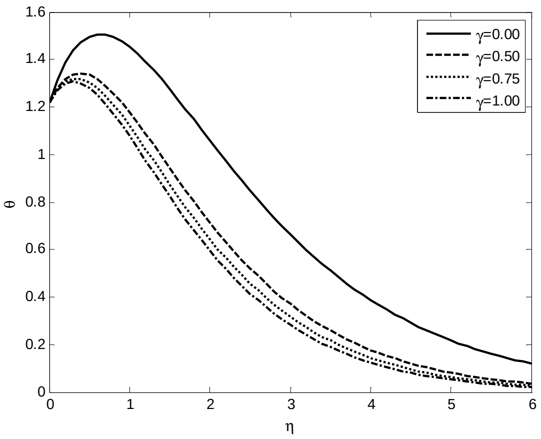

Fig.7 Effects of γ on temperature profiles with $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 0.3, Pr = 0.7, A = 0.5, Gr_T = 4, Gr_C = 2, t = 1, Q_1 = 2, D = 0.5$

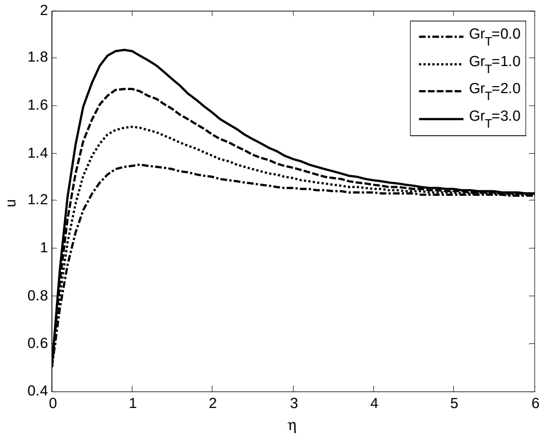

Fig.8 Effects of Gr_T on velocity profiles with $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_C = 2, t = 1, Q_1 = 2, \gamma = 0.5, Du = 0.5, M = 2, K = 0.5$

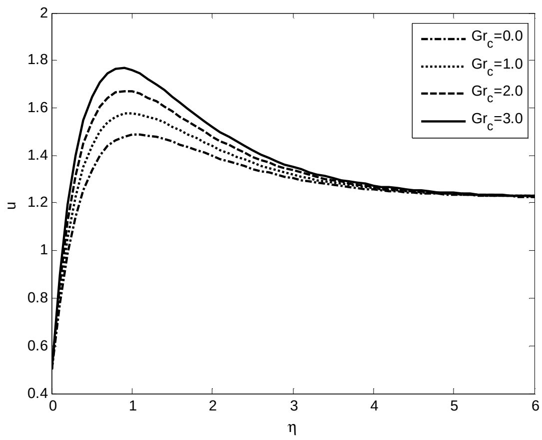

Fig.9 Effects of Gr_c on velocity profiles with $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_T = 2, t = 1, Q_1 = 2, \gamma = 0.5, Du = 0.5, M = 2, K = 0.5$

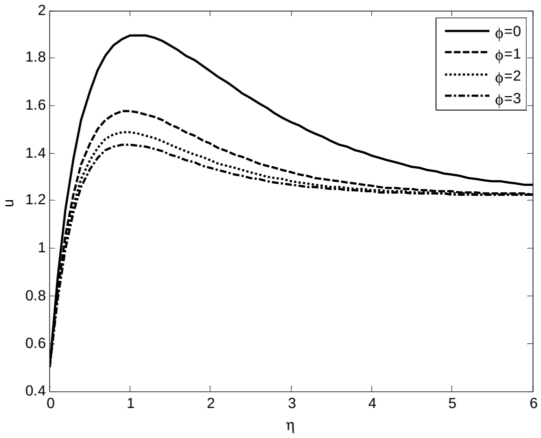

Fig.10 Effects of $\emptyset$ *on velocity profiles with* $Sc = 0.60, \varepsilon = 0.2, n = 0.1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_T = 2, Gr_C = 2, t = 1, Q_1 = 2, \gamma = 0.5, Du = 0.5, M = 2, K = 0.5$

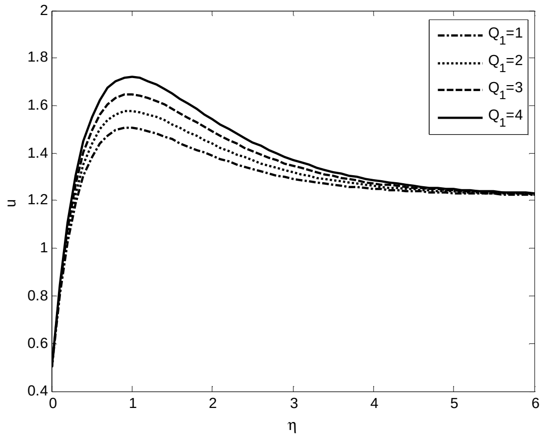

Fig.12 Effects of Q_1 *on velocity profiles with* $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_T = 2, Gr_C = 2, t = 1, Du = 0.5, M = 2, K = 0.5$

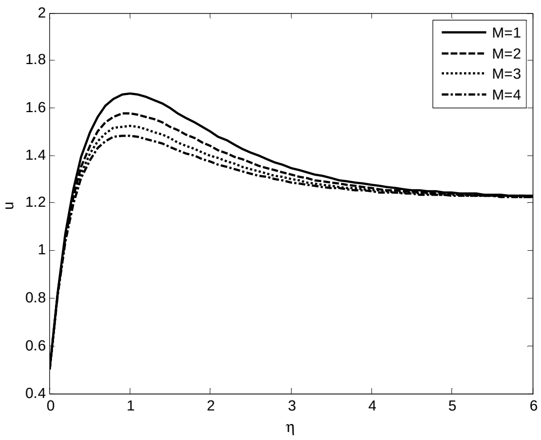

Fig.11 Effects of M *on velocity profiles with* $\varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_T = 2, Gr_C = 2, t = 1, Q_1 = 2, Du = 0.5, K = 0.5$

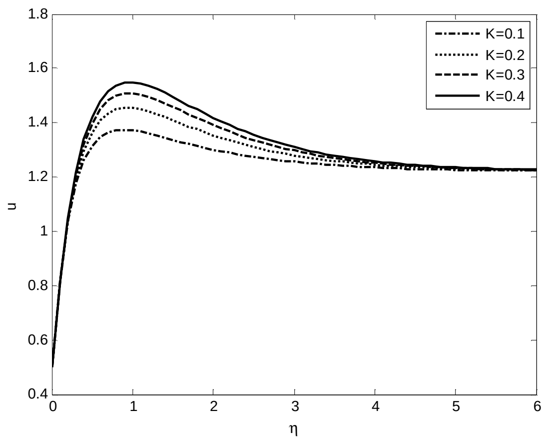

Fig.13 Effects of K *on velocity profiles with* $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_T = 2, Gr_C = 2, t = 1, Q_1 = 2, Du = 0.5, M = 2$

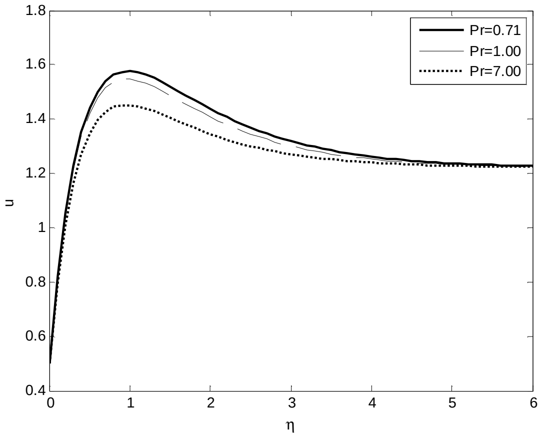

Fig.14 Effects of Pr on velocity profiles with $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, A = 0.5, Gr_T = 2, Gr_C = 2, t = 1, Q_1 = 2, Du = 0.5, M = 2, K = 0.5$

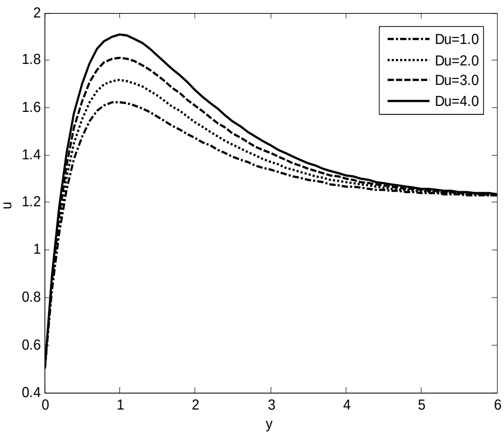

Fig.15 Effects of Du on velocity profiles with $Sc = 0.60, \varepsilon = 0.2, n = 0.1, \emptyset = 1, Up = 0.5, Pr = 0.7, A = 0.5, Gr_T = 2, Gr_C = 2, t = 1, Q_1 = 2, M = 2, K = 0.5$

V. RESULTS AND DISCUSSION

Numerical evaluation of the analytical results reported in the previous section was performed and a representative set of results is reported graphically in Figs. 1–15. These results are obtained to illustrate the influence of the Diffusion thermo parameter (Du) the chemical reaction parameter γ the absorption radiation parameter Q_1, the Schmidt number Sc the heat source coefficient $\emptyset$, the magnetic field parameter M and porous permeability parameter $\emptyset_1$ on the velocity, temperature and the concentration profiles, while the values of the physical parameters are fixed at real constants, A = 0.5, $\varepsilon = 0.2$, the frequency of oscillations n = 0.1, Prandtl number Pr = 0.7 and t = 1.0.

Fig.1 shows that species concentration profiles for different values of Schmidt number Sc. It is clear that the concentration boundary layer thickness decreases with Sc, concentration decreases exponentially and attains free stream condition for large values of Sc.

Fig.2 illustrate the concentration profiles for different values of chemical reaction γ. From this figure, it is observed that the concentration with increasing values of γ.

The temperature profiles for different values of heat absorption parameter are depicted in fig.3. It is noticed that the temperature decreases significantly with the increasing values of $\emptyset$, because when heat is absorbed, the buoyancy force decreases the temperature profiles.

Fig.4 represents the decreases in temperature profiles when the Schmidt number Sc is increases. Also we observe that for low values of Sc (0.16) the temperature is very high comparing with higher values Sc (2.0).

It is seen from fig.5 that an increasing by radiation parameter Q_1 causes to increase the fluid temperature, and hence the maximum peak value is attained at the near the porous plate.

Fig.6 has been plotted to depict the temperature profiles against y for different values of Du and hence the thermal buoyancy layer thickness can be increases with Du. It is clear that the temperature increases with increasing values of Du.

From fig.7, it is appear that the temperature profiles decreases as γ increases. The effect of chemical reaction parameter is to increase the thermal boundary layer.

Velocity distribution for various values Gr_T and solutal buoyancy force parameter Gr_C are plotted in fig.8 and fig.9. As seen from this figures that the maximum peak value is observed in the absence of buoyancy force, this is due to fact that buoyancy force enhances fluid velocity and increase the buoyancy layer thickness with increase in the values of Gr_T and Gr_C.

Fig.10 represents the decrease in fluid velocity when the heat absorption parameter $\emptyset$ is increased, it is clear that the hydromagnetic boundary layer decreases as the heat absorption effect increase also observed that in the absence of heat absorption the velocity attains maximum peak value.

The effect of magnetic field parameter M on velocity is shown in fig.11. This figure shows that the velocity decreases with increasing values of M and hence the velocity decreases considerably for large large values of M.

Fig.12 displays the velocity profiles for different values of radiation parameter Q_1. From this figure it is obvious that the velocity increases as Q_1 increases and the velocity starts from minimum value of zero at the surface and increases till attain the peak value.

The influence of the permeability parameter K on velocity is shown in fig.13, as seen from this figure that maximum peak value attains for $K = 0.4$ and minimum peak value is observed for $K = 0.1$, also it is clear that the velocity increases significantly with the increasing values of K.

Fig.14 illustrates the velocity profiles for various values of prandtl number Pr. From this figure it is obvious that the velocity decreases for different fluids and hence the effect is significant for large values of prandtl number $Pr = 7.0\ (water)$.

Fig.15 illustrates the effect of Dufour on velocity, from this figure it is clear the velocity reaches the maximum peak value at near the boundary surface and it reaches the free stream condition far away from the plate, also observed that on introducing the Dufour number the velocity reaches maximum value

Gr_C	C_f	Nu_x/Re_x	Sh_x/Re_x
0	3.1712	-0.2485	-1.1864
1	3.6593	-0.2485	-1.1864
2	4.1474	-0.2485	-1.1864
3	4.6355	-0.2485	-1.1864
4	5.1236	-0.2485	-1.1864

Table:1 :Numerical values of Solutal Grashof number Gr_C on C_f, Nu_x/Re_x, Sh_x/Re_x for the reference values $Gr_T = 2, t = 1, Sc = 0.6, Q_1 = 2, \gamma = 0.5, Du = 0.5$.

$\emptyset$	C_f	Nu_x/Re_x	Sh_x/Re_x
0	4.2544	1.1895	-1.1864
1	3.6593	-0.2485	-1.1864
2	3.4599	-0.8891	-1.1864
3	3.3429	-1.3408	-1.1864

Table:2 : Numerical values of $\emptyset$ on C_{fx}, Nu_x/Re_x, Sh_x/Re_x for the reference values of $Gr_C = 1, Gr_T = 2, t = 1, Sc = 0.6, Q_1 = 2, \gamma = 0.5, Du = 0.5$

Sc	C_f	Nu_x/Re_x	Sh_x/Re_x
0.16	4.0959	0.2773	-0.4731
0.60	3.6593	-0.2485	-1.1864
1.0	3.5107	-0.3329	-1.7648
2.0	3.3573	-0.1633	-3.1473

Table:3 : Numerical values of Sc on C_{fx}, Nu_x/Re_x, Sh_x/Re_x for the reference values of $Gr_C = 1, Gr_T = 2, t = 1, Q_1 = 2, \gamma = 0.5, Du = 0.5.$

The effects of Solutal Grashof number Gr_C , the heat absorption coefficient $\emptyset$ and the Schmidt number Sc on the skin-friction coefficientC_f, Nusselt number and Sherwood number respectively are presented in tables1-3. From this tables it is seen that the effect of $Gr_C$is to increase the skin-friction coefficientC_f, but the effects of $\emptyset$ and Sc are to decrease the skin-friction coefficient where as no effect of Gr_C is observed on nusselt number and Sherwood number (see table-1). Also no effect of $\emptyset$ is seen on Sherwood number (see Table-2). The effect of $\emptyset$ and Sc is to decrease the nusselt number as seen from tables-2 and 3.Further it is found from table-3 that Sherwood number decreases with increase in Schmidt number Sc

CONCLUSIONS

In this paper we have studied the Diffusion-thermo and radiation absorption effects on an unsteady MHD free convective heat and mass transfer flow past a semi-infinite moving plate. From the present investigation the following conclusions can be drawn.

1. There is a considerable effect of heat absorption parameter Q on the velocity.

2. It is found that on introducing the generative chemical reaction species concentration and
Temperatures are decreases significantly.

3. The fluid temperature can be reduced increased the Dufour numberDu.

4. The effect of Sc on Sherwood number is very significant.

APPENDIX

$$N = \left(M + \frac{1}{K}\right), \quad P_1 = \frac{Sc+\sqrt{(Sc^2+4Sc\gamma)}}{2},$$

$$m_2 = \frac{Pr+\sqrt{Pr^2+4\emptyset Pr}}{2}, m_3 = \frac{1+\sqrt{1+4(N+n)}}{2}$$

$$m_4 = \frac{Sc+\sqrt{Sc^2+4Sc(\gamma+n)}}{2}, m_5 = \frac{Pr+\sqrt{Pr^2+4\mathrm{Pr}\,(\emptyset+n)}}{2}$$

$$m_6 = \frac{1+\sqrt{1+4N}}{2}, \quad A_1 = \frac{(-PrQ_1 - DuP1^2)}{(P_1^2-PrP_1-\emptyset Pr)},$$

$$A_2 = \frac{(Gr_T A_1 + Gr_c)}{(P_1^2-P_1-N)}, A_3 = \frac{Gr_T(1-A_1)}{(m_2^2-m_2-N)}$$

$$A_4 = \frac{Am_6B_4}{(m_6^2-m_6-(N+n))}, \quad A_5 = \frac{AScP_1}{(P_1^2-P_1Sc-Sc(\gamma+n))}$$

$$A_6 = \frac{(-PrQ_1A_5 - DuA_5P_1^2 + PrP_1AA_1)}{(P_1^2-PrP_1-\mathrm{Pr}\,(\emptyset+n))},$$

$$A_7 = \frac{(PrAm_2 - PrAA_1m_2)}{(m_2^2-m_2Pr-\mathrm{Pr}\,(\emptyset+n))}$$

$$A_8 = \frac{(-PrQ_1 + PrA_5Q_1 - Dum_4^2 + DuA_5m_4^2)}{(m_4^2-m_4Pr-\mathrm{Pr}\,(\emptyset+n))},$$

$$A_9 = 1 - (A_6 + A_7 + A_8),$$

$$A_{10} = \frac{AA_3m_2 + cA_7}{(m_2^2-m_2-(N+n))}, \quad B_1 = \frac{AA_2P_1 + Gr_TA_6 + Gr_cA_5}{P_1^2-P_1-(N+n)},$$

$$B_2 = \frac{Gr_TA_9}{m_5^2-m_5-(N+n)},$$

$$B_3 = \frac{Gr_TA_8 + Gr_c(1-A_5)}{m_4^2-m_4-(N+n)},$$

$$B_4 = \left(U_p - 1 + A_2 + A_3\right),$$

$$B_5 = -(1 + A_4 - A_{10} - B_1 - B_2 - B_3)$$

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