International Journal of Engineering and Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 9|| September 2017 || PP. 30-40

Joule Heating Effect in Presence of Thermal Radiation on MHD Convective Flow Past Over A Vertical Surface in A Porous Medium

*Bhavtosh Awasthi
Department of Mathematics, JECRC University, Jaipur 303905, Rajasthan, India
Corresponding Author: Bhavtosh Awasthi

Abstract: *This paper presents the effects of Joule heating and viscous dissipation on magneto-hydrodynamic convection flow of steady, viscous, incompressible and electrically conducting fluid past a semi infinite vertical plate embedded in a porous medium in presence of thermal radiation with constant heat and mass fluxes. The governing partial differential equations are converted into a set of ordinary differential equations using non dimensional quantities. Perturbation method has been applied to solve the system of partial differential equations. The expressions for skin-friction, rate of heat transfer, and rate of mass transfer are also derived. The effects of various physical parameters, encountered in the problem, on the velocity field, temperature field, and concentration field are shown numerically through graphs.*

Keywords: *Chemical reaction, Radiation, MHD, Joule heating, heat and mass fluxes, Perturbation technique.*

Date of Submission: 19-08-2017 Date of acceptance: 09-09-2017

NOMENCLATURE

C : Concentration of species
D : Chemical molecular diffusivity
q : Constant heat flux
m: Constant mass flux
g : Acceleration due to gravity
M: Magnetic parameter
N_u : Nusselt Number
C_p : Specific molecular diffusivity
Gm : Grashof number for mass transfer
P_r : Prandtl number
Sc : Schmidt number
T : The fluid temperature
T_∞ : The fluid temperature at infinity
v_0 : Scale of suction velocity
B_0 : Magnetic flux density
Sh : Sherwood number
C_∞ : Species concentration at infinity
F : Radiation Parameter
Gr: Grashof number for heat transfer
Gm: Grashof number for mass transfer
Kr : Chemical reaction parameter
E: Eckert Number

Greek symbols

α : Permeability parameter
β_1 : The volumetric coefficient expansion due to temperature

β_2 : Coefficient of the volume expansion with species concentration

μ : Dynamic viscosity

k_p : Permeability of porous medium

$\theta(\eta)$: Dimensionless temperature

ν : Kinematic viscosity

ρ : Density of the fluid

λ : Thermal conductivity

σ : Electrical conductivity

τ : Skin fraction

η : Distance

I. INTRODUCTION

In industrial and real life problems, there exist flows which are stimulated not only by the differences of temperature but also by differences of concentration. These mass transfer differences affect the rate of heat transfer. The phenomenon of heat and mass transfer frequently exists in many chemical processes industries like food processing and polymer process. Free convection flows are of great interest in many industrial applications such as fiber and granular insulation, geothermal systems etc. Lin & Wu (1995) had investigated Simultaneous effect of heat and mass transfer in laminar free convection boundary-layer flow along a vertical plate. Chamkha (2004) have carried out the unsteady MHD convective heat and mass transfer over a semi-infinite vertical permeable moving plate with heat absorption.

The study of Magneto-hydrodynamics(MHD) with heat and mass transfer in the presence of radiation has attracted many researchers due to diverse applications in different areas of sciences and technologies. Effect of radiation on MHD is of considerable interest because of its wider applications in space technology and other area of technology and sciences. Many researchers studied the effect of radiation on magneto hydrodynamic free convection flows under diverse surface boundary conditions using different techniques of Mathematics. Lot of engineering processes takes place at high temperatures and so the knowledge of radiation and heat transfer is essential for designing various types of industrial equipments. Nuclear power plants, gas turbines and various propulsion devices for aircraft, missiles and satellites are some examples of such processes. Cogley (1968) developed differential approximations for radiative heat transfer in a non-linear equations non-grey gas near equilibrium. The unsteady hydro magnetic free convection flow with radioactive transfer in a rotating fluid was discussed by Bestman and Adjepong (1998). Hossain et al. (1999) had analyzed the effect of radiation on free convection from a porous vertical plate. Combined free convective boundary-layer flow with thermal radiation and mass transfer past a moving vertical porous plate, when the plate moves in its own plane was studied by Makinde (2005). Pathak and Maheshwari [2006] discussed the influence of radiation on an unsteady free convection flow bounded by an oscillating plate with variable wall temperature. Mamun et al.(2008) analyzed the conjugate effect of heat transfer and MHD for a vertical plate in presence of viscous dissipation and heat generation. Mankinde and Aziz (2010) discussed MHD mixed convection from a vertical plate embedded in a porous medium with a convective boundary condition. Rajesh and Verma (2010) introduced radiation effects on MHD flow through a porous medium with variable temperature and mass diffusion. Saxena, and Dubey (2011) investigated MHD free convection heat and mass transfer flow of visco-elastic fluid embedded in a porous medium with variable permeability, radiation effect and heat source in slip flow region. Sudhakar et. al. (2013) analyzed the effect of chemical reaction and radiation on MHD free convective flow through a porous medium bounded by a vertical surface in presence of constant heat and mass fluxes. The velocity slips effects on the heat and mass fluxes of a viscous electrically conducting fluid flow over a stretching sheet in the presence of viscous dissipation, Ohmic dissipation and thermal radiation have discussed by Kayalvizhi et al. (2016).

Chemical reactions can be coded either as heterogeneous or homogeneous processes. They depend on whether they occur at an interface or as a single phase volume reaction. The reaction is heterogeneous if it takes place at an interface level and homogeneous if it takes place in solution. In most of chemical reactions, the reaction rate depends on the concentration of the species. The first ordered chemical reaction in the neighborhood of a horizontal plate has been examined by Chambre and Young (1958). 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 (2005). Al-Mudhaf and Chamkha [2005] analyzed the MHD thermosolutal Marangoni convection boundary layer. They have studied the effects of heat generation/absorption, Hartmann number, the chemical reaction parameter and the suction/injection parameter on the flow. 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 (2009). The case of unsteady MHD convective heat and mass transfer in a boundary layer slip flow over a vertical permeable with thermal radiation and chemical reaction was examined by Pal et al. (2010). Kishan and Amrutha (2010) analyzed the effects of viscous dissipation on MHD flow with heat and mass transfer over a stretching surface with heat source. Sarada and Shanker (2013) have investigated the effect of chemical reaction on an unsteady magneto hydrodynamic flow over an infinite vertical porous plate with variable suction and heat convective mass transfer, where the plate temperature oscillates with the frequency as that of variable suction velocity. Effect of chemical reaction on MHD flow of continuously moving vertical surface with heat and mass flux through porous medium has been discussed by Girish Kumar (2013). Mangathai et al. (2015) have presented an exact analysis of combined effects of radiation and chemical reaction on the magneto hydrodynamic (MHD) free convection flow of an electrically conducting incompressible viscous fluid over an inclined plate embedded in a porous medium.

The effects of Joule heating is usually characterized by the product of the Eckert number and magnetic parameter. It have a very important rule in geophysical flows and in nuclear. With this understanding, many researchers studied the effects of Joule heating in various geometries. Alim et al [2007] analyzed the effects of suction or injection on boundary layer flow. Palani and Kim (2011) employed implicit finite difference scheme of Crank-Nicolson method to analyze the importance of Joule heating and viscous dissipation effects on MHD flow along inclined plate subject to variable surface temperature.

The present work is concerned with the effect of thermal radiation and joule heating on magneto hydrodynamic convection flow of steady, viscous, incompressible and electrically conducting fluid past a semi infinite vertical plate embedded in a porous medium. Here, we assume that a chemically reactive species is emitted from the surface and diffuses into the fluid. The reaction is assumed to take place entirely in the stream. The governing partial differential equations have been converted into a set of ordinary differential equations using non dimensional quantities. Perturbation technique has been applied to solve the system of partial differential equations. The effects of various governing parameters on the velocity, temperature, concentration, skin friction coefficient, rate of heat transfer and rate of mass transfer will be shown and discussed.

II. MATHEMATICAL ANALYSIS

Consider two dimension steady flow of a viscous incompressible electrically conducting fluid through a porous medium occupying semi infinite region of space bounded by a vertical infinite surface subjected to a thermal radiation and joule heating. The x^* axis is chosen along the plate and the y^* axis is perpendicular to it. The uniform magnetic field of strength B_0 in the presence of radiation and joule heating is imposed transversely in the direction of y^* axis. The induced magnetic field is neglected under the assumption that the magnetic Reynolds number is small. The properties of fluid are assumed to be constant except for the density. A chemically reactive species is emitted from the vertical surface into a hydrodynamic flow field. It diffuses into the fluid, where it undergoes a homogeneous chemical reaction. The reaction is assumed to take place entirely in the stream. The governing equations for the study are based on the conservation of mass, linear momentum and energy.

Taking into consideration the assumptions made above, equations in Cartesian frame of reference are given by

Continuity equation

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

Momentum equation

$$v^* \frac{\partial u^*}{\partial y^*} = v \frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_1 (T^* - T_\infty) + g\beta_2 (C^* - C_\infty) - \frac{\nu u^*}{k_p} - \frac{\sigma B_0^2 u^*}{\rho} \tag{2}$$

Energy equation

$$v^* \frac{\partial T^*}{\partial y^*} = \frac{\lambda}{\rho C_p} \frac{\partial^2 T^*}{\partial y^{*2}} + \frac{v}{C_p}\left(\frac{\partial u^*}{\partial y^*}\right)^2 - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*} - \frac{\sigma B_0^2}{\rho C_p} u^{*2} \tag{3}$$

Species equation

$$v^{*}\frac{\partial C^{*}}{\partial y^{*}}=D\frac{\partial^{2}C^{*}}{\partial y^{*2}}-k_{c}C^{*}\tag{4}$$

Where u^{*} and v^{*} are the components of the dimensional velocities along x^{*} and y^{*} directions respectively.

Let the level of species concentration is very low. Therefore the heat generated due to the chemical reaction is neglected.

From equation (1),

$$v^{*}=\text{constant}=-v_{0}\tag{5}$$

Where $v_0 \succ 0$ corresponding to steady suction velocity normal at the surface and v is the steady normal velocity of suction on the surface.

Cogley et al. [1968] have shown that in the optically thin limit for a non-gray gas near equilibrium, the radiative heat flux is represented by the following form:

$$\frac{\partial q_{r}}{\partial y^{*}}=4(T^{*}-T_{*})I^{*}\tag{6}$$

Where $I^{*}=\int K_{\lambda}\frac{\partial e_{\lambda}}{\partial T^{*}}d\lambda$, K_{λ} the absorption coefficient at the plate and e_{λ} be the plank's function.

The relevant boundary conditions are

$$\left.\begin{aligned}
&u^{*}=0,\,T^{*}=T_{\infty},C^{*}=C_{\infty}\;\; for\;any\;value\;of\;\; y^{*},t\le 0\\
&u^{*}=0,\,\frac{\partial T^{*}}{\partial y^{*}}=-\frac{q}{\lambda},\frac{\partial C^{*}}{\partial y^{*}}=-\frac{m}{D},\; y^{*},t\succ 0\\
&u^{*}\to 0,\,T^{*}\to T_{\infty},C^{*}\to C_{\infty}\;\; y^{*}\to\infty,\,t\succ 0
\end{aligned}\right\}\tag{7}$$

Using equation (5), equations (2), (3) and (4) reduces to

$$-v^{*}\frac{\partial u^{*}}{\partial y^{*}}=v\frac{\partial^{2}u^{*}}{\partial y^{*2}}+g\beta_{1}(T^{*}-T_{\infty})+g\beta_{2}(C^{*}-C_{\infty})-\frac{vu^{*}}{k_{p}}-\frac{\sigma B_{0}^{2}u^{*}}{\rho}\tag{8}$$

$$-v*\frac{\partial T^{*}}{\partial y^{*}}=\frac{\lambda}{\rho C_{p}}\frac{\partial^{2}T^{*}}{\partial y^{*2}}+\frac{v}{C_{p}}\left(\frac{\partial u^{*}}{\partial y^{*}}\right)^{2}-\frac{1}{\rho C_{p}}\frac{\partial q_{r}}{\partial y^{*}}-\frac{\sigma B_{0}^{2}}{\rho C_{p}}u^{*2}\tag{9}$$

$$-v^{*}\frac{\partial C^{*}}{\partial y^{*}}=D\frac{\partial^{2}C^{*}}{\partial y^{*2}}-k_{c}C^{*}\tag{10}$$

Now, we introduce the dimensionless variables as follows

$$\left.\begin{aligned}
&f(\eta)=\frac{u^{*}}{v_{0}},\;\eta=\frac{v_{0}y^{*}}{\upsilon},\Pr=\frac{\upsilon\rho C_{p}}{\lambda},\;F=\frac{4\upsilon^{2}I^{*}}{\lambda v_{0}^{2}},\;\alpha=\frac{v_{0}^{2}k_{p}}{\upsilon^{2}},C=\frac{\left(C^{*}-C_{\infty}\right)D}{m},\\
&G_{r}=\frac{g\beta_{1}q\upsilon}{\lambda v_{0}^{3}},S_{c}=\frac{\upsilon}{D},\theta=\frac{(T^{*}-T_{\infty})\lambda}{\upsilon q},\;Kr=\frac{k_{c}\upsilon}{v_{0}^{2}},M=\frac{\sigma\upsilon B_{0}^{2}}{\rho v_{0}^{2}},\;E=\frac{\lambda v_{0}^{2}}{qC_{p}},Gm=\frac{g\beta_{2}m\,v}{Dv_{0}^{3}}
\end{aligned}\right\}\tag{11}$$

Using (11), the governing equations (8), (9) and (10) reduce to the following form:

$$f''+f'-(\frac{1}{\alpha}+M)f=-Gr\,\theta-GmC\tag{12}$$

$$\theta'' + \Pr\,\theta' - F\theta = -E\Pr(f')^2 - \Pr EMf^2 \qquad (13)$$

$$C'' + ScC' = ScKrC \qquad (14)$$

where all primes are w.r.to η .

The boundary conditions (7) in the dimensionless form can written as

$$\left.\begin{aligned} &\eta = 0,\ f = 0, \theta' = -1, C' = -1 \\ &\eta \to \infty,\ f \to 0,\ \theta \to 0, C \to 0 \end{aligned}\right\} \qquad (15)$$

III. SOLUTION OF THE PROBLEM

To obtain the solution of above coupled non linear system of equations (12)-(14) with the boundary conditions (15), we expand f, θ and C in powers of Eckert number E assuming that it is very small. This is justified in low speed incompressible flow. Hence we can write

$$\left.\begin{aligned} f &= f_0 + Ef_1 + o(E^2) \\ \theta &= \theta_0 + E\theta_1 + o(E^2) \\ C &= C_0 + Ef_1 + o(E^2) \end{aligned}\right\} \qquad (16)$$

Substituting equations (16) into equations (12)-(14) and equating like powers of E and neglecting the coefficient of $O(E^2)$, we get the following pairs of equations

$$f_0'' + f_0' - \delta f_0 = -Gr\,\theta_0 - GmC_0 \qquad (17)$$

$$f_1'' + f_1' - \delta f_1 = -Gr\,\theta_1 - GmC_1 \qquad (18)$$

$$\theta_0'' + \Pr\,\theta_0' = F\theta_0 \qquad (19)$$

$$\theta_1'' + \Pr\,\theta - F\theta_1 = -\Pr\,f_0'^2 - \Pr\,Mf_0^2 \qquad (20)$$

$$C_0'' + ScC_0' = ScK_rC_0 \qquad (21)$$

$$C_1'' + ScC_1' = ScK_rC_1 \qquad (22)$$

The corresponding boundary conditions can be written as

$$\left.\begin{aligned} &f_0 = 0,\ f_1 = 0, \theta_0' = -1, \theta_1' = 0, C_0' = -1, C_1' = 0,\ at\ \eta = 0 \\ &f_0 \to 0,\ f_1 \to 0,\ \theta_0 \to 0,\ \theta_1 \to 0,\ C_0 \to 0, C_1 \to 0, at\ \eta \to \infty \end{aligned}\right\} \qquad (23)$$

The solutions of equations (17)-(22) which satisfy the boundary conditions (23) are given by

$$f_0 = K_3e^{h_2\eta} + K_1e^{e_2\eta} + K_2e^{d_2\eta} \qquad (24)$$

$$f_1 = K_{30}e^{h_2\eta} + K_{17}e^{e_2\eta} + K_{18}e^{2h_2\eta} + K_{19}e^{2e_2\eta} + K_{20}e^{2d_2\eta} + K_{21}e^{(h_2+e_2)\eta} + K_{22}e^{(d_2+e_2)\eta}$$
$$+ K_{23}e^{(d_2+h_2)\eta} + K_{24}e^{2h_2\eta} + K_{25}e^{2e_2\eta} + K_{26}e^{2d_2\eta} + K_{27}e^{(e_2+h_2)\eta} + K_{28}e^{(d_2+e_2)\eta} + K_{29}e^{(h_2+d_2)\eta} \qquad (25)$$

$$\theta_0 = -\frac{1}{e_2}e^{e_2\eta} \qquad (26)$$

$$\theta_1 = K_{16}e^{e_2\eta} + K_4e^{2h_2\eta} + K_5e^{2e_2\eta} + K_6e^{2d_2\eta} + K_7e^{(h_2+e_2)\eta} + K_8e^{(d_2+e_2)\eta} + K_9e^{(d_2+h_2)\eta}$$
$$+ K_{10}e^{2h_2\eta} + K_{11}e^{2e_2\eta} + K_{12}e^{2d_2\eta} + K_{13}e^{(e_2+h_2)\eta} + K_{14}e^{(d_2+e_2)\eta} + K_{15}e^{(d_2+h_2)\eta}$$
(27)

$$C_0 = -\frac{1}{d_2}e^{d_2\eta}$$
(28)

$$C_1 = 0$$
(29)

Substituting the solutions of equations (24)-(289 in (16), we obtain

$$f(\eta) = K_3e^{h_2\eta} + K_1e^{e_2\eta} + K_2e^{d_2\eta} + E(K_{30}e^{h_2\eta} + K_{17}e^{e_2\eta} + K_{18}e^{2h_2\eta} + K_{19}e^{2e_2\eta} + K_{20}e^{2d_2\eta}$$
$$+ K_{21}e^{(h_2+e_2)\eta} + K_{22}e^{(d_2+e_2)\eta} + K_{23}e^{(d_2+h_2)\eta} + K_{24}e^{2h_2\eta} + K_{25}e^{2e_2\eta} + K_{26}e^{2d_2\eta} + K_{27}e^{(e_2+h_2)\eta}$$
$$+ K_{28}e^{(d_2+e_2)\eta} + K_{29}e^{(d_2+h_2)\eta}$$
(30)

$$\theta(\eta) = -\frac{1}{e_2}e^{e_2\eta} + E(K_{16}e^{e_2\eta} + K_4e^{2h_2\eta} + K_5e^{2e_2\eta} + K_6e^{2d_2\eta} + K_7e^{(h_2+e_2)\eta} + K_8e^{(d_2+e_2)\eta}$$
$$+ K_9e^{(d_2+h_2)\eta} + K_{10}e^{2h_2\eta} + K_{11}e^{2e_2\eta} + K_{12}e^{2d_2\eta} + K_{13}e^{(e_2+h_2)\eta} + K_{14}e^{(d_2+e_2)\eta} + K_{15}e^{(d_2+h_2)\eta})$$
(31)

$$C(\eta) = -\frac{1}{d_2}e^{d_2\eta}$$
(32)

The rate of heat transfer in terms of the Nusselt number is given by

$$N_u = -\left(\frac{\partial\theta}{\partial\eta}\right)_{\eta=0} = 1 - E[K_{16}e_2 + 2K_4h_2 + 2K_5e_2 + 2K_6d_2 + (e_2+h_2)K_7 + (d_2+e_2)K_8$$
$$+ (d_2+h_2)K_9 + 2K_{10}h_2 + 2K_{11}e_2 + +2K_{12}d_2 + (e_2+h_2)K_{13} + (d_2+e_2)K_{14} + (d_2+h_2)K_{15}]$$
(33)

The rate of mass transfer in term of Sherwood number (Sh) is given by

$$Sh = \left(\frac{\partial C}{\partial\eta}\right)_{\eta=0} = -1 + E*(-1) = -(1+E)$$
(34)

The non dimensional skin friction (τ) at the surface is given by

$$\tau = \left(\frac{\partial f}{\partial\eta}\right)_{\eta=0} = K_3a_6 + K_1e_2 + K_2d_2 + E[K_{30}h_2 + K_{17}e_2 + 2K_{18}h_2 + 2K_{19}e_2 + 2K_{20}d_2$$
$$+ 2K_{14}a_6 + K_{21}(e_2+h_2) + K_{22}(d_2+e_2) + K_{23}(d_2+h_2) + 2K_{24}h_2 + 2K_{25}e_2 + 2K_{26}d_2$$
$$+ K_{27}(e_2+h_2) + K_{28}(e_2+d_2) + K_{29}(d_2+h_2)]$$
(35)

IV. RESULT AND DISCUSSION

The problem of the influence of radiation and jule heating on magneto hydrodynamic steady convective heat and mass transfer past a semi-infinite vertical porous plate by perturbation technique is dealt. Based on these assumptions, we have carried out numerical computations for the velocity, temperature and concentration for various values of the material parameters like Permeability parameter (α), Grashof number for heat transfer (Gr), Grashof number for mass transfer (Gm), Prandtl number (Pr), Magnetic parameter (M), Chemical reaction parameter (Kr), Schmidt number (Sc), Eckert Number (E) etc.

4.1 VELOCITY PROFILES The velocity profiles are depicted in figures 1-8. Fig.1 displays the effects of permeability coefficient of a porous medium (α) velocity profile. It is observed that velocity decreases with increase in (α). It is interesting to observe that the fluid velocity increases and reaches its maximum over a very short distance from the plate and then decreases gradually to zero for positive value of α. Fig.2 displays the effects of chemical reaction parameter (Kr). It is observed that velocity decreases with increase in Kr. Fig.3 shows the effect of Schmidt Number (Sc) on the velocity profile. An increase in Schmidt Number (Sc) results in decrease in the velocity. Fig. 4 shows the effect of Gr on velocity. Velocity increases with increasing Gr. Fig.5 shows the effect of Eckert Number (E) on the velocity profile. An increase in Eckert Number (E) results in decrease in the velocity. Effect of Gm on velocity has been displayed by Fig. 6. It is seen that velocity increases with increasing Gm. Effect of Radiation parameter (F) on the velocity profile is depicted in Fig.7.It is observed that the velocity increases with increase in radiation parameter. Effect of Prandtl Number (Pr) on the velocity profile is depicted in Fig. 8. It is observed that the velocity decreases with increase in Prandtl Number (Pr). The skin friction has been depicted in Fig. 17. It is observed that skin friction decreases with increasing α and Gr.

4.2 TEMPERATURE PROFILES The temperature profiles are depicted in figures 9-13. Fig. 9 shows the effect of permeability parameter (α) on temperature. It is observed that temperature is directly proportional to (α). In Fig.10, the influence of Eckert Number (E) on temperature is shown. It seen that the temperature increases with increase in Eckert Number (E). Effect of chemical reaction parameter (Kr) on the temperature is depicted in Fig. 11. It is observed that the temperature decreases with increase in chemical reaction parameter (Kr). The Effect of Radiation parameter (F) on the temperature is depicted in Fig.12. It is observed that the temperature decreases with increase in Radiation parameter (F). Fig.13 displays the effects of Mass Grashof Number (Gm). It is observed that temperature increases with increasing Gm. A variation in the heat transfer rate in terms of the Nusselt number N is shown in figures 16 and 18. It is observed that N decreases with increasing Gr and increases with with increasing Kr.

4.3 CONCENTRATION PROFILES The concentration profiles are depicted in figures 14-15. The effect of Schmidt Number (Sc) on the concentration is presented in figure 14. It is noted that the concentration decreases with increase in Schmidt Number (Sc). In figure 15, the effect of chemical reaction parameter (Kr) on the concentration is presented. It is seen that the concentration decreases with increase in chemical reaction parameter (Kr).

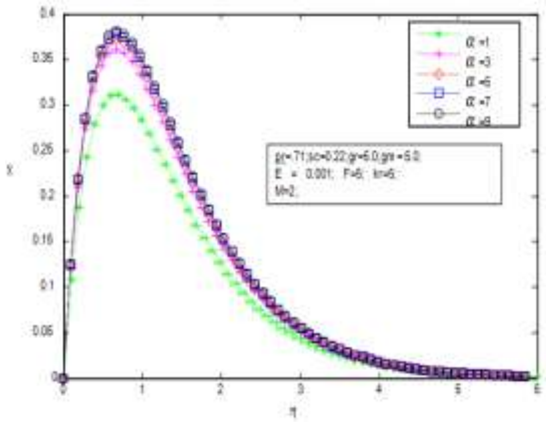

Fig.1 Velocity profile for different value of Permeability parameter (α)

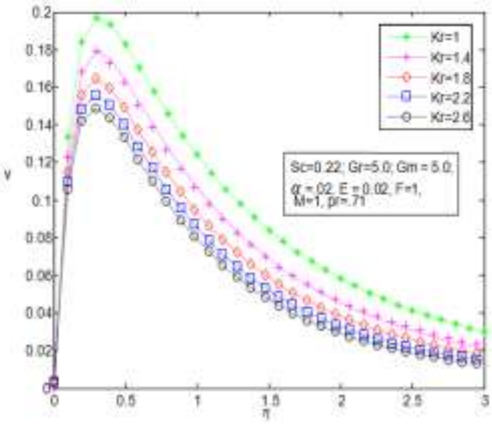

Fig.2 Velocity profile for different value of Chemical Reaction parameter (*Kr*)

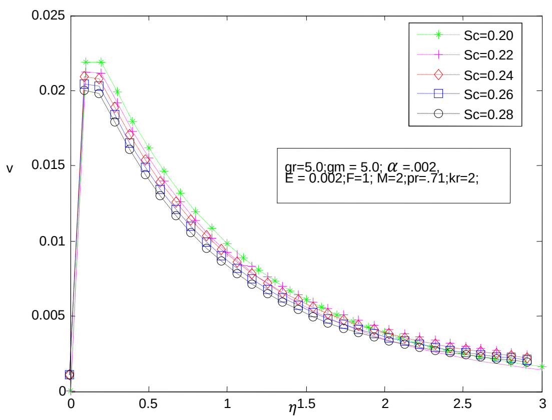

Fig.3 Velocity profile for different value of

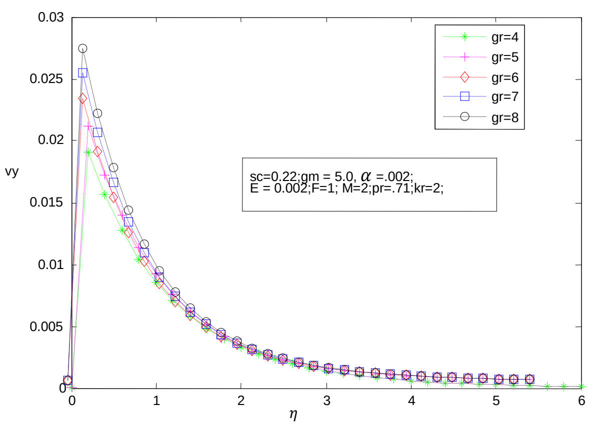

Fig.4 Velocity profile for different value of

Schmidt Number (Sc)

Grashof number for heat transfer(Gr)

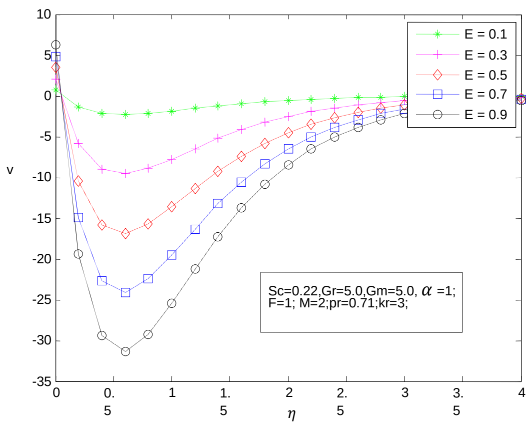

Fig.5 Velocity profile for different value of Grashof number for mass transfer (Gm)

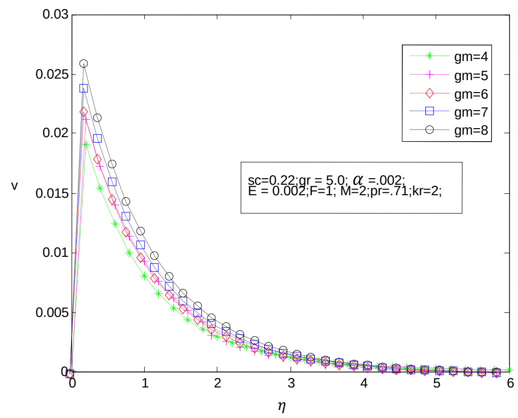

Fig.6 Velocity profile for different value of Eckert Number (E)

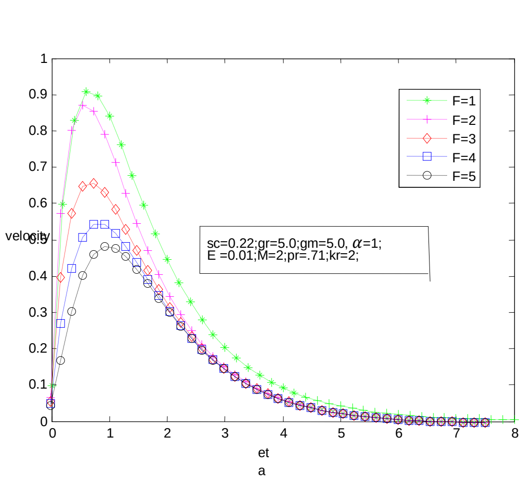

Fig.7 Velocity profile for different value of Radiation Parameter (F)

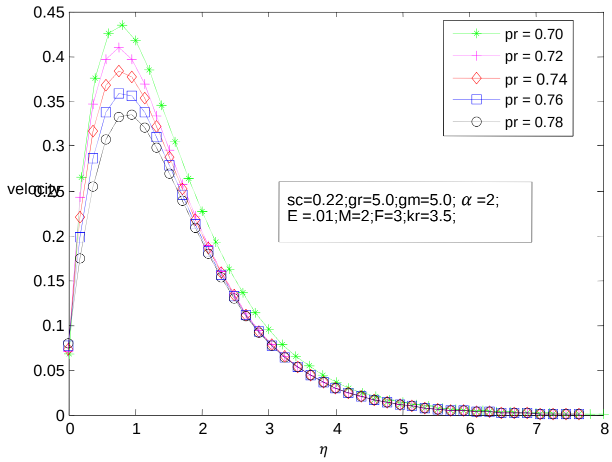

Fig.8 Velocity profile for different value of Prandtl Number (Pr).

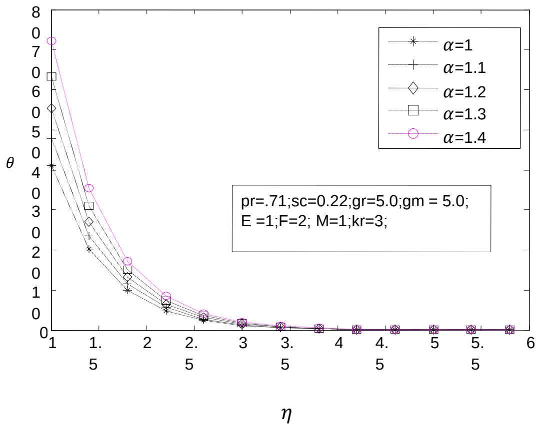

Fig.9 Temperature profile for different value of permeability parameter (α)

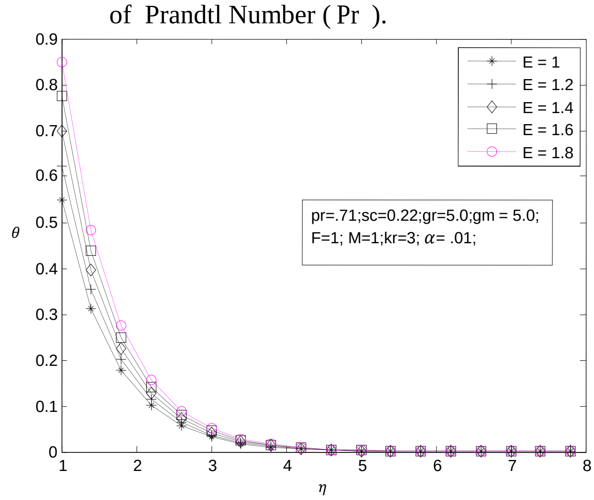

Fig.10 Temperature profile for different value of Eckert Number (E)

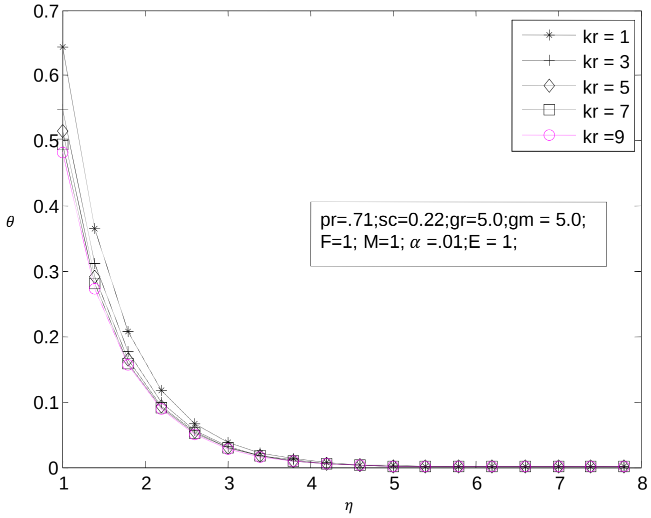

Fig.11 Temperature profile for different value of of Chemical 0Reaction parameter (Kr)

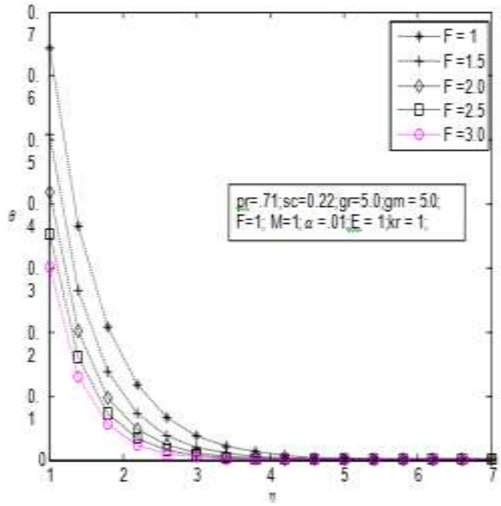

Fig.12 Temperature profile for different value Radiation parameter (F)

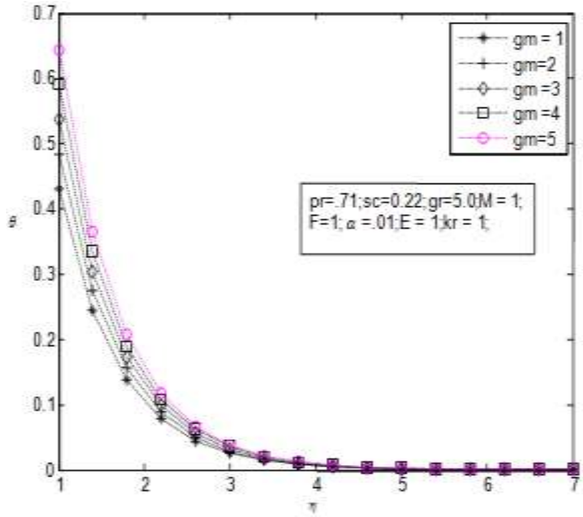

Fig.13 Temperature profile for different value of Grashof number for mass transfer (Gm)

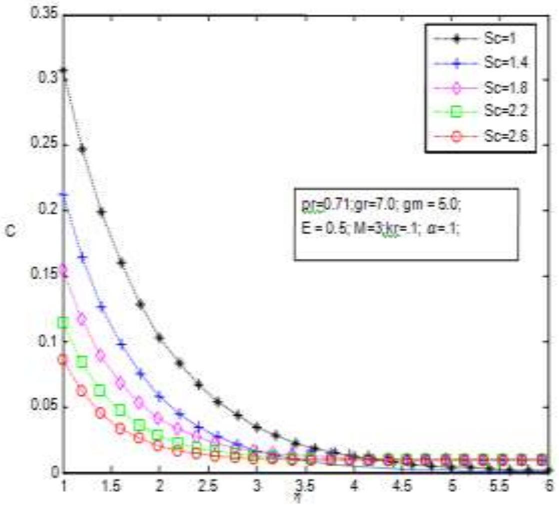

Fig.14 Concentration profile for different value of Schmidt Number (Sc)

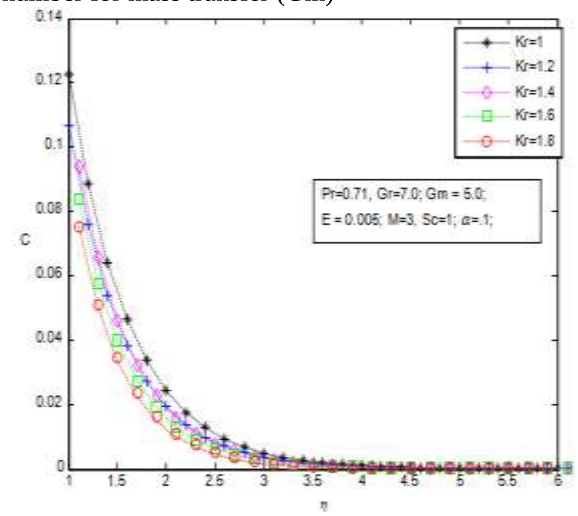

Fig.15 Concentration profile for different value of Chemical Reaction parameter (Kr)

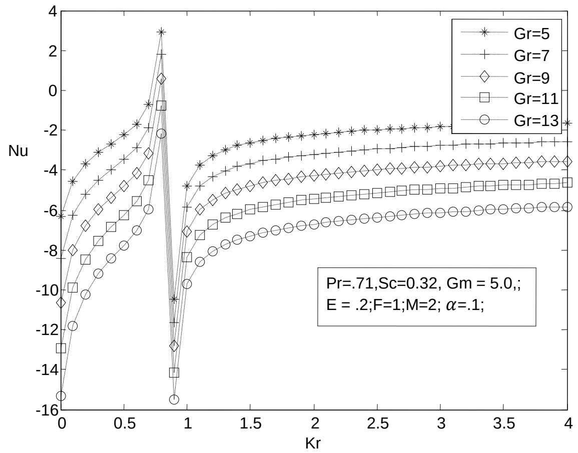

Fig.16 Nusselt Number (N) against the thermal Grashof Number (Gm)

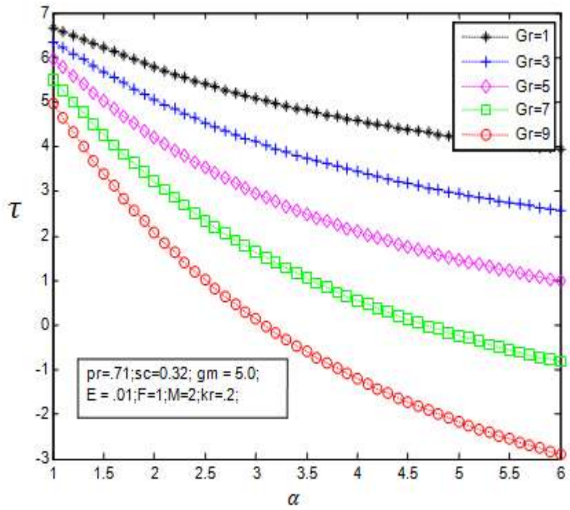

Fig.17 Skin friction against the permeability parameter different (α) with different values of Gr

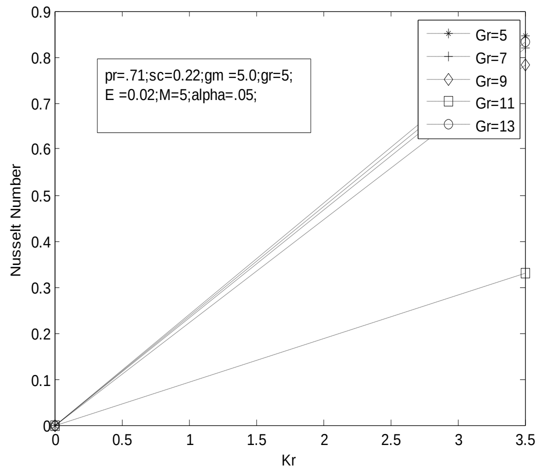

Fig.18 Nusselt Number (N) against the Kr at value of Gr

V. COCLUSION

The problem of the influence of radiation and joule heating in presence of constant heat and mass fluxes on magneto-hydrodynamic convection flow of steady, viscous, incompressible and electrically conducting fluid past a semi infinite vertical plate embedded in a porous medium is studied. Solution of governing partial differential equations has been obtained by perturbation technique. Based on solutions, numerical computations for various values of the material parameters are carried our and following results have been observed:

1. The velocity of fluid flow increases with increase in Grashof number for mass transfer (Gm), Grashof number for heat transfer (Gr) Radiation parameter (F).
2. The velocity of fluid flow decreases with increase in Schemidt number (Sc), chemical reaction parameter (K_r) and Prandtl Number (P_r), Eckert Number (E) and permeability coefficient of a porous medium (α).
3. The temperature of fluid increases with increase in Eckert Number (E), Grashof Number (G_m) and permeability coefficient of a porous medium (α)..
4. The temperature of fluid decreases with increase in chemical reaction parameter (Kr) and Radiation parameter (F).
5. The concentration of fluid decreases with increase in Schmidt Number (S_c) and chemical reaction parameter (K_r).
6. The value Nusselt Number (N) decreases with the increase in Thermal Grashof Number (G_r) and increases with the increase in chemical reaction parameter (Kr)
7. The value of Skin friction decreases against thermal Grashof number (G_r) and also decreases against permeability coefficient of a porous medium (α).

REFERENCES

[1] H.T. Lin and C. M. Wu, Combined heat and mass transfer by laminar natural convection from a vertical plate, Heat and Mass Transfer, 30, 1995, 369–376..

[2] A.J. Chamkha, Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption, Int. J. of Engg. Science, 42, 2004, 217-230.

[3] A.C. Cogley, W.G. Vincent and S.E. Giles. Differential approximation to radiative heat transfer in a non-grey gas near equilibrium. AIAA J, 6, 1968, 551-553.

[4] R.A.Henkes and W.M. Hoogendoorn, Laminar, Natural convection boundary layer flow along a heated vertical plate in a stratified environment, International Journal of Heat Mass Transfer, 32(1), 1989, 147-155.

[5] A.R. Bestman and S.K. Adjepong, Unsteady hydro magnetic free convection flow with radiative transfer in a rotating fluid, Astrophysics Space Sci.,1 (143), 1998, 73-80.

[6] A.M. Hossain, M. A. Alim and D.A.S. Rees, Int. J. Heat Mass Transfer, 42, 1999, 181-191.

[7] O. D. Makinde, Free convection flow with thermal radiation and mass transfer past a moving vertical porous plate, Int.Comm. Heat Mass Transfer, 32(10), 2005, 1411–1419.

[8] G. Pathak and C.H. Maheshwari, Effect of radiation on unsteady free convection flow bounded by an oscillating plate with variable wall temperature, International Journal of Applied Mechanics and Engineering, 11(2), 2006, 371-382.

[9] A.A. Mamun, Z. R. chowdhary, M. A. Azim and M. M. Molla, MHD conjugate heat transfer analysis for a vertical flate plate in presence of viscous dissipation and heat generation, International Journal of Communications in Heat and Mass Transfer, 35, 2008, 1275-1280.

[10] O. D. Mankinde and A. Aziz, MHD mixed convection from a vertical plate embedded in a poous medium with a convective boundary condition, International Journal of Thermal Sciences, 49, 2010, 1813-1820.

[11] V. Rajesh and S. V. K. Verma, Radiation effects on MHD flow through a porous medium with variable temperature and mass diffusion, International Journal of Applied Mathematics and Mechanics, 6(11), 2010, 39-57.

[12] S. S. Saxena, and G. K. Dubey, MHD free convection heat and mass transfer flow of visco-elastic fluid embedded in a porous medium of variable permeability with radiation effect and heat source in slip flow regime, Advances in Applied Science Research, 2(5), 2011, 115- 129.

[13] T. Sudhakar, M. C. Raju and S. V. K. Verma, Chemical reaction and radiation effects on MHD free convective flow through a porous medium bounded by a vertical surface with constant heat and mass flux, Journal of Computational and Applied Research in Mechanical Engineering, 3(1), 2013, 53-62.

[14] M. Kayalvizhi , R. Kalaivanan and N. Vishnu Ganesh, Velocity slip effects on heat and mass fluxes of MHD viscous–Ohmic dissipative flow over a stretching sheet with thermal radiation, Ain Shams Engineering Journal, 7, 2016, 791–797 .

[15] P. L. Chambre and J.D. Young, On the diffusion of a chemically reactive species in a laminar boundary layer flow, phys. Fluids flow, l(1), 1958, 48-54.

[16] M.A. Seddek, Finite-element method for the effects of Chemical Reaction, Variable Viscosity, Thermophoresis and Heat Generation/Absorption on a Boundary-layer Hydro Magnetic Flow with Heat and Mass Transfer Over a Heat Surface, Acta Mech 177, 2005, 1-18.

[17] A. Al-Mudhaf, A.J. Chamkha, Similarity solutions for MHD thermosolutal Marangoni convection over a flat surface in the presence of heat generation or absorption effects, Heat Mass Transfer, 42, 2005, 112-121.

[18] M. Sudheer Babu and P.V.Satyanarayana, Effects of the chemical reaction and radiation absorption on free convection flow through porous medium with variable suction in the presence of uniform magnetic field, Journal of Heat and mass transfer 3, 2009, 219-234.

[19] D. Pal and B. Talukdar , Perturbation analysis of unsteady magneto hydro dynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction, Communications in Nonlinear Science and Numerical Simulation, 15(7), 2010, 1813-1830.

[20] N. Kishan and P. Amrutha, Effects of viscous dissipation on MHD flow with heat and mass transfer over a stretching surface with heat source, thermal stratification and chemical reaction, Journal of Noval archit Marine Engineering, vol. 7, 2010, 11-18.

[21] K. Sarada and B. Shanker, The effect of chemical reaction on an unsteady MHD free convection flow past an infinite vertical porous plate with variable suction, International journal of Modern Engineering Research (IJNER), 3, 2013, 725-735.

[22] . J. Girish, Chemical reaction effects on MHD flow of continuously moving vertical surface with heat and mass flux through porous medium, International Journal of Science, Engineering and Technology Research, 2 (4), 881-886 (2013).

[23] P. Mangathai, G. V. Ramana Reddy and B. Rami Reddy , Heat and Mass Transfer Effects on MHD Free Convection Flow over an Inclined Plate Embedded in a Porous Medium, International Journal of Advanced Computer and Mathematical Sciences, 7(1), 2015, 1-12.

[24] M. A. Alim, M. D. Alam, and A. Mamun, Joule heating effect on the coupling of conduction with magnetohydrodynamic free convection flow from a vertical plate, Nonlinear Analysis Modelling and Control, 12(3), 2007, 307–316.

[25] G. Palani and K. Y. Kim, Joule heating and viscous dissipation effects on MHD flow past a semi-infinite inclined plate with variable surface temperature, Journal of Engineering Thermophysics, 20, 2011, 501-517.

International Journal of Engineering and Science Invention (IJESI) is UGC approved Journal with Sl. No. 3822, Journal no. 43302.

Bhavtosh Awasthi. "Joule Heating Effect in Presence of Thermal Radiation on MHD Convective Flow Past Over A Vertical Surface in A Porous Medium." International Journal of Engineering and Science Invention (IJESI), vol. 6, no. 9, 2017, pp. 30–40.