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UNSTEADY MHD FREE CONVECTIVE HEAT AND MASS TRANSFER FLOW PAST A SEMI-INFINITE VERTICAL PERMEABLE MOVING PLATE WITH HEAT ABSORPTION, RADIATION, CHEMICAL REACTION AND SORET EFFECTS

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ABSTRACT

We consider a problem of two dimensional unsteady laminar boundary-layer flow of a viscous, incompressible, electrically conducting and heat-absorbing fluid along a semi-infinite vertical permeable moving plate with a uniform transverse magnetic field in presence of radiation, chemical reaction, soret effect and thermal diffusion effects. The plate is assumed to move with a constant velocity in the direction of fluid flow while the free stream velocity is assumed to follow the exponentially increasing small perturbation law. Time-dependent wall suction is assumed to occur at the permeable surface. The dimensionless governing equations for this investigation are solved analytically using 2-term harmonic and non-harmonic functions. The transformation of governing partial differential equations into ordinary differential equations and numerical evaluation of the analytical results are performed. Some graphical results for the velocity, temperature and concentration distributions within the boundary layer and tabulated results for the skin-friction, the Nusselt number and the Sherwood number are presented and discussed.

KEY WORDS: *MHD, Free convection, heat and Mass transfer flow, radiation, heat absorption, chemical reaction, thermal diffusivity, Soret effect.*

I. INTRODUCTION

Free convection arises in the fluid when temperature changes cause density variation leading to buoyancy forces acting on the fluid elements. The study of heat and mass transfer to chemical reacting MHD free convection flow with radiation effects on a vertical plate has received a growing interest during the last decades. Accurate knowledge of the overall convection heat transfer has vital importance in several fields such as thermal insulation, drying of porous solid materials, heat exchanges, stream pipes, water heaters, refrigerators, electrical conductors and , industrial, geophysical and astrophysical applications, such as polymer production, manufacturing of ceramic, packed-bed catalytic reactors, food processing, cooling of nuclear reactors, enhanced oil recovery, underground energy transport, magnetized plasma flow, high speed plasma wind, cosmic jets and stellar system. For some industrial applications such as glass production, furnace design, propulsion systems, plasma physics and spacecraft re-entry aerothermodynamics which operate at higher temperatures and radiation effect can also be significant. A clear understanding of the nature of interaction between thermal and concentration buoyancies is necessary. Consolidated effects of Heat and Mass Transfer problems are of importance in many chemical formulations and reactive chemicals. Therefore, considerable attention had been paid in recent years to study the influence of the participating parameters on the velocity field. More such engineering application can be seeing in electrical power generation systems when the electrical energy is extracted directly from a moving conducting fluid. Further, the diffusion and chemical reaction in the above said applications occurs simultaneously. When diffusion is much faster than the chemical reaction, chemical factors influence the chemical reaction rate. The study of heat generation or absorption influences significantly in moving fluids. Therefore, such a pilot studies is essential while the chemical reaction is either exothermic or endothermic.

Chamkha (2004) [1] studied the unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption. Natural convection boundary layer flow along a heated vertical plate in a Stratified environment was studied by Henkes et al. (1989) [2]. The effects of chemical reaction, thermophoresis and variable viscosity on a study of hydro magnetic flow with heat and mass transfer over a flat plate in the presence of heat generation/absorption was examined by Seddeek [3]. Takhar et al. (1996) [4] investigated the radiation effects on MHD free convection flow of a radiating gas past a semi-infinite vertical plate. The unsteady hydro magnetic free convection flow with radiative transfer in a rotating fluid was discussed by Bestman and Adjepong (1998) [5]. Muthucumaraswamy and Ganesan (2002) [6] studied the diffusion and first-order chemical reaction on impulsively started infinite vertical plate with variable temperature. Badruddin et al. (2005) [7] analyzed the free convection and radiation characteristics for a vertical plate embedded in a porous medium. Abd-ElAziz(2006) [8] investigated the thermal radiation effects on a magneto hydrodynamic mixed convection flow of a micro polar fluid past a continuously moving semi-infinite plate for high temperature differences. The influence of chemical reaction on transient MHD free convection over a moving vertical plate was discussed by Al-Odat and Al-Azab(2007) [9]. The heat and mass transfer of unsteady MHD natural convection flow of a rotating fluid past a vertical porous plate in the presence of radiative heat transfer was analyzed by Mbeledogu and Ogulu (2007) [10]. Orhan and Ahmet(2008) [11] presented radiation effects on MHD mixed convection flow about a permeable vertical plate. The radiation effects on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium was studied by Ramachandra Prasad et al [12]. Madhusudhana Rao B, Viswanatha reddy G and Raju M.C [13] studied MHD transient free convection and chemically reactive flow past a porous vertical plate with radiation and temperature gradient dependent heat source in slip flow regime. The First ordered chemical reaction in the neighborhood of a horizontal plate has been examined by Chambre and Young [14]. Later, the effect of chemical reaction and radiation absorption on free convection flow through porous medium with variable suction in the presence of uniform magnetic field was investigated by Sudheer Babu and Satyanarayana [15]. Recently, the case of unsteady MHD convective heat and mass transfer in a boundary layer slip flow part a vertical permeable with thermal radiation and chemical reaction was examined by Dulal pal et al [16]. The mathematical analysis of time-varying 2-dimensional natural convective flow of an incompressible, electrically conducting fluid along an infinite vertical porous plate embedded in a porous medium was studied by Rapits [17]. Gribben [18] studied the boundary layer flow over a semi-infinite plate with an aligned magnetic field in the presence of a pressure gradient and obtained the solutions for large and small magnetic prandtl number, using the method of matched asymptotic expansion.

The object of the present paper is to study the Unsteady MHD free convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate with heat absorption, radiation, chemical reaction, soret effect and thermal diffusivity. In obtaining the solution, the terms regarding radiation effect, temperature gradient dependent heat source are taken into account of energy equation and chemical reaction parameter, soret effect and thermal diffusion effect are taken into account of concentration equation. Most of the earlier works are assumed that the semi-infinite plate is at rest. But in the present project the plate is embedded in a uniform porous medium and moves with a constant velocity in the direction of flow and in the presence of a transverse magnetic field. The Permeability of the porous medium and the suction velocity are considered to be as exponentially decreasing function of time.

II. MATHEMATICAL ANALYSIS

We consider a two-dimensional unsteady free convection flow of an incompressible viscous fluid past an infinite vertical porous plate. In rectangular Cartesian coordinate system, we take x-axis along the plate in the direction of flow and y-axis normal to it. Further the flow is considered in presence of temperature gradient dependent heat source and effect of radiation and chemical reaction.

In the analysis the magnetic Reynolds number is taken to be small so that the induced magnetic field is neglected. Likewise for small velocity the viscous dissipation and Darcy's dissipation are neglected. The flow in the medium is entirely due to buoyancy force caused by temperature difference between the porous plate and the fluid. Introduce the boundary layer and Boussineq's approximations. Under the above assumptions, the equations governing the conservation of mass (continuity), momentum, energy and concentration can be written as follows.

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

$$\frac{\partial u^1}{\partial t^1} + v^1\frac{\partial u^1}{\partial y^1} = \frac{1}{\rho}\frac{\partial p^1}{\partial x^1} + g\beta_T(T^1 - T^1_\infty) + g\beta_c(C^1 - C^1_\infty) + \upsilon\frac{\partial^2 u^1}{\partial y^{1^2}} - \frac{\upsilon}{k^1}u^1 - \frac{\sigma B_0{}^2}{\rho}u^1 \tag{2}$$

$$\frac{\partial T^1}{\partial t^1} + v^1\frac{\partial T^1}{\partial y^1} = \alpha\frac{\partial^2 T^1}{\partial y^{1^2}} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^1} - \frac{Q_0}{\rho C_p}(T^1 - T^1_\infty) \tag{3}$$

$$\frac{\partial C^1}{\partial t^1} + v^1\frac{\partial C^1}{\partial y^1} = D\frac{\partial^2 C^1}{\partial y^{1^2}} - R(C^1 - C^1_\infty) + D_1\frac{\partial^2 T^1}{\partial y^{1^2}} \tag{4}$$

The boundary conditions relevant to the problem are

$$u^1 = U^1_p, \quad T^1 = T^1_w + \varepsilon(T^1_w - T^1_w)e^{n^1t^1}, \quad C^1 = C^1_w + \varepsilon(C^1_w - C^1_w)e^{n^1t^1} \quad \text{at} \quad y^1 = 0$$

$$u^1 \to U^1_\infty = U_0(1 + \varepsilon e^{n^1t^1}), \quad T^1 \to T^1_\infty, \quad C^1 \to C^1_\infty \quad \text{as} \quad y^1 \to \infty \tag{5}$$

Where u^1 and v^1 are the components of velocity along x-axis and y-axis directions, t is the time, g is the acceleration due to gravity, β_T and β_c are the coefficients of thermal expansion and concentration expansion respectively, υ is the kinematic viscosity, k^1 is the permeability of the porous medium, ρ is the density of the fluid, σ is the electrical conductivity of the fluid , B_0 is the uniform magnetic field, T^1 is the temperature, α is the thermal diffusivity, C_p is the specific heat at constant pressure, q_r is the radioactive heat flux, Q_0 is the heat source, T^1_w is the temperature of the wall as well as the temperature of the fluid at the plate, T^1_∞ is the temperature of the fluid far away from the plate, C^1 is the concentration, D is the molecular diffusivity, C^1_∞ is the concentration of the wall as well as the concentration of the fluid at the plate. U^1_p is the wall dimensional velocity, U^1_∞ is the free stream dimensional velocity, U_0 and n^1 are constants, R is chemical reaction parameter and D_1 is thermal diffusivity. The equation of continuity (1) that v^1 is either a constant or some function of time, hence we assume that

$$v^1 = -V_0(1 + \varepsilon A e^{n^1t^1}) \tag{6}$$

Where V_0>0 is the suction velocity at the plate and n^1 is a positive constant, here the negative sign indicates that the suction velocity acts towards the plate, A is a real positive constant and ε<<<1, εA<<<1. Outer side of the boundary layer, the equation (2) gives that

$$-\frac{1}{\rho}\frac{\partial p^1}{\partial x^1} = \frac{dU^1_\infty}{dt^1} + \frac{\upsilon}{k^1}U^1_\infty + \frac{\sigma B_0{}^2}{\rho}U^1_\infty \tag{7}$$

Consider the fluid which is optically thin with a relatively low density and radioactive heat flux is given by Ede [18] in the following;

$$\frac{\partial q_r}{\partial y^1} = 4T(T_w^1 - T_\infty^1)I^1 \tag{8}$$

Where $I^1 = \int_0^\infty K_\lambda \frac{\partial e_\lambda}{\partial T_w^1} d\lambda$, K_λ is the absorption coefficient at the plate and e_λ is plank's function.

III. METHOD OF SOLUTION

We employ the non-dimensional quantities given below;

$$u = \frac{u^1}{U_0}, \quad v = \frac{v^1}{V_0} \quad y = \frac{y^1 V_0}{\upsilon}, \quad U_\infty = \frac{U_\infty^1}{U_0}, \quad U_p = \frac{U_p^1}{U_0}, \quad n = \frac{\upsilon n^1}{V_0^{\,2}}, \quad t = \frac{V_0^{\,2} t^1}{\upsilon},$$

$$T = \frac{T^1 - T_\infty^1}{T_w^1 - T_\infty^1}, \qquad C = \frac{C^1 - C_\infty^1}{C_w^1 - C_\infty^1}, \qquad K = \frac{V_0^{\,2} K^1}{\upsilon^2} \tag{9}$$

In presence of the above discussed equations (6)--(9), the general equations (2), (3), (4) remain;

$$\frac{\partial u}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial u}{\partial y} = G_T T + G_c C + \frac{dU_\infty}{dt} + \frac{\partial^2 u}{\partial y^2} + N(U_\infty - u) \tag{10}$$

$$\frac{\partial T}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial T}{\partial y} = \frac{1}{P_r}\frac{\partial^2 T}{\partial y^2} - (F + H)T \tag{11}$$

$$\frac{\partial C}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial C}{\partial y} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} - K_c C + S_0 \frac{\partial^2 T}{\partial y^2} \tag{12}$$

Where,

$$G_T = \frac{g\beta_T \upsilon (T_w^1 - T_\infty^1)}{U_0 V_0^{\,2}}, \quad G_c = \frac{g\beta_c \upsilon (C_w^1 - C_\infty^1)}{U_0 V_0^{\,2}}, \quad F = \frac{Q_0 \upsilon}{\rho C_p V_0^{\,2}}, \quad H = \frac{4\upsilon I^1}{\rho C_p V_0^{\,2}},$$

$$P_r = \frac{\upsilon}{\alpha} = \frac{\upsilon \rho C_p}{K},$$

$$N = M + \frac{1}{K}, \quad M = \frac{\upsilon \sigma B_0^{\,2}}{\rho V_0^{\,2}}, \quad S_c = \frac{\upsilon}{D}, \quad K_c = \frac{R\upsilon}{V_0^{\,2}}, \quad S_0 = \frac{D_1}{\upsilon}\left(\frac{T_w^1 - T_\infty^1}{C_w^1 - C_\infty^1}\right)$$

Here G_T is thermal Grashof number, G_c is the solutal Grashof number, F is Radiation parameter, H is Heat source parameter, Pr is Prandtl number, M is magnetic field parameter, K is Permeability of porous medium, Sc is the Schmidit number, Kc is chemical reaction parameter and S_0 is Soret number.

Moreover, the dimensionless grammar of the boundary conditions (5) takes the form;

$$u = U_p, \quad T = 1 + \varepsilon e^{nt}, \quad C = 1 + \varepsilon e^{nt}, \quad \text{at} \quad y^1 = 0$$

$$u \to U_\infty, \quad T \to 0, \quad C \to 0, \quad \text{as} \quad y^1 \to \infty$$

(13)

IV. SOLUTION OF THE PROBLEM

The partial differential equations (10), (11), (12) cannot be solved in closed form. So we solve analytically by converting them into ordinary differential equations in dimension less grammar. Therefore the expressions for velocity, temperature and concentration are represented in the following form.

$$u(y,t) = f_0(y) + \varepsilon e^{nt} f_1(y) + O(\varepsilon^2) \tag{14}$$

$$T(y,t) = g_0(y) + \varepsilon e^{nt} g_1(y) + O(\varepsilon^2) \tag{15}$$

$$C(y,t) = h_0(y) + \varepsilon e^{nt} h_1(y) + O(\varepsilon^2) \tag{16}$$

Substituting above expressions (14)--(16) into the equations (10)--(12), equating the harmonic and non-harmonic terms that is coefficients of $\varepsilon^0, \varepsilon^1$ and neglecting the higher order terms of $O(\varepsilon^2)$, one obtains the following set of ordinary differential equations.

$$f_0^{11}(y) + f_0^1(y) - Nf_0(y) = -N - G_T g_0(y) - G_c h_0(y) \tag{17}$$

$$f_1^{11}(y) + f_1^1(y) - (N+n) f_1(y) = -(N+n) - Af_0^1(y) - G_T g_1(y) - G_c h_1(y) \tag{18}$$

$$g_0^{11}(y) + P_r g_0^1(y) - (F+H) P_r g_0(y) = 0 \tag{19}$$

$$g_1^{11}(y) + P_r g_1^1(y) - [nP_r + (F+H)P_r] g_1(y) = -AP_r g_0^1(y) \tag{20}$$

$$\frac{1}{S_c} h_0^{11}(y) + h_0^1(y) - K_c h_0(y) = -S_0 g_0^{11} \tag{21}$$

$$\frac{1}{S_c} h_1^{11}(y) + h_1^1(y) - (n+K_c) h_1(y) = -Ah_0^1 - S_0 g_1^{11} \tag{22}$$

And the boundary conditions (13) can be taken as,

$$\begin{aligned} &f_0 = U_p, \quad f_1 = 0, \quad g_0 = 1, \quad g_1 = 1, \quad h_0 = 1, \quad h_1 = 1 \quad at \quad y = 0 \\ &f_0 \to 1, \quad f_1 \to 1, \quad g_0 \to 0, \quad g_1 \to 0, \quad h_0 \to 0, \quad h_1 \to 0 \quad as \quad y \to \infty \end{aligned} \tag{23}$$

The equations from (17) to (22) are second order linear ordinary differential equations with constant coefficients. The solutions (that is the mean velocity, temperature, concentration (f_0, g_0, h_0) and the transient state velocity, temperature, concentration (f_1, g_1, h_1)) of these paired equations under the boundary conditions (23) are,

$$h_0(y) = A_3 e^{-m_1 y} + A_4 e^{-m_3 y} \tag{24}$$

$$h_1(y) = A_5 e^{-m_1 y} + A_6 e^{-m_2 y} + A_7 e^{-m_3 y} + A_8 e^{-m_4 y} \tag{25}$$

$$g_0(y) = e^{-m_1 y} \tag{26}$$

$$g_1(y) = A_1 e^{-m_1 y} + A_2 e^{-m_2 y} \tag{27}$$

$$f_0(y) = 1 + A_9 e^{-m_1 y} + A_{10} e^{-m_3 y} + A_{11} e^{-m_5 y} \tag{28}$$

$$f_1(y) = 1 + A_{12} e^{-m_1 y} + A_{13} e^{-m_2 y} + A_{14} e^{-m_3 y} + A_{15} e^{-m_4 y} + A_{16} e^{-m_5 y} + A_{17} e^{-m_6 y} \tag{29}$$

Where the constants are given in the appendix.

In view of the above solutions (24)--(29) and the equations (14)--(16), the velocity distribution u(y, t), the temperature distribution T(y, t) and the concentration distribution C(y, t) in the boundary layer become;

$$u(y,t) = 1 + A_9 e^{-m_1 y} + A_{10} e^{-m_3 y} + A_{11} e^{-m_5 y} + \varepsilon e^{nt}\left(1 + A_{12} e^{-m_1 y} + A_{13} e^{-m_2 y} + A_{14} e^{-m_3 y} + A_{15} e^{-m_4 y} + A_{16} e^{-m_5 y} + A_{17} e^{-m_6 y}\right) \tag{30}$$

$$T(y,t) = e^{-m_1 y} + \varepsilon e^{nt}\left(A_1 e^{-m_1 y} + A_2 e^{-m_2 y}\right) \tag{31}$$

$$C(y,t) = A_3 e^{-m_1 y} + A_4 e^{-m_3 y} + \varepsilon e^{nt}\left(A_5 e^{-m_1 y} + A_6 e^{-m_2 y} + A_7 e^{-m_3 y} + A_8 e^{-m_4 y}\right) \tag{32}$$

Skin friction:

The expression for skin-friction (τ) at the plate is,

$$\begin{aligned} \tau = \left(\frac{du}{dy}\right)_{y=0} &= \left(\frac{df_0}{dy}\right)_{y=0} + \varepsilon e^{nt}\left(\frac{df_1}{dy}\right)_{y=0} \\ &= A_{18} + \varepsilon e^{nt} A_{19} \end{aligned} \tag{33}$$

Nusselt number:

The expression for Nusselt number (N_u) is,

$$N_u = \left(\frac{dT}{dy}\right)_{y=0} = \left(\frac{dg_0}{dy}\right)_{y=0} + \varepsilon e^{nt}\left(\frac{dg_1}{dy}\right)_{y=0}$$

$$= -m_1 + \varepsilon e^{nt} A_{20} \tag{34}$$

Sherwood number:

The expression for the Sherwood number (S_h) is,

$$S_h = \left(\frac{dC}{dy}\right)_{y=0} = \left(\frac{dh_0}{dy}\right)_{y=0} + \varepsilon e^{nt}\left(\frac{dh_1}{dy}\right)_{y=0}$$

$$= A_{21} + \varepsilon e^{nt} A_{22} \tag{35}$$

V. RESULTS AND DISCUSSIONS

To assess the physical depth of the problem, the effects of various parameters like Schimidt number Sc, thermal Grashof number G_T, Magnetic parameter M, Permeability of Porous medium K, Heat source parameter H, Radiation parameter F, Chemical reaction parameter Kc, Mass Grashof number G_c, Soret effect number So and Prandtl number Pr on Velocity distribution, Temperature distribution and Concentration distribution are studied in figures 1-15, while keeping the other parameters as constants. Figure.1&2 show the velocity profiles with the variations in thermal Grashof number G_T and Mass Grashof number G_c, it is observed that the significance of the velocity is maximum near the plate and there after it decreases and reaches to the stationary position at the other side of the plate. As expected velocity increases with an increase in thermal Grashof number G_T and Mass Grashof number G_c. The effects of Radiation parameter F and Heat source parameter H on velocity distribution are represented in figure 3&4. From these figures it is noticed velocity decreases as an increase in radiation parameter and heat source parameter. In figure 5 the effects of Soret number So on velocity is shown. From this figure it is notified that velocity increases as So increases. In figure.6&7 the velocity decrease as Schimidt number Sc and chemical reaction parameter Kc increase. In figure.8 the velocity increases as porous medium parameter K increases. From figure.9, it is observed that the velocity decreases as Magnetic parameter M increases. From the figures.10, 11, 12, it is observed that the Temperature distribution decreases as the prandtl number Pr, radiation parameter F and heat source parameter H increase. In figures.13&14, it is clearly shown that the Concentration profile decrease as the Schimidt number Sc and chemical reaction parameter Kc increase. This result the concentration buoyancy effects decrease yielding a reduction in the fluid velocity. These reductions in the velocity and concentration are accompanied by simultaneous reductions in the velocity and concentration boundary layers shown in the figures. 6 and 13. And finally from the figure.15, the Concentration distribution increases as the Soret effect So increases.

To be realistic, the numerical values of Prandtl number Pr are chosen as Pr=0.71, and Pr=7.00, which correspond to air and water at 20^{o}C respectively. The numerical values of the remaining parameters are chosen arbitrarily.

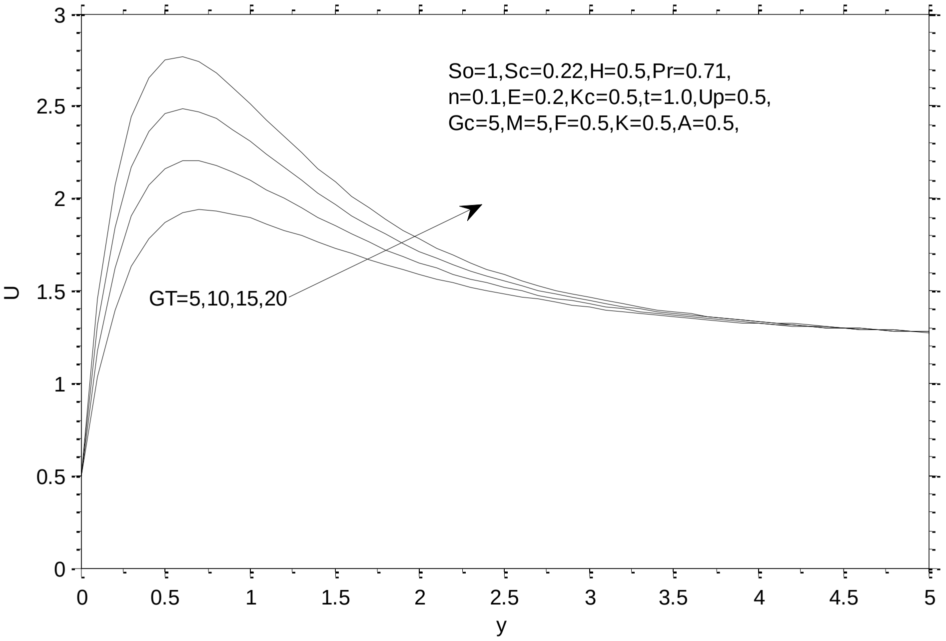

Fig.1; Effects of thermal Grashof number $\mathbf{G_T}$ on Velocity

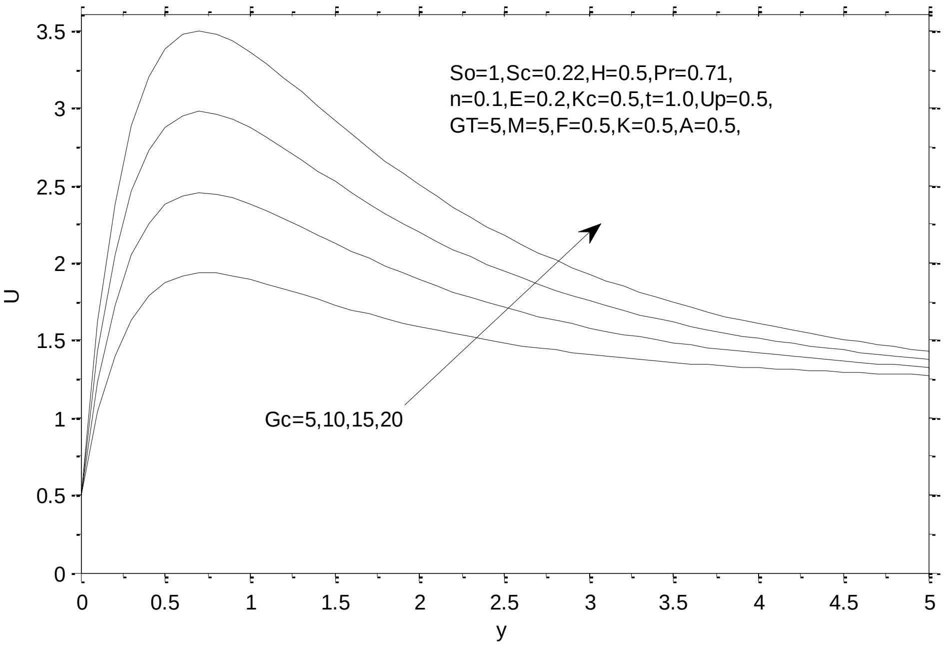

Fig.2; Effects of mass Grashof number **Gc** on Velocity

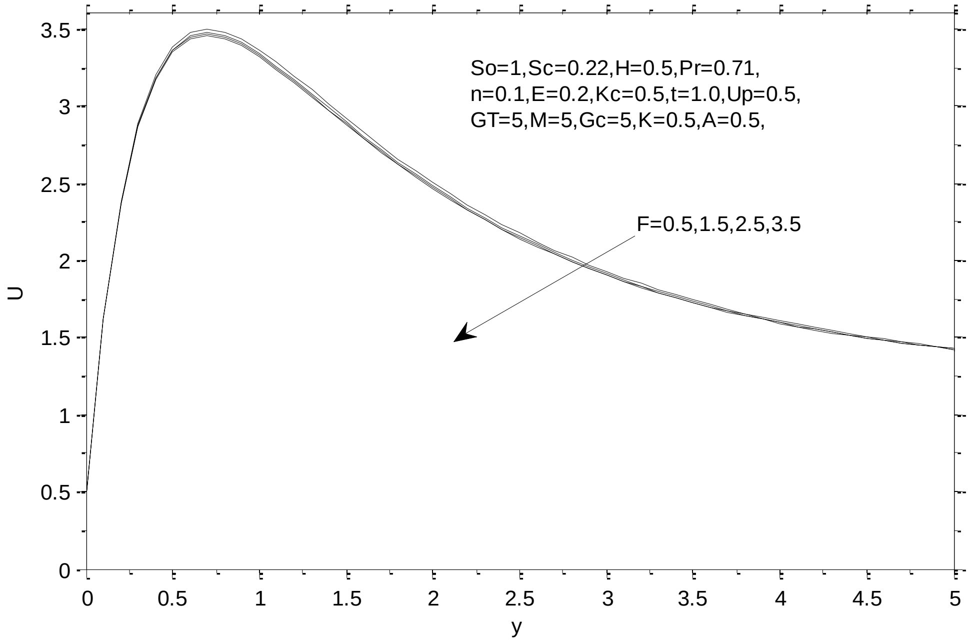

Fig.3; Effects of Radiation parameter **F** on Velocity

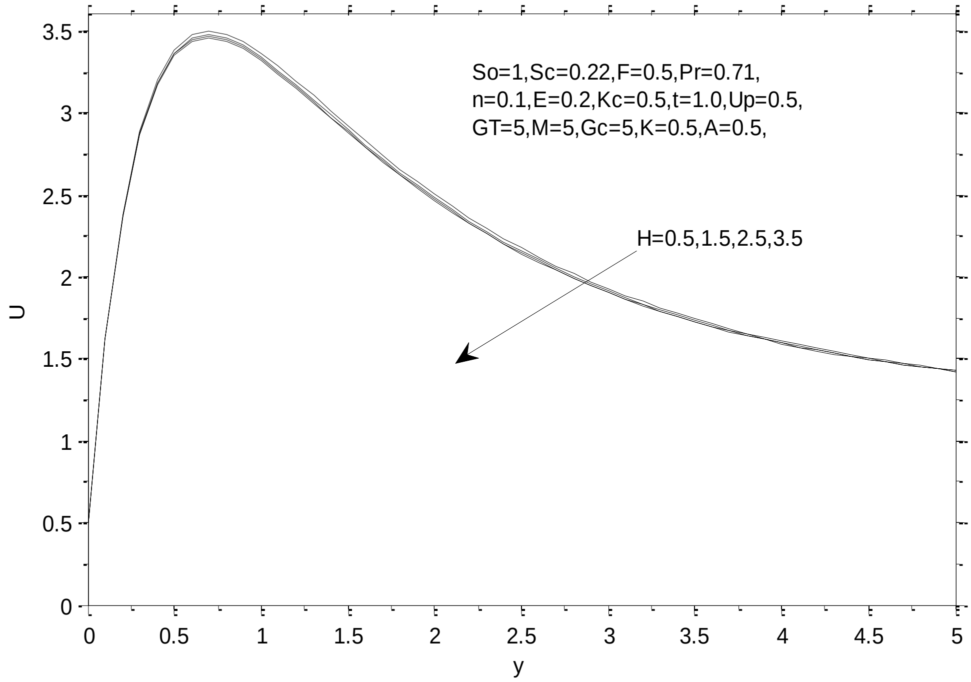

Fig.4; Effects of Heat source parameter **H** on Velocity

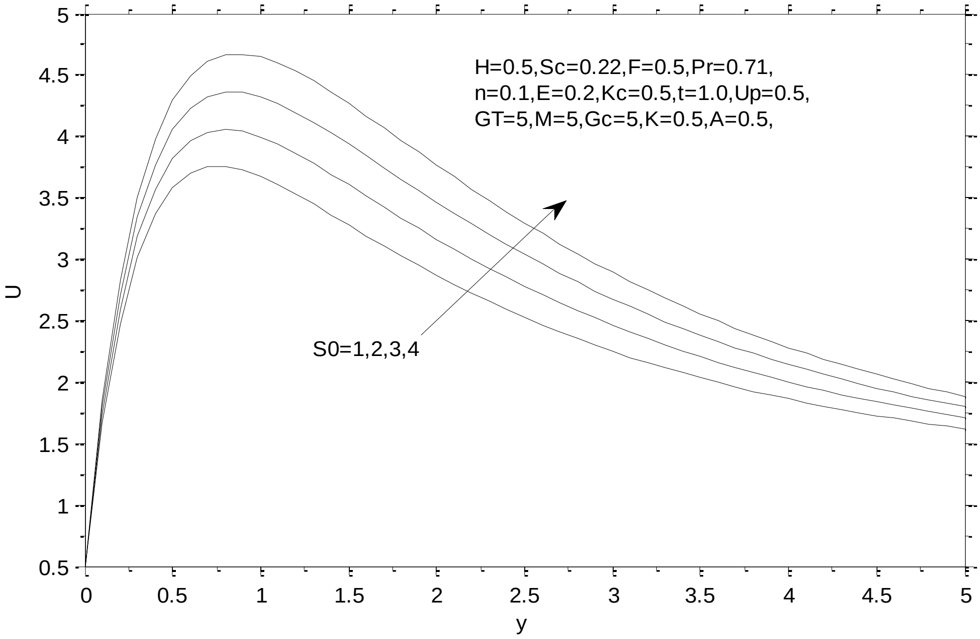

Fig.5; Effects of Soret number **So** on Velocity

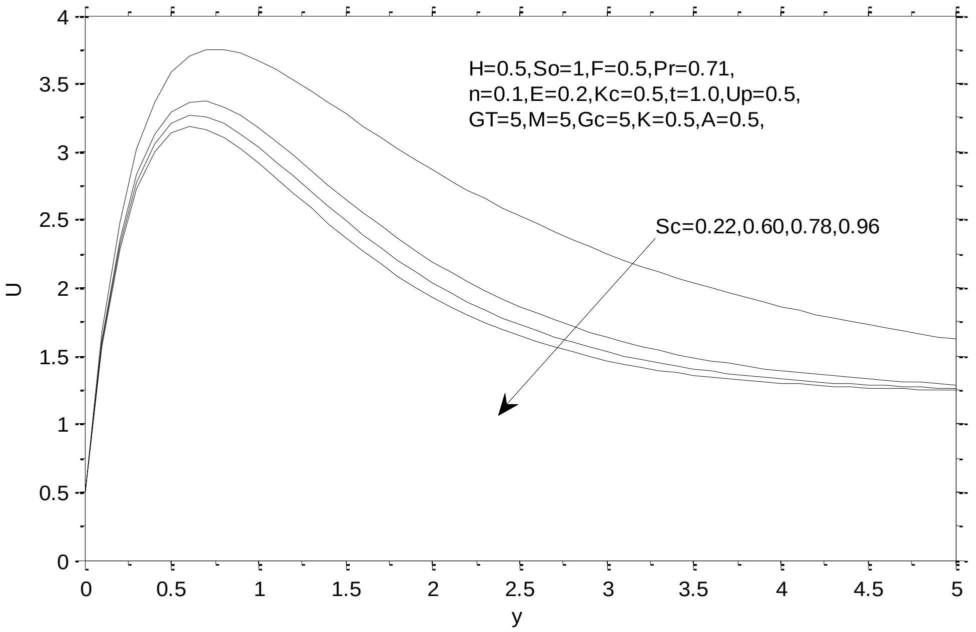

Fig.6; Effects of Schimidt number **Sc** on Velocity

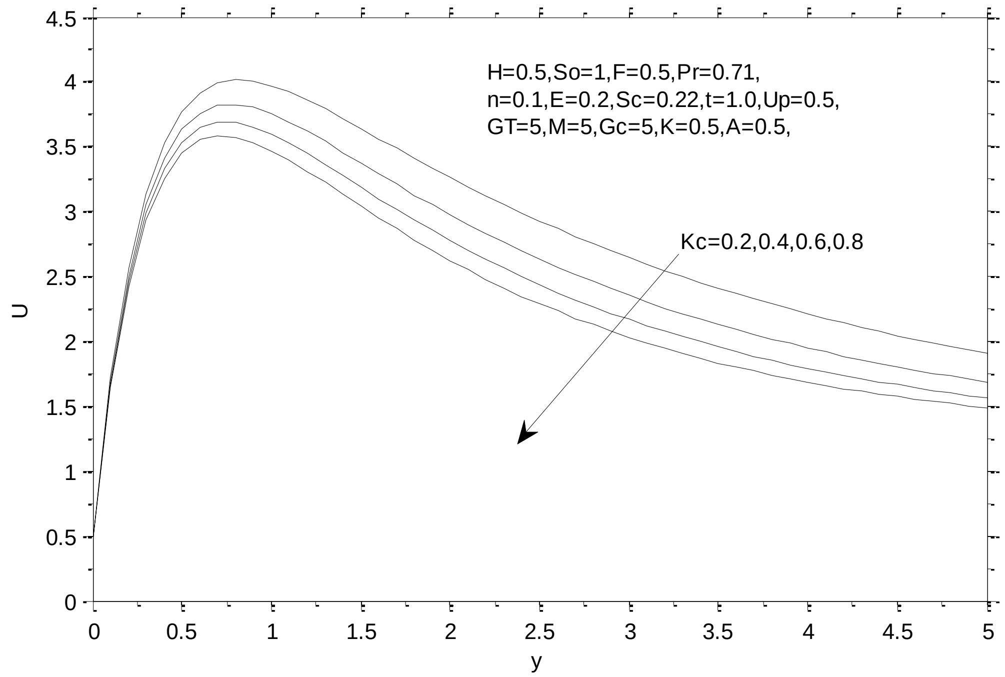

Fig.7; Effects of Chemical reaction parameter **Kc** on Velocity

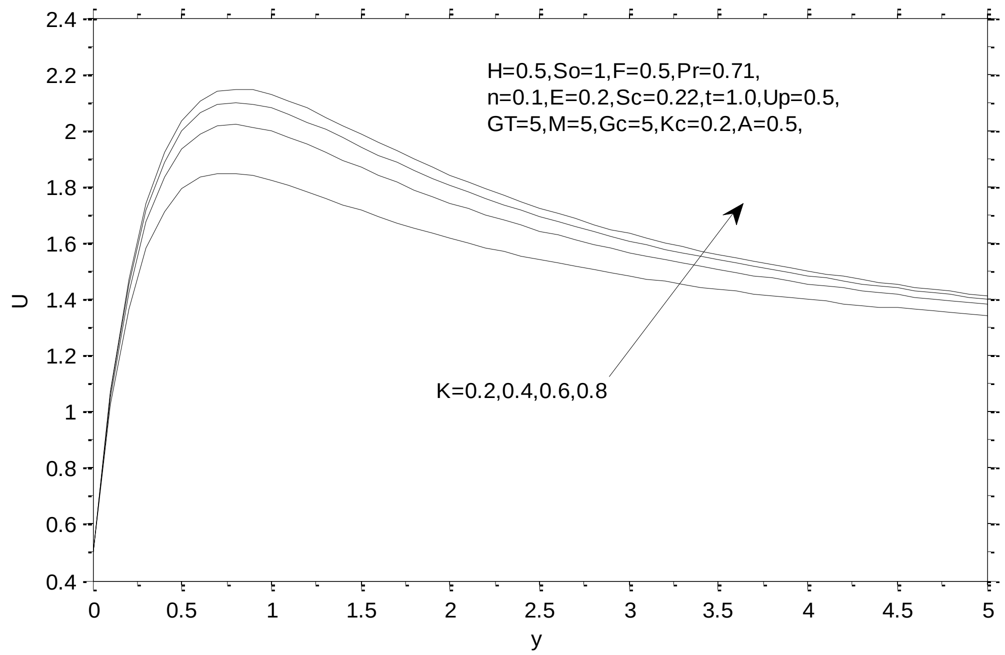

Fig.8; Effects of Porous medium **K** on Velocity

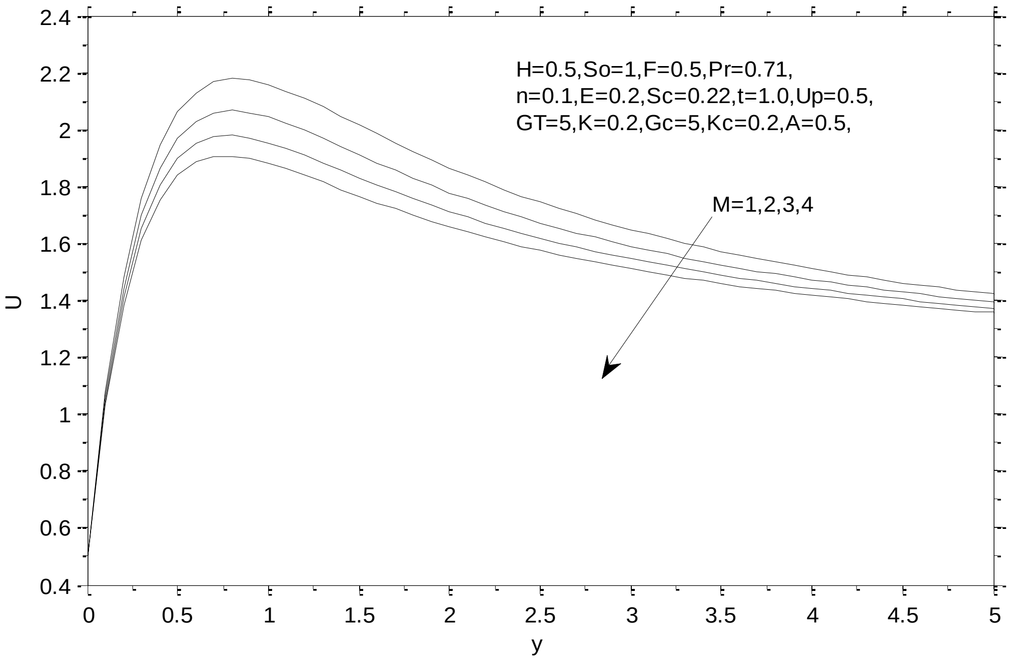

Fig.9; Effects of magnetic parameter **M** on Velocity

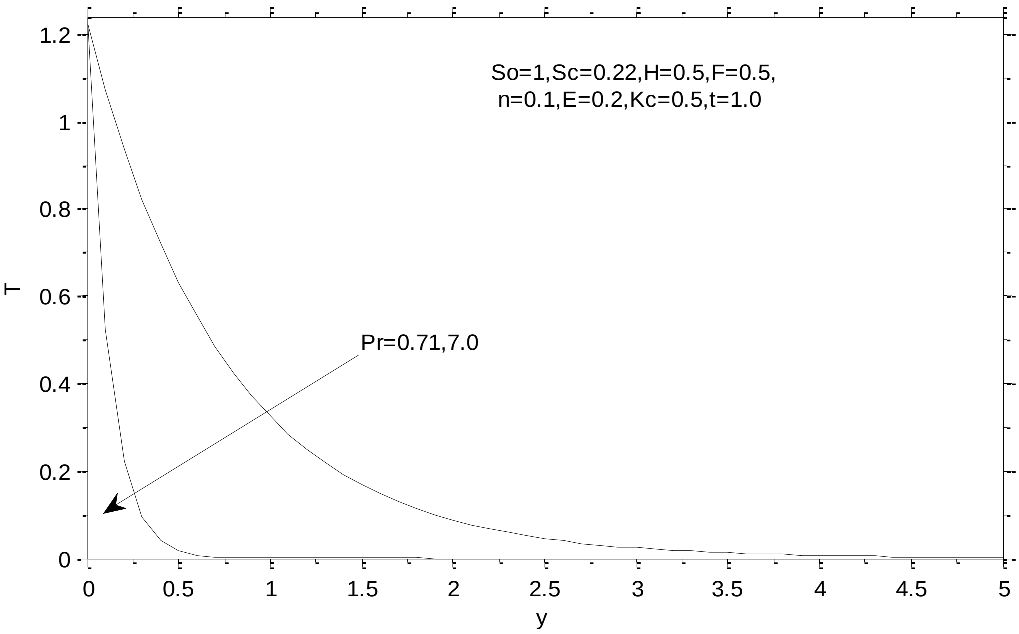

Fig.10; Effects of Prandtl number **Pr** on Temperature

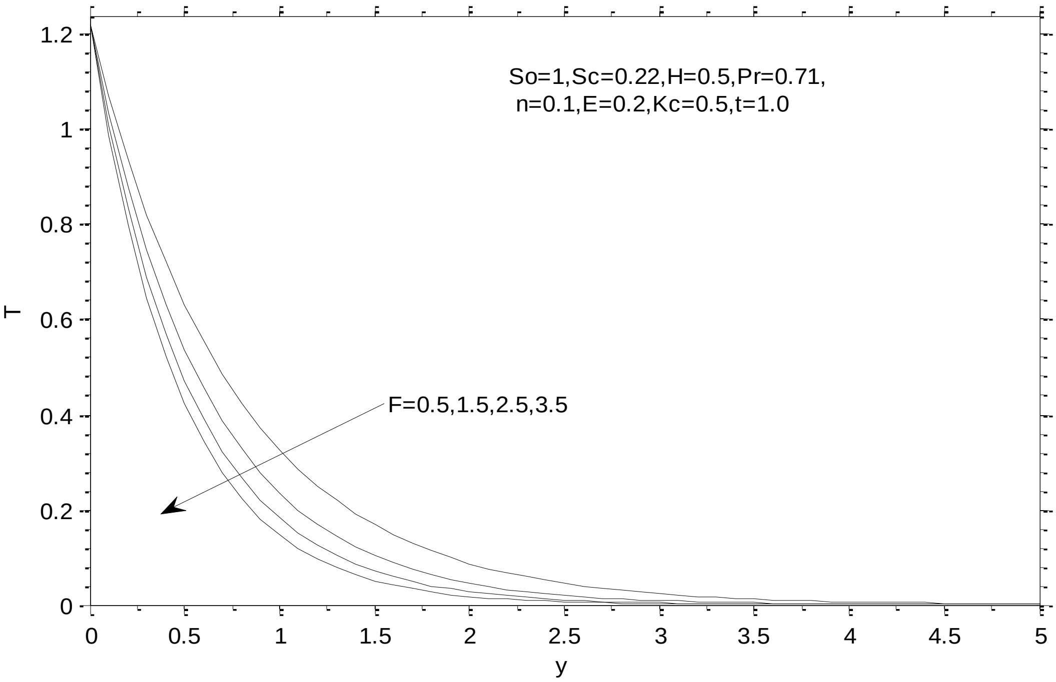

Fig.11; Effects of Radiation parameter **F** on Temperature

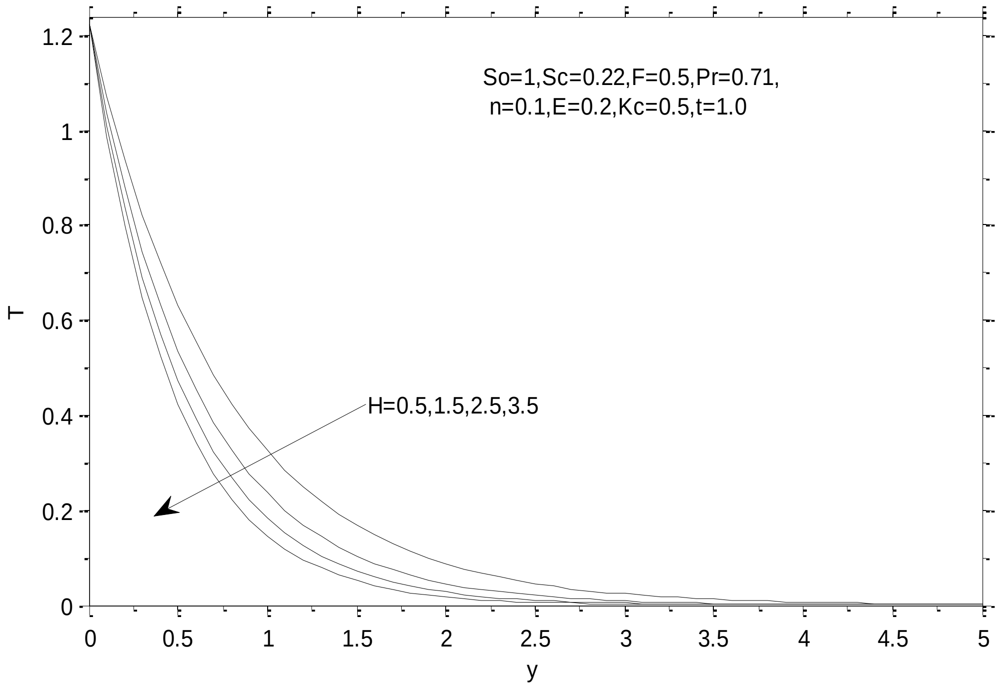

Fig.12; Effects of Hear Source parameter **H** on Temperature

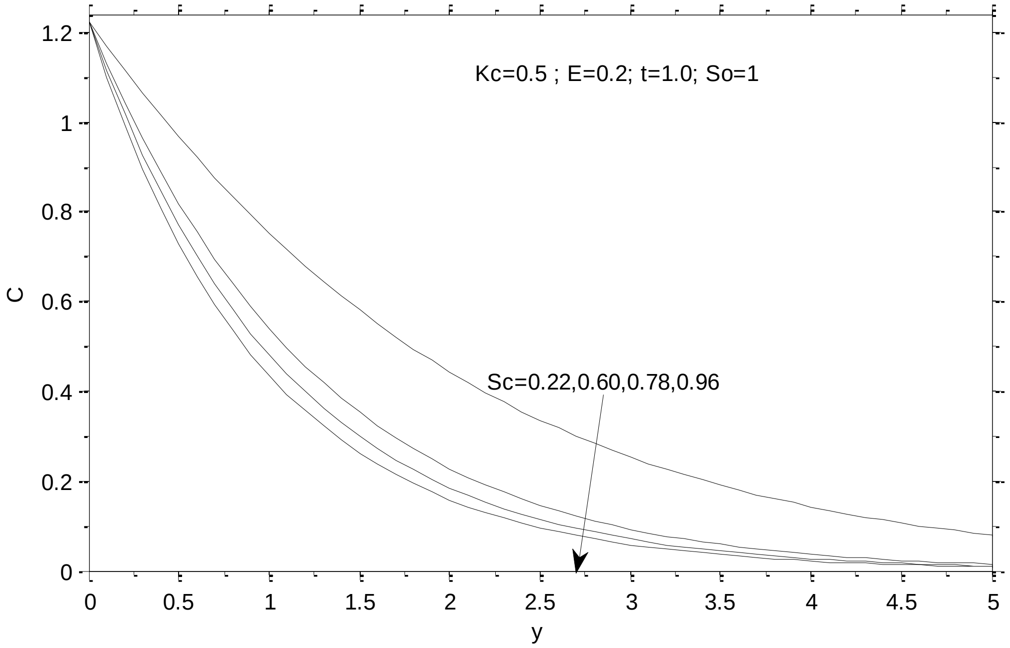

Fig.13; Effects of Schimidt number **Sc** on Concentration

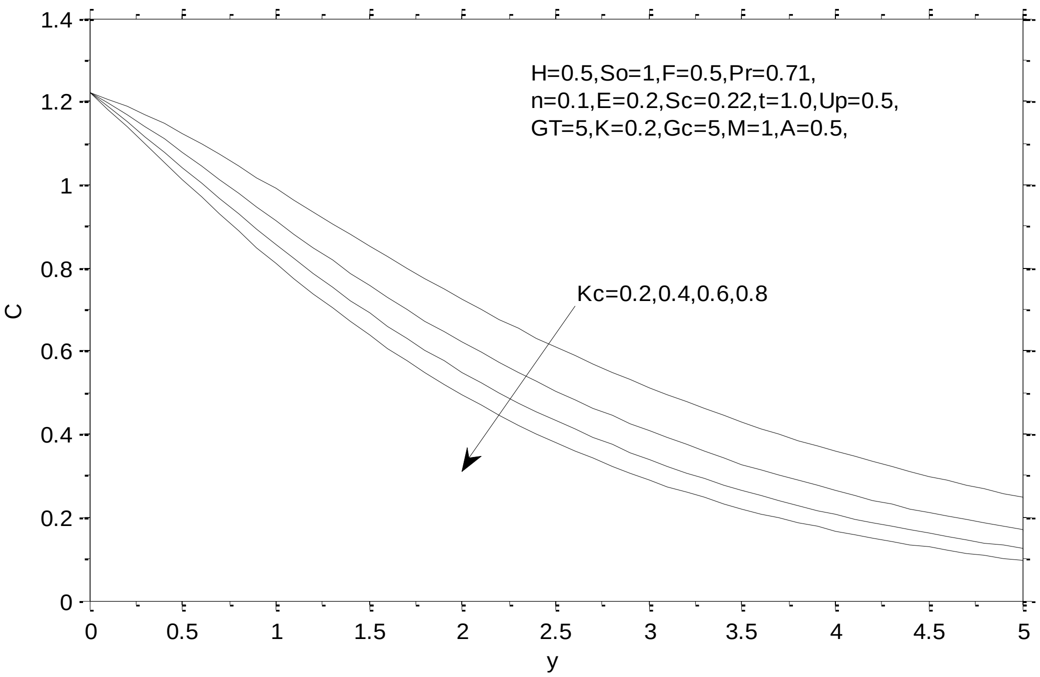

Fig.14; Effects of chemical reaction parameter **Kc** on Concentration

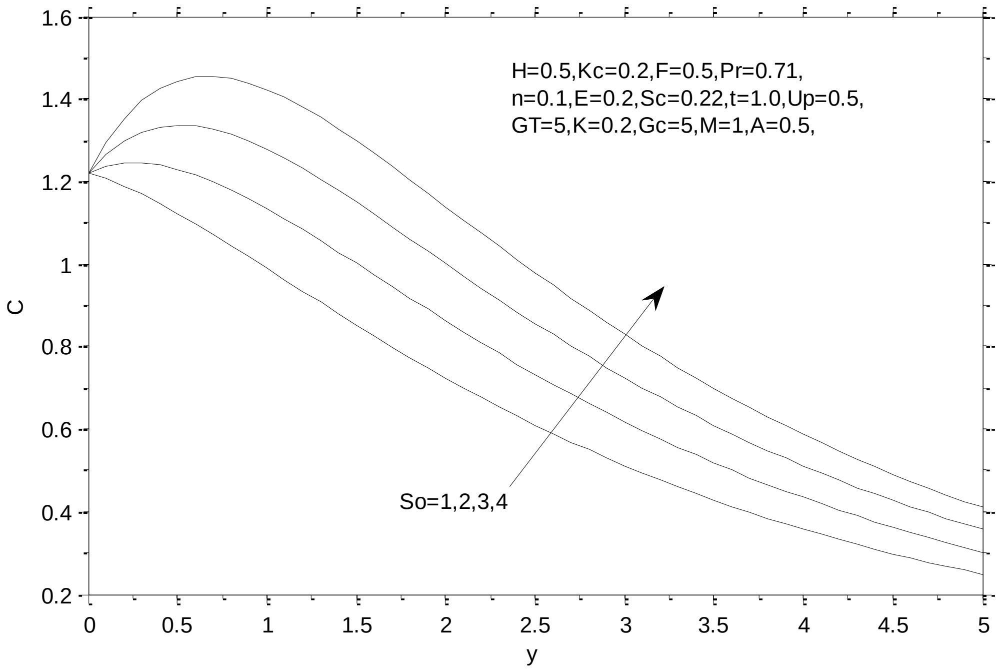

Fig.15; Effects of Soret number **So** on Concentration

The variations in skin friction, the rate of heat transfer in the form of Nusselt number and the rate of mass transfer in the form of Sherwood number are studied through the tables 1-3.

G_T	G_c	F	H	S_0	S_c	K_c	K	M	τ
5	5	0.5	0.5	1	0.22	0.2	0.2	1	**4.0760**
10	5	0.5	0.5	1	0.22	0.2	0.2	1	**-16.1603**
15	5	0.5	0.5	1	0.22	0.2	0.2	1	**-34.1921**
5	10	0.5	0.5	1	0.22	0.2	0.2	1	**-3.0785**
5	15	0.5	0.5	1	0.22	0.2	0.2	1	**-0.6347**
5	5	1.5	0.5	1	0.22	0.2	0.2	1	**-6.7102**
5	5	2.5	0.5	1	0.22	0.2	0.2	1	**-9.9323**
5	5	0.5	1.5	1	0.22	0.2	0.2	1	**-6.7102**
5	5	0.5	2.5	1	0.22	0.2	0.2	1	**-9.9323**
5	5	0.5	0.5	2	0.22	0.2	0.2	1	**-2.0695**
5	5	0.5	0.5	3	0.22	0.2	0.2	1	**-0.1042**
5	5	0.5	0.5	1	0.60	0.2	0.2	1	**2.3753**
5	5	0.5	0.5	1	0.78	0.2	0.2	1	**1.3722**
5	5	0.5	0.5	1	0.22	0.4	0.2	1	**-4.0966**
5	5	0.5	0.5	1	0.22	0.6	0.2	1	**-4.0987**
5	5	0.5	0.5	1	0.22	0.2	0.4	1	**-10.8346**
5	5	0.5	0.5	1	0.22	0.2	0.6	1	**-17.6158**
5	5	0.5	0.5	1	0.22	0.2	0.2	2	**-3.0152**
5	5	0.5	0.5	1	0.22	0.2	0.2	3	**-2.2795**

Table 1: Skin friction at the plate when Pr=0.71, n=0.1, t=1 and ε=0.2

Pr	F	H	Nu
0.71	0.5	0.5	**-1.6117**
7.00	0.5	0.5	**-10.3375**
0.71	1.5	0.5	**-2.0078**
0.71	2.5	0.5	**-2.3208**
0.71	0.5	1.5	**-2.0078**
0.71	0.5	2.5	**-2.3208**

Table 2: Nusselt number at the plate

Kc	Sc	S_0	S_h
0.2	0.22	1	**-0.1261**
0.4	0.22	1	**-0.2367**
0.6	0.22	1	**-0.3243**
0.2	0.6	1	**-0.1271**
0.2	0.78	1	**-0.1297**
0.2	0.22	2	**0.1970**
0.2	0.22	3	**0.5202**

Table 3: Sherwood number at the plate

VI. CONCLUSIONS

1. The governing equations for unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat absorption, radiation parameter and soret effect were formulated. The plate is maintained at constant velocity and flow is subjected to a transverse magnetic field.
2. The governing partial differential equations were transformed in to ordinary differential equations and analytical solutions, graphical results were shown depending on the some physical parameters.
3. It was found that when the Thermal Grashof number and Mass Grashof number increased, the fluid velocity increased. The presence of heat source effects and radiation effects caused the reductions in the fluid temperature which resulted in decreasing in the fluid velocity. Also, when Schmidt number was increased, the concentration was decreased, this resulted in decreasing in the fluid velocity.
4. The presence of soret effect caused the reductions in the concentration distribution and this resulted in decreasing in the fluid velocity.
5. In addition, it was found that the skin friction and Sherwood number are increased due to increase in soret effect parameter; Skin friction and Sherwood number are decreased due to increase in Schmidt number and chemical reaction parameter. Similarly, Skin friction and Nusselt number are decreased due to increase in radiation parameter and heat source parameter.

Appendix

$$m_1 = \frac{P_r + \sqrt{P_r^{\,2} + 4P_r(F+H)}}{2} \qquad m_2 = \frac{P_r + \sqrt{P_r^{\,2} + 4P_r(n+F+H)}}{2}$$

$$m_3 = \frac{S_c + \sqrt{S_c^{\,2} + 4K_cS_c}}{2} \qquad m_4 = \frac{S_c + \sqrt{S_c^{\,2} + 4(n+K_c)S_c}}{2} \qquad m_5 = \frac{1+\sqrt{1+4N}}{2}$$

$$m_6 = \frac{1+\sqrt{1+4(n+N)}}{2} \qquad A_1 = \frac{AP_rm_1}{m_1^{\,2} - P_rm_1 - P_r(n+F+H)} \qquad A_2 = 1 - A_1$$

$$A_3 = \frac{-S_0m_1^{\,2}}{\left(\frac{1}{S_c}\right)m_1^{\,2} - m_1 - K_c} \qquad A_4 = 1 - A_3$$

$$A_5 = \frac{AA_3m_1 - A_1S_0m_1^{\,2}}{\left(\frac{1}{S_c}\right)m_1^{\,2} - m_1 - (n+K_c)} \qquad A_6 = \frac{-A_2S_0m_2^{\,2}}{\left(\frac{1}{S_c}\right)m_2^{\,2} - m_2 - (n+K_c)}$$

$$A_7 = \frac{AA_4 m_3}{\left(\frac{1}{S_c}\right) m_3^2 - m_3 - (n+K_c)} \qquad A_8 = 1 - A_5 - A_6 - A_7 \qquad A_9 = \frac{-G_T - A_3 G_c}{m_1^2 - m_1 - N}$$

$$A_{10} = \frac{-A_4 G_c}{m_3^2 - m_3 - N} \qquad A_{11} = U_p - 1 - A_9 - A_{10} \qquad A_{12} = \frac{AA_9 m_1 - G_T A_1 - A_5 G_c}{m_1^2 - m_1 - (n+N)}$$

$$A_{13} = \frac{-G_T A_2 - A_6 G_c}{m_2^2 - m_2 - (n+N)} \qquad A_{14} = \frac{AA_{10} m_3 - A_7 G_c}{m_3^2 - m_3 - (n+N)} \qquad A_{15} = \frac{-A_8 G_c}{m_4^2 - m_4 - (n+N)}$$

$$A_{16} = \frac{AA_{11} m_5}{m_5^2 - m_5 - (n+N)} \qquad A_{17} = -1 - A_{12} - A_{13} - A_{14} - A_{15} - A_{16}$$

$$A_{18} = -A_9 m_1 - A_{10} m_3 - A_{11} m_5 \qquad A_{19} = -A_{12} m_1 - A_{13} m_2 - A_{14} m_3 - A_{15} m_4 - A_{16} m_5 - A_{17} m_6$$

$$A_{20} = -A_1 m_1 - A_2 m_2 \qquad A_{21} = -A_3 m_1 - A_4 m_3 \qquad A_{22} = -A_5 m_1 - A_6 m_2 - A_7 m_3 - A_8 m_4$$

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