INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

MHD FLOW OVER AN INFINITE VERTICAL OSILATING POROUS PLATE WITH RADIATION ,CHEMICAL REACTION AND DUFOUR EFFECT

B Lavanya[1*], P.Sriveni[2], P. Ramireddy[3]
[1*]Department of Mathematics Priyadarshini College of Engineering. Nellore
[2]Academic consultant , Vikrama Simhapuri University kavali
[3]Research scholar of Krishna university Machalipatnam 521002 AP.
Correspondence Author*:* lavanyab2015@gmail.com

Keywords: Dufour effect, Radiation, chemical reaction, heat transfer, MHD, vertical plate.

Abstract
This work analyses the non linear MHD flow heat and mass transfer characteristics of an incompressible, viscous, electrically conducting and Boussinesq fluid over a vertical oscillating porous permeable plate in presence of homogeneous chemical reaction of first order, thermal radiation and Dufour effects. The problem is solved analytically using the perturbation technique for the velocity, the temperature, and the concentration field. The expression for the skin friction, Nusselt number and Sherwood number are obtained. The effects of various thermo-physical parameters on the velocity, temperature and concentration as well as the skin-friction coefficient, Nusselt number and Sherwood number has been computed and discussed qualitatively.

Introduction
Magnetohydrodynamics (MHD) is the branch of continuum mechanics which deals with the flow of electrically conducting fluids in electric and magnetic fields. Many natural phenomena and engineering problems are worth being subjected to an MHD analysis. Magnetohydrodynamic flows have applications in meteorology, solar physics, cosmic fluid dynamics, astrophysics, geophysics and in the motion earth’s core. In addition from the technological point view, MHD free convection flows have significant applications in the field of stellar and planetary magnetosphere, aeronautical plasma flows, chemical engineering and electronics. An excellent summary of applications is given by Huges and Young[1]. Raptis[2] studied mathematically the case of time varying two dimensional natural convective flow of an incompressible, electrically conducting fluid along an infinite vertical porous plate embedded in a porous medium. Helmy[3] analyzed MHD unsteady free convection flow past a vertical porous plate embedded in porous medium. Elabashbeshy[4] studied heat and mass transfer along a vertical plate in the presence of magnetic field. Chamkha[5] analyzed an unsteady, MHD convective, viscous incompressible, heat and mass transfer along a semi-infinite vertical porous plate in the presence of transverse magnetic field, thermal and concentration buoyancy effects.
The radiation effects have important applications in physics and engineering, particularly in space technology and high temperature processes. But very little is known about the effects of radiation on the boundary layer. Thermal radiation effects on the boundary layer may play important role in controlling heat transfer in polymer processing industry where the quality of the final product depends on the heat controlling factors to some extent. High temperature plasmas, cooling of nuclear reactors, liquid metal fluids, power generation systems are some important applications of radiative heat transfer. England and Emery [6] have studied the radiation effects of an optically thin gray gas bounded by a stationary plate. Raptis and Massalas [7] investigated the effects of radiation on the oscillatory flow of a gray gas, absorbing-emitting in presence induced magnetic field and analytical solutions were obtained with help of perturbation technique. They found out that the mean velocity decreases with the Hartmann number, while the mean temperature decreases as the radiation increases. The hydrodynamic free convective flow of an optically thin gray gas in the presence of radiation, when the induced magnetic field is taken into account was studied by Raptis *et al.* [8] using perturbation technique. They concluded that the velocity and induced magnetic field increase as the radiation increases. Hossain *et al.* [9] determined the effect of radiation on the natural convection flow of an optically dense incompressible fluid along a uniformly heated vertical plate with a uniform suction. Magnetohydro-dynamic mixed free–forced heat and mass convective steady incompressible laminar boundary layer flow of a gray optically thick electrically conducting viscous fluid past a semi-infinite vertical plate for high temperature and concentration differences have studied by Emad and Gamal [10]. Orhan and Kaya [11] investigated the mixed convection heat transfer about a permeable vertical plate in the presence of magneto and thermal radiation effects using the Keller box scheme, an efficient and accurate finite-difference scheme. They concluded that, an increase in the radiation parameter decreases the local skin friction parameter and increases the local heat transfer parameter. Ghosh *et al.* [12] considered an exact solution for the hydromagnetic natural convection boundary layer flow past an infinite vertical flat plate under the influence of a transverse magnetic field with magnetic induction effects and the transformed ordinary differential equations are solved exactly. As the importance of radiation in the fields of aerodynamics as well as space science technology, the present study is motivated towards this direction.

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

It has been found that energy flux can be generated not only by temperature gradient but also by concentration gradient as well. The energy flux caused by concentration gradient is called Dufour effect . These effects are very significant when the temperature and concentration gradient are very high. Anghel et al. [13] studied the Dufour and Soret effects on free convection boundary layer over a vertical surface embedded in a porous medium. Postelnicu [14] analyzed the influence of magnetic field on heat and mass transfer from vertical surfaces in porous media considering Soret and Dufour effects. Alam et al. [15] investigated the Dufour effects on steady MHD mixed convective and mass transfer flow past a semi-infinite vertical plate. Chamkha and Ben-Nakhi [16] analyzed MHD mixed convection-radiation interaction along a permeable surface immersed in a porous medium in the presence of Dufour's effects.
In many chemical engineering processes a chemical reaction between a foreign mass and the fluid does occurs. These processes take place in numerous industrial applications, such as the polymer production, the manufacturing of ceramics or glassware, the food processing and so on Singh *et.al*[17] analyzed the effects of chemical reaction and radiation absorption on MHD free convective heat and mass transfer flow past a semi-infinite vertical moving plate withtime dependent suction. Ibrahim et.al[18] presented the effect of chemical reaction and radiation absorption on MHD flow past a continuously moving permeable surface with heat source and time dependent suction.
The main objective of this paper was to explore the effects of Dufour , radiation , chemical reaction on MHD flow fluid over an infinite vertical oscillating porous plate . The magnetic field is imposed transversely to the plate. The temperature and concentration of the plate is oscillating with time about a constant nonzero mean value. The dimensionless governing equations involved in the present analysis are solved using a closed analytical method and discussed qualitatively and graphically.

Mathematical formulation.

Unsteady MHD flow of a viscous incompressible fluid past along a vertical oscillating plate with Thermal radiation and mass transfer effects on variable temperature and also with variable mass diffusion in the presence of transverse applied magnetic field has been studied. The x' – axis is taken along the plate in the vertical upward direction and the y'-axis is taken normal to the plate. Initially it is assumed that the plate and fluid are at the same temperature $T_\infty^{'}$ in the stationary condition with concentration level $C_\infty^{'}$ at all the points. At time t>0, the plate is given an oscillatory motion in its own plane with velocity $U_0\cos(w^{'}t^{'})$. At the same time the plate temperature is raised linearly with time and also mass is diffused from the plate linearly with time. A transverse magnetic field of uniform strength B_0 is assumed to be applied normal to the plate. The induced magnetic field and viscous dissipation is assumed to be negligible as the magnetic Reynold's number of the flow is taken to be very small. The fluid considered here is gray, absorbing/emitting radiation but a non-scattering medium. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations.

$$\frac{\partial u^{'}}{\partial t^{'}}=\frac{\partial^2 u^{'}}{\partial y^2}+g\beta(T^{'}-T^{'}{}_\infty)+g\beta^*(C^{'}-C^{'}{}_\infty)-\frac{u^{'}}{K^{'}}-\frac{\sigma}{\rho}B_0{}^2u^{'} \quad (1)$$

$$\frac{\partial T^{'}}{\partial t^{'}}=\frac{K}{\rho C_p}\frac{\partial^2 T^{'}}{\partial y^{'2}}-\frac{1}{\rho C_p}\frac{\partial^2 q_r}{\partial y^{'}}+\frac{D_m K_T}{C_S C_P}\frac{\partial^2 C'}{\partial y^2} \quad (2)$$

$$\frac{\partial C^{'}}{\partial t^{'}}=D\frac{\partial^2 C^{'}}{\partial y^{'2}}-k_{r^{'}}(c^{'}-c_\infty^{'}) \quad (3)$$

The boundary conditions for the velocity, temperature and concentration fields are:

$$t^{'}\le 0: u^{'}=0, T^{'}=T_\infty^{'}, C^{'}=C_\infty^{'}\forall y$$

$$t^{'}>0\begin{cases} u^{'}=U_0\cos(w^{'}t^{'}), T^{'}=T_\infty^{'}+\varepsilon(T_w^{'}+\varepsilon(T_w^{'}+T_\infty^{'})e^{n^{'}t^{'}}, C^{'}=C_\infty^{'}+\varepsilon(C_w^{'}+C_\infty^{'})e^{n^{'}t^{'}} at y^{'}=0 \\ u^{'}\to 0, T^{'}\to T_\infty^{'}, C^{'}\to C_\infty^{'} as y^{'}\to\infty \end{cases} \quad (4)$$

Where u' is the velocity in the x' –direction, K' is the permeability parameter, β is the volumetric coefficient of thermal expansion, β^* is the volumetric coefficient of expansion for concentration, ρ is the density, σ is the electrical conductivity, K- is the thermal conductivity, g is the acceleration due to gravity, T' is the temperature, T'_w is the fluid temperature at he plate, T'_∞ is the fluid temperature in the free stream, C' is the species concentration C_p is the specific heat at constant pressure, $C_\infty^{'}$ is the

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

species concentration in the free stream C'_w is the species concentration at surface, D is the chemical molecular diffusivity, q_r is the radiative heat flux.
The radiant absorption for the case of an optically thin gray gas is expressed as

$$\frac{\partial^2 q_r}{\partial y'} = 4a'\sigma'(T'^4_\infty - T'^4) \qquad (5)$$

Where σ' an a' are the Stefan-Boltzmann constant and the Mean absorption coefficient, respectively. we assume that the temperature differences within the flow are sufficiently small so that T'^4 can be expressed as a linear function of T' after using Taylor's series to expand T'^4 about the free stream temperature T'_∞ and neglecting higher order terms. This results in the following approximations.

$$T'^4 \cong 4T'^3_\infty T' - 3T'^4_\infty \qquad (6)$$

$$\frac{\partial T'}{\partial t'} = \frac{K}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{16a'\sigma'}{\rho C_p} T'^3_\infty (T' - T'_\infty) \qquad (7)$$

In order to write the governing equations and the boundary conditions in dimensionless form,the following non dimensional quantities are introduced.

$$\left.\begin{array}{l} u = \dfrac{u'}{u_0}, y = \dfrac{u_0 y'}{v}, t = \dfrac{t' u^2{}_0}{v}, \theta = \dfrac{T' - T'_\infty}{T'_w - T'_\infty}, \phi = \dfrac{C' - C'_\infty}{C'_w - C'_\infty}, \omega = \dfrac{\omega' v}{u_0^2} \\ K = \dfrac{K' u_0^2}{v^2}, \Pr = \dfrac{v\rho C_p}{k}, Sc = \dfrac{v}{D}, M = \dfrac{\sigma B_0^2 v}{\rho u_0^2}, Gr = \dfrac{v\beta g(T' - T'_\infty)}{u_0^3}, A = \dfrac{u_0^2}{v} \\ Gm = \dfrac{vg\beta^* C'_w - C'_\infty)}{u_0^3}, Kr = \dfrac{K'_r v}{u_0^2}, R = \dfrac{16a' v\sigma' T'^3_\infty}{k u_0^2}, Du = \dfrac{1}{V}\dfrac{D_m K_t}{C_S C_P}\dfrac{C'_w - C'_\infty}{T_w - T_\infty} \end{array}\right\} \qquad (8)$$

Using the transformations (8), the non dimensional forms of (1), (3) and (7) are

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + Gm\phi - (M + \frac{1}{K})u \qquad (9)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} - \frac{R}{\Pr}\theta + Du\frac{\partial^2 \phi}{\partial y^2} \qquad (10)$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - Kr\phi \qquad (11)$$

The corresponding boundary conditions are;

$$\begin{array}{llll} u = \cos(\omega t), & \theta = t, & \phi = t, & \text{at } y=0 \\ U \to 0 & \theta \to 0 & \phi \to 0 & \text{as } y \to \infty \end{array} \qquad (12)$$

Where *Gr, Gm, M, K, R, Pr ,Kr, Sc, Du,* are the magnetic parameter, permeability , Grashof number for heat transfer, Grashof number for mass transfer, Prandtl number, chemical reaction parameter, Schmidt number radiation parameter and dufour respectively.

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

Method of solution

In order to reduce the above system of partial differential equations to a system of ordinary differential equations in dimensionless form, we assume the trail solution for the velocity, temperature and concentration as:

$$u(y,t) = u_0(y)e^{i\omega t} \tag{13}$$

$$\theta(y,t) = \theta_0(y)e^{i\omega t} \tag{14}$$

$$\phi(y,t) = \phi_0(y)e^{i\omega t} \tag{15}$$

Substituting Equations (13), (14), and (15) in equations (9), (10) and (11) we obtain:

$$u_o'' - A_3^2 u_0 = -[Gr\theta_0 + Gm\phi_0] \tag{16}$$

$$\theta_o'' - A_2^2 \theta_0 = -Du\Pr\phi_0'' \tag{17}$$

$$\phi_o'' - A_1^2 \phi_0 = 0 \tag{18}$$

Here the primes denote the differentiation with respect to y.
The corresponding boundary conditions can be written as

$$u_0 = e^{i\omega t}\cos(\omega t)\ ,\quad \theta_0 = te^{i\omega t}\ ,\quad \phi_0 = te^{i\omega t} \quad \text{at} \quad y = 0$$

$$u_0 \to 0, \quad \theta_0 \to 0, \quad \phi_0 \to 0, \quad \text{as} \quad y \to \infty, \tag{19}$$

The analytical solutions of equations (16) - (18) with satisfying the boundary conditions (19) are given by

$$u_0(y) = (A_9 e^{-A_3 y} + A_6 e^{-A_2 y} + A_7 e^{-A_1 y} + A_8 e^{-A_1 y})e^{-i\omega t} \tag{20}$$

$$\theta_0(y) = (A_5 e^{-A_2 y} - A_4 e^{-A_1 y})e^{-i\omega t} \tag{21}$$

$$\phi_0(y) = (te^{-A_1 y})e^{-i\omega t} \tag{22}$$

In view of the above solutions, the velocity, temperature and concentration distributions in the boundary layer become

$$u_0(y) = A_9 e^{-A_3 y} + A_6 e^{-A_2 y} + A_7 e^{-A_1 y} + A_8 e^{-A_1 y} \tag{23}$$

$$\theta_0(y) = A_5 e^{-A_2 y} - A_4 e^{-A_1 y} \tag{24}$$

$$\phi_0(y) = te^{-A_1 y} \tag{25}$$

It is now important to calculate the physical quantities of primary interest, which are the local wall shear stress, the local surface heat, and mass flux. Given the velocity field in the boundary layer, we can now calculate the local wall shear stress (i.e., Skin-friction) is given by

$\tau_w^* = \mu\left(\frac{\partial u'}{\partial y'}\right)_{y'=0}$, and in dimensionless form, we obtain

$$C_f = \left(\frac{\partial u}{\partial y}\right)_{y=0} = A_3 A_9 + A_2 A_6 + A_1 A_8 + A_1 A_7$$

From temperature field, now we study the rate of mass transfer which is given in non-dimensional form as:

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = A_2 A_5 + A_1 A_4$$

From concentration field, now we study the rate os mass transfer which is given in non-dimensional form as:

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} = tA_1$$

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

Where

$$A_1 = \sqrt{Sc(Kr + i\omega)}, \qquad A_2 = \sqrt{i\omega \Pr + R}, \quad A_3 = \sqrt{M + i\omega + \frac{1}{K}}$$

$$A_4 = \frac{du \Pr A_1^2 t e^{i\omega t}}{A_1^2 + A_1 A_2^2}, \qquad A_5 = te^{iwt} + A_3, \qquad A_6 = \frac{-G\ r_5 A}{A_2^2 + A_2 A_3^2}, \qquad A_7 = \frac{GrA_4}{A_1^2 + A_1 A_3^2}, \quad A_8 = \frac{-Gm}{A_1^2 - A_1 A_3^2},$$

$$A_9 = e^{-i\omega t}\cos\omega t - A_6 - A_7 - A_8$$

Results and discussions:

To find out the results , analytical computation has been carried out using the method described in the previous paragraph of various governing parameters namely thermal Grashof number *Gr.* Modified Grashof number *Gm*, the magnetic field parameter *M*, permeability parameter *K*, prandtl number *Pr,* radiation parameter *R*, *Du* Dufour parameter, Schmidt number Sc and Kr chemical reaction parameter. in present study the following default parameter are adopted for computations *Gr=5, Gm=5, M=1, K=0.5, Pr=0.71, Sc=0.60, Du=0.1, Kr=0.5* $\omega = 1$. *t=pi/2.* All graphs therefore correspond to these values unless specically indicated on the appropriate graph. In order to get a physical insight in to the problem the effect of various governing parameters on the physical quantities are computed and represented in figures 1-14 and discussed in detail.

For the case of different values of thermal Grashof number the velocity profiles on the boundary layer are shown in Fig-1 shows the Velocity profiles for different value of magnetic parameter. As the magnetic parameter increases velocity decreases Fig.2. As expected, it is observed that an increase in Grashof number leads to increase in the values of velocity due to enhancement in buoyancy force. Here the positive values of Grashof number correspond to cooling of the surface. Fig-3 shows the velocity profile for radiation parameter as radiation parameter increases velocity decreases. Type of resisting force slows down the fluid velocity as shown in this figure. the velocity profiles for different values of the radiation parameter, clearly as radiation parameter increases the peak values of the velocity tends to increases. Fig.4 represents typical velocity profiles in the boundary layer for various values of the modified Grashof number, while all other parameters are kept at some fixed values. The velocity distribution attains a distinctive maximum value in the vicinity of the plate surface and then decrease properly to approach the free stream value. As expected, the fluid velocity increases and the peak value more distinctive due to increase in the concentration buoyancy effects represented by modified Grashof number. This is evident in the increase in the value of velocity as modified Grashof number increases. For different values of the Schmidt number the velocity profiles are plotted in Fig.5. It is obvious that an increase in the Schmidt number results in decrease in the velocity within the boundary layer. Fig.6 illustrates the behavior velocity for different values of chemical reaction parameter. It is observed that an increase in leads to a decrease in the values of velocity *Kr.* values of the velocity tends to increase. Fig.7 shows the velocity profiles for different values of the permeability parameter, clearly as permeability parameter increases the peak values of the velocity tends to increase. For different values of time on the velocity profiles are shown in Fig.8. It is noticed that an increase in the velocity with an increasing time *t.*

Fig.9 illustrates the temperature profiles for different values of Prandtl number. It is observed that the temperature decrease as an increasing the Prandtl number. The reason is that smaller values of Prandtl number are equivalent to increase in the thermal conductivity of the fluid and therefore heat is able to diffuse away from the heated surface more rapidly for higher values of Prandtl number. Hence in the case of smaller Prandtl number the thermal boundary layer is thicker and the rate of heat transfer is reduced. Fig.10 has been plotted to depict the variation of temperature profiles for different values of radiation parameter by fixing other physical parameters. From this Graph we observe that temperature decrease with increase in the radiation parameter *R.* for different values of dufour parameter on the temperature profiles are shown in Fig-11. it is noticed that an increase in the temperature with the increase in dufour parmeter. Fig.12 displays the effect of Schmidt number ***Sc*** on the concentration profiles respectively. As the Schmidt number increases the concentration decrease. Fig.13 illustrates the concentration profiles for different values of chemical reaction parameter . It is observed that concentration decreases with the increase in chemical reaction parameter .

From Table.1 shows the increase in magnetic field parameter increase in the skin friction. Table.2 indicates the increase in radiation parameter shows the increase in the skin friction and Nusselt number.Table 3. Displays the increase in Prandtl number displays the increase in skin friction and Nusselt number. Table-4. Effects of dufour shows the decrease in Nusselt number.

ISSN: 2349- 5197
Impact Factor (PIF): 2.138

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

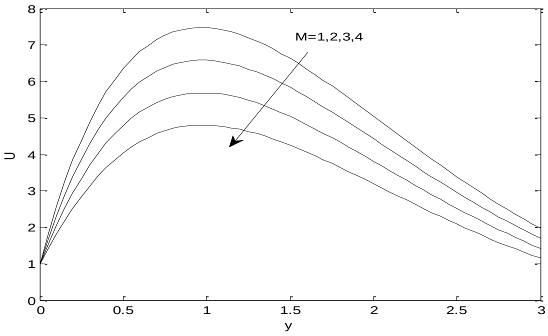

Fig -1. Velocity profiles for different values of magnetic parameter.

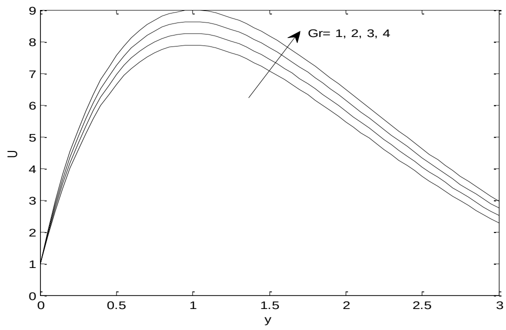

Fig-2. Velocity profiles for different values of Grash of number

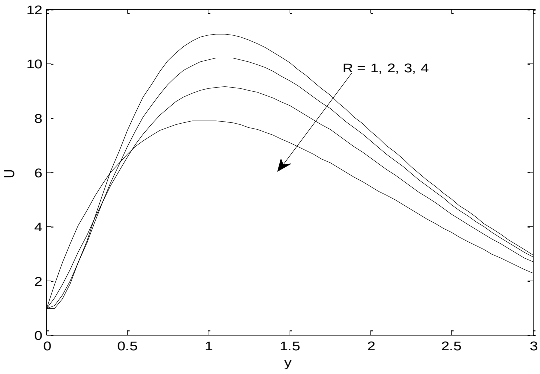

Fig-3. Velocity profiles for different values of radiation parameter.

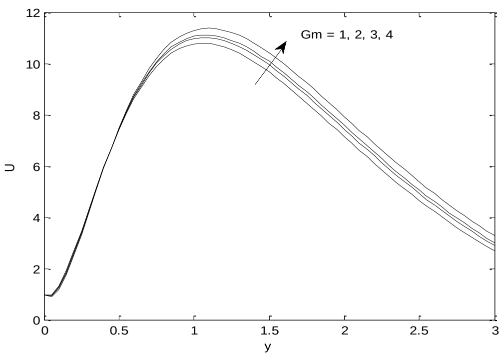

Fig-4. Velocity profiles for different values of modified Grashof number

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

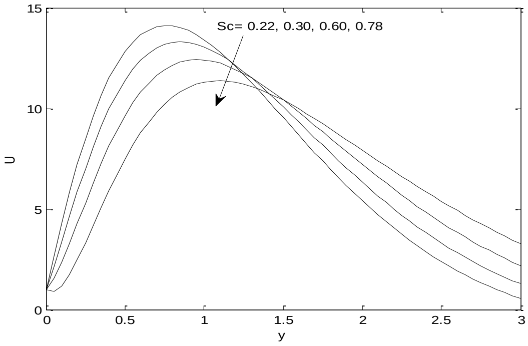

Fig-5. Velocity profiles for different values of Schmidt number.

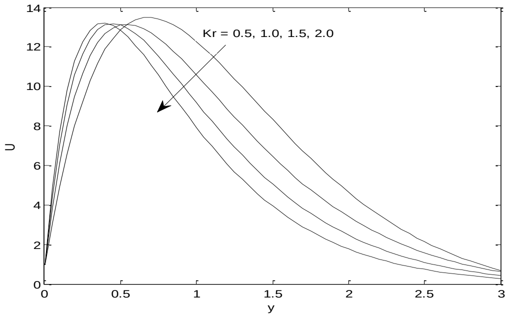

Fig-6. Velocity profiles for different values of Chemical reaction parameter.

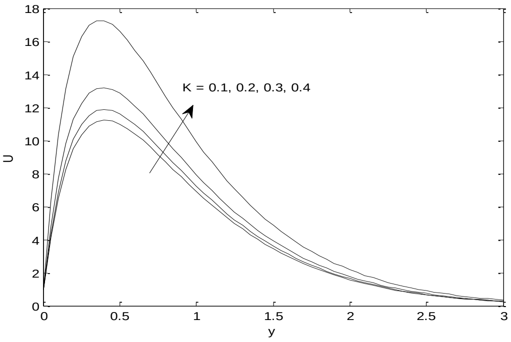

Fig-7. Velocity profiles for different values of permeability parameter.

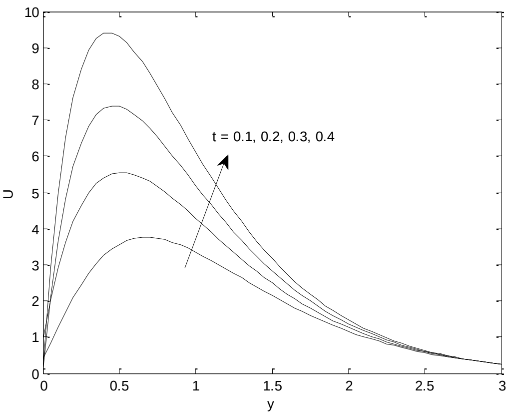

Fig-8. Velocity profiles for different values of time.

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

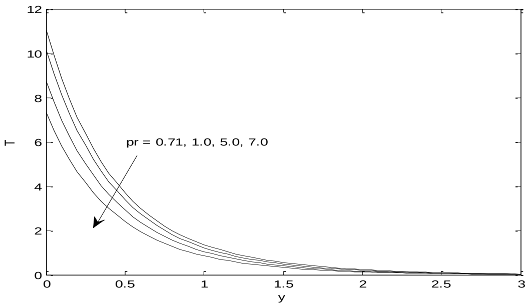

Fig-9. Temprature profiles for different values of Prandtl number.

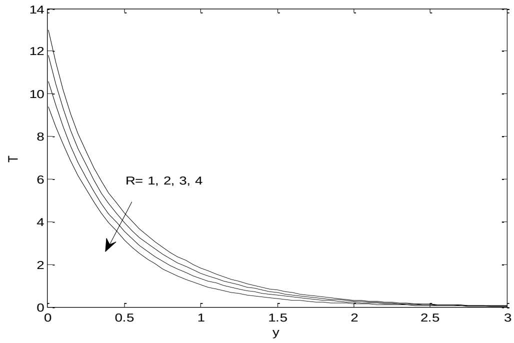

Fig-10. Temprature profiles for different values of Radiation parameter.

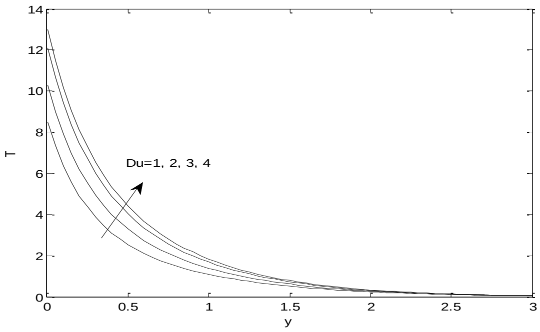

Fig-11. Temprature profiles for different value of Dufour effect

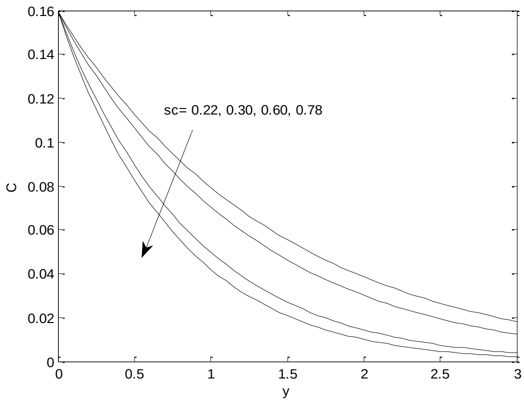

Fig-12. concentration profiles for different values Schmidt number.

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

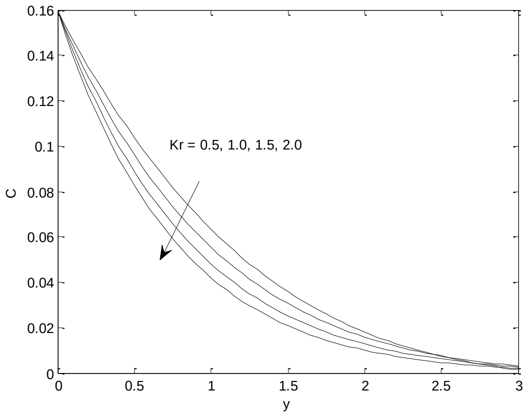

Fig-13. concentration profiles for different values chemical reaction parameter.

Table-1. Effects of magnetic parameter on skin friction.

M	*Cf*
1.0	0.5795
1.2	0.4001
1.3	0.3021
1.4	0.1987

Table-2. Effects of Radiation parameter on skin friction and nusselt number.

R	*Cf*	*Nu*
0.5	1.7282	1.8682
1.0	2.2127	2.4324
1.5	1.5578	2.9620
2.0	0.5795	3.4537

Table-3. Effects of Prandtl number on skin friction and Nusselt number.

Pr	*Cf*	*Nu*
0.71	-3.7966	4.3043
1.00	-3.9456	4.3198
5.00	1.1406	5.1234
7.00	5.5088	5.5500

Table-4. Effects of dufour number on Nusselt number.

Du	*Nu*
0.1	4.3198
0.2	4.3532
0.3	3.8332
0.4	3.5390

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

References

1. Huges WF and young FJ. The electro-magneto dynamics of fluids. Jhon wiley and sons, New York.
2. Raptis A. Flow through a porous medium in the presence of magnetic field. International journal of energy Resources, vol.10,pp.97-101.
3. Helmy KA.MHD unsteady free convection flow past a vertical porous plate.ZAMM, vol.78,pp.225-270.
4. Elabashbeshy EMA. Heat and mass transfer along a vertical plate with variable temperature and concentration in the presence of magnetic field. International journal of engineering sciences, vol.34,pp.515-522.
5. Chamka AJ . unsteady MHD convective heat and mass transfer past a semi –infinite vertical permeable moving plate with heat absorption. International journal of Engineering sciences, vol.42, pp.217-30.
6. England, W. G. and Emery, A. F. (1969): Thermal radiation effects on the laminar free convection boundary layer of an absorbing gas, J. of Heat Transfer, Vol. 91, pp. 37-44.
7. Raptis, A., and Massalas, C. V. (1998): Magnetohydrodynamic flow past a plate by the presence of radiation, Heat and Mass transfer, Vol. 34, pp. 107-109.
8. Raptis, A. A., Perdikis, C. and Leontitsis, A. (2003): Effects of radiation in an optically thin gray gas flowing past a vertical infinite plate in the presence of a magnetic field, Heat and mass Transfer, Vol. 39, pp. 771-773.
9. Hossain, M. A., Alim, M. A. and Rees, D. A. S. (1999): The effect of radiation on free convection from a porous vertical plate, Int. J. Heat and Mass Transfer, Vol. 42, No. 1, pp. 181-191.
10. Emad M. A. and Gamal El-Din A. A. (2005): Thermal radiation effects on magnetohydrodynamic flow past a semi-infinite vertical plate in the presence of mass diffusion, Can. J. Phys., Vol. 83, No. 3. Pp. 243–256.
11. Orhan A. and Ahmet K. (2008): Radiation effect on MHD mixed convection flow about a permeable vertical plate, Heat Mass Transfer, Vol. 45, pp. 239–246.
12. . S. K. Ghosh, Bég, O. A. and Zueco, J. (2009): Hydromagnetic free convection flow with induced magnetic field effects, Physics and Astronomy, Volume 45, Number 2, 175-185.
13. 27. M. Anghel, H.S. Takhar, I. Pop (2000), Dufour and Soret effects on free convection boundary layer over a vertical surface embedded in a porous medium, Stud. *Univ. Babes-Bolyai, Math*., 45, pp. 11–21, 2000.
14. 28. A. Postelnicu (2004), Influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects, *Int. J. Heat Mass Transfer*, 47, pp. 1467–1472.
15. 29. M.S. Alam, M.M. Rahman, M.A. Maleque, M. Ferdows (2006), Dufour and Soret effects on steady MHD combined free-forced convective and mass transfer flow past a semi-infinite vertical plate, *Thammasat Int. J. Sci. Technol*., 11(2), pp. 1–12.
16. 30. A.J. Chamkha, A. Ben-Nakhi (2008), MHD Mixed convection-radiation interaction along a permeable surface immersed in a porous medium in the presence of Soret and Dufour's Effects, *Heat Mass Transfer*, 44, pp. 845–856.
17. Singh H, Ram p and Kumar R: A study of the effect of chemical reaction and radiation absorption on MHD convective heat and mass transfer flow past a semi-infinite vertical moving plate with time dependent suction. International journal of appied Mathematical and Mechanics, Vol7(20):pp13-21.
18. Ibrahim FS, Elaiw AM and Bakr AA: effect of chemical reaction and radiation absorption on unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source/suction. Communication in Non-Linear Science and Numerical Simulation, Vol 13, pp.1056-1066.