IOSR Journal of Mathematics (IOSR-JM)
e-ISSN: 2278-5728, p-ISSN: 2319-765X. Volume 12, Issue 5 Ver. VI (Sep. - Oct.2016), PP 42-49
www.iosrjournals.org

Thermo-Diffusion Effects on Unsteady MHD Natural Convective Flow Past An Infinite Vertical Plate In Presence of Heat Absorption

K. Rajeshwar Reddy[1*] and M. Chenna Krishna Reddy[2]
[1]*Department of Mathematics, Malla Reddy College of Engg & Tech, Ranga Reddy-500100.*
[2]*Department of Mathematics, Osmania University, Hyderabad- 500007,*
Telangana State, India.

Abstract: *In this paper, we investigate the effects thermo-diffusion on unsteady MHD natural convective flow past an infinite vertical plate in presence of heat absorption. The dimensionless governing equations are solved numerically using Galerkin finite element method. The numerical results for some special cases were compared with previously published work and were found to be in good agreement. The effects of various pertinent flow parameters on velocity, temperature and concentration are shown graphically where as skin friction, Nusselt number and Sherwood number are presented in tabular form.*
Keywords: *Thermo-diffusion, Unsteady, MHD, Heat absorption, Finite element method.*

I. Introduction

The problem of free convective flow caused by combined buoyancy effects of thermal and mass diffusion has been analyzed by many researchers. It has many applications in various industries and environments such as nuclear power plants, polymer production, chemical catalytic reactors, food processing, and geophysical flows. Free convection flows that occurs in nature and in engineering practice is very large and has been extensively considered by many authors. When heat and mass transfer occurs simultaneously between the fluxes the driving potentials are more intricate in nature. An energy flux is generated not only by temperature gradients but by composition gradients as well. Temperature gradients can also create mass fluxes and this is the Soret or thermal-diffusion effect. Generally, the thermal-diffusion and diffusion-thermo effects of smaller order magnitude than the effects prescribed by Fourier's or Fick's laws and are often neglected in heat and mass transfer processes. Due to the importance of thermal-diffusion and diffusion-thermo effects for the fluids with very light molecular weight as well as medium molecular weight many investigators have studied and reported results for these flows and the contributors such as Dursunkaya and Worek [1], Anghel et al. [2], Postelnicu [3] are worth mentioning.

Abdul El – Aziz [4] has investigated the combined effects of thermal diffusion and diffusion thermo on MHD heat and mass transfer over a permeable stretching surface with thermal radiation. Afify [5] carried out an analysis to study free convective heat and mass transfer of an incompressible, electrically conducting fluid over a stretching sheet in the presence of suction and injection with thermal diffusion and diffusion thermo effects. Alam and Rahman [6] studied numerically the Dufour and Soret effects on mixed convection flow past a vertical plate embedded in a porous medium. Alam *et al.* [7] studied numerically the Dufour and Soret effects on combined free – forced convection and mass transfer flow past a semi – infinite vertical plate, under the influence of transversely applied magnetic field. Shivaiah and Anand Rao [8] have studied Chemical reaction effect on an unsteady MHD free convection flow past a vertical porous plate in the presence of suction or injection. Chamkha and Ben – Nakhi [9] considered the mixed convection flow with thermal radiation along a vertical permeable surface immersed in a porous medium in the presence of Soret and Dufour effects. Gaikwad *et al.* [10] investigated the onset of double diffusive convection in a two component couple of stress fluid layer with Soret, and Dufour effects using both linear and nonlinear stability analysis. Anand Rao and Shivaiah [11] analyzed Chemical reaction effects on an unsteady MHD flow past a semi – infinite vertical porous plate with viscous dissipation Hayat *et al.* [12] analyzed a mathematical model in order to study the heat and mass transfer characteristics in mixed convection boundary layer flow about a linearly stretching vertical surface in a porous medium filled with a viscoelastic fluid, by taking into account the diffusion thermo (Dufour) and thermal diffusion (Soret) effects. Influence of viscous dissipation and radiation on unsteady MHD free convection flow past an infinite heated vertical plate in a porous medium with time – dependent suction studied by Israel – Cookey *et al.* [13]. Kinyanjui *et al.* [14] presented simultaneous heat and mass transfer in unsteady free convection flow with radiation absorption past an impulsively started infinite vertical porous plate subjected to a strong magnetic field. Li *et al.* [15] took an account of the thermal diffusion and diffusion thermo effects, to study the properties of the heat and mass transfer in a strongly endothermic chemical reaction system for a porous medium. Lyubimova *et al.* [16] dealt with the numerical investigation of the influence of static and vibrational acceleration on the measurement of diffusion and Soret coefficients in binary mixtures, in low gravity conditions. Chamkha [17] studied Unsteady MHD convective heat and mass transfer past a semi – vertical permeable moving plate with heat absorption. Shivaiah and Anand Rao [18] investigated Soret and Dufour effects on transient MHD flow past a semi- infinite vertical porous plate with chemical reaction.

The object of the present paper is to study the thermo-diffusion on unsteady MHD natural convective flow past an infinite vertical plate in presence of heat absorption. The problem is governed by the system of coupled non – linear partial differential equations whose exact solutions are difficult to obtain, if possible. So, finite element method has been adopted for its solution, which is more economical from computational point of view.

II. Mathematical Formulation

An unsteady two – dimensional hydromagnetic laminar mixed convective boundary layer flow of a viscous, incompressible, electrically conducting and chemically reacting fluid in an optically thin environment, past a semi – infinite vertical permeable moving plate embedded in a uniform porous medium, in the presence of thermal radiation is considered. Th $x'-$ axis is taken in the upward direction along the plate and $y'-$ axis normal to it. The physical model and coordinate system are shown in figure (a). A uniform magnetic field is applied in the direction perpendicular to the plate. The transverse applied magnetic field and magnetic Reynolds number are assumed to be very small, so that the induced magnetic field is negligible. Also, it is assumed that the there is no applied voltage, so that the electric field is absent. The concentration of the diffusing species in the binary mixture is assumed to be very small in comparison with the other chemical species which are present, and hence the Soret and Dufour effects are negligible. Further due to the semi – infinite plane surface assumption, the flow variables are functions of normal distance y' and t' only. Now, under the usual Boussinesq's approximation, the governing boundary layer equations are:

Continuity equation:

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

Momentum equation:

$$\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = g\beta(T'-T'_\infty) + g\beta^*(C'-C'_\infty) - \frac{1}{\rho}\frac{\partial p'}{\partial x'} + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\nu}{K'}u' - \frac{\sigma B_O^2}{\rho}u' \tag{2}$$

Energy Equation:

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{1}{\rho C_P}k\frac{\partial^2 T'}{\partial y'^2} - \frac{S_o}{\rho C_P}(T'-T'_\infty) \tag{3}$$

Concentration Equation:

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} + \frac{D_m k_T}{T_m}\left(\frac{\partial^2 T'}{\partial y'^2}\right)$$

(4)

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

$$\left.\begin{array}{l} t'<0:\ u'=0,\ T'=0,\ C'=0 \quad for\ all\ \ y' \\ t'\ge 0:\begin{cases} u'=u'_p\ ,\ T'=T'_\infty+\varepsilon(T'_W-T'_\infty)e^{n't'},\ C'=C'_\infty+\varepsilon(C'_W-C'_\infty)e^{n't'}\ at\ \ y'=0 \\ u'=U'_\infty=U_O(1+\varepsilon A e^{n't'}),\ T'\to T'_\infty,\ C'\to C'_\infty\ as\ \ y'\to\infty \end{cases} \end{array}\right\} \tag{5}$$

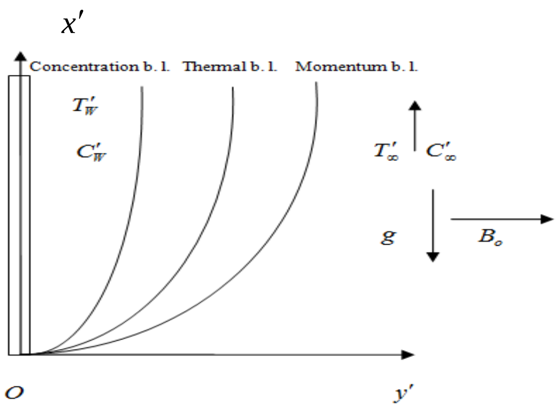

Figure a. Physical model and coordinate system

From equation (1) it is clear that the suction velocity at the plate is either a constant or function of time only. Hence the suction velocity normal to the plate is assumed in the form

$$v' = -V_O(1+\varepsilon A e^{n't'}) \tag{6}$$

Where $\varepsilon A << 1$. Here V_O is mean suction velocity, which are a non – zero positive constant and the minus sign indicates that the suction is towards the plate.

Outside the boundary layer, equation (2) gives

$$-\frac{1}{\rho}\frac{\partial p'}{\partial x'} = \frac{dU'_\infty}{dt'} + \frac{\nu}{K'}U'_\infty + \frac{\sigma}{\rho}B_o^2 U'_\infty \tag{7}$$

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

$$\left.\begin{array}{l} u = \dfrac{u'}{U_o},\ v = \dfrac{v'}{V_o},\ \eta = \dfrac{V_o y'}{\nu},\ t = \dfrac{t' V_o^2}{\nu},\ \Pr = \dfrac{\rho C_p \nu}{k},\ Sc = \dfrac{\nu}{D},\ \theta = \dfrac{T' - T'_\infty}{T'_w - T'_\infty},\ S = \dfrac{\nu S_o}{\rho C_p V_o^2},\ n = \dfrac{\nu n'}{V_o^2}, \\ \phi = \dfrac{C' - C'_\infty}{C'_w - C'_\infty},\ K = \dfrac{K' V_o^2}{\nu^2},\ Gr = \dfrac{g\beta\nu(T'_w - T'_\infty)}{U_o V_o^2},\ Gc = \dfrac{\nu g\beta(C'_w - C'_\infty)}{U_o V_o^2},\ M = \dfrac{\sigma B_o^2 \nu}{\rho V_o^2},\ K = \dfrac{K'\nu}{V_o^2}, \\ Sr = \dfrac{D_m k_T (T'_w - T'_\infty)}{\nu T_m (C'_w - C'_\infty)},\ U_\infty = \dfrac{U'_\infty}{U_o},\ U_p = \dfrac{u'_p}{U_o} \end{array}\right\} \tag{8}$$

In view of equations (5), (6), (7) and (8), equations (2), (3) and (4) reduce to the following dimensionless form:

$$\frac{\partial u}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial u}{\partial \eta} = \frac{dU_\infty}{dt} + Gr\theta + Gc\phi + \frac{\partial^2 u}{\partial \eta^2} + N(U_\infty - u) \tag{9}$$

$$\frac{\partial \theta}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial \theta}{\partial \eta} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial \eta^2} - S\theta \tag{10}$$

$$\frac{\partial \phi}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial \phi}{\partial \eta} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial \eta^2} + Sr\left(\frac{\partial^2 \theta}{\partial \eta^2}\right) \tag{11}$$

where $N = M + \left(\dfrac{1}{K}\right)$

The corresponding dimensionless boundary conditions are:

$$\left.\begin{array}{l} u = U_p,\ \theta = 1+\varepsilon e^{nt},\ \phi = 1+\varepsilon e^{nt}\ \ at\ \eta = 0 \\ u \to U_\infty,\ \theta \to 0,\ \phi \to 0\ \ as\ \eta \to \infty \end{array}\right\} \tag{12}$$

The mathematical formulation of the problem is now completed. Equations (9) – (11) are coupled non – linear systems of partial differential equations, and are to be solved by using the initial and boundary conditions given in equation (12). However, exact solutions are difficult if possible. Hence these equations are solved by finite element method. All the physical parameters are defined in the nomenclature.

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 and in dimensionless form, we obtain Knowing the temperature field, it is interesting to study the effect of the free convection and radiation on the rate of heat transfer. This is given by which is written in dimensionless form as

$$\tau = \frac{\tau_w}{\rho u_w^2},\ \tau_w = \left[\mu\frac{\partial u'}{\partial y'}\right]_{y'=0} = \rho U_o^2 u'(0) = \left[\frac{\partial u}{\partial \eta}\right]_{\eta=0} \tag{13}$$

The dimensionless local surface heat flux (i.e., Nusselt number) is obtained as

$$N_u(x') = \left[\frac{x'}{(T'_w - T'_\infty)}\frac{\partial T'}{\partial y'}\right]_{y'=0} \quad \text{then} \quad Nu = \frac{N_u(x')}{R_{e_x}} = \left[\frac{\partial \theta}{\partial \eta}\right]_{\eta=0} \tag{14}$$

The definition of the local mass flux and the local Sherwood number are respectively given by with the help of these equations, one can write

$$S_h(x') = \left[\frac{x'}{(C'_w - C'_\infty)} \frac{\partial C'}{\partial y'} \right]_{y'=0} \quad \text{then } Sh = \frac{S_h(x')}{R_{e_x}} = \left[\frac{\partial \phi}{\partial \eta} \right]_{\eta=0} \tag{15}$$

Where $R_{e_x} = \dfrac{U_o x'}{\nu}$ is the Reynold's number.

III. Method of Solution

The finite element method has been implemented to obtain numerical solutions of equations (9) – (11) under boundary conditions (12). This technique is extremely efficient and allows robust solutions of complex coupled, nonlinear multiple degree differential equation systems. The fundamental steps comprising the method are now summarized. An excellent description of finite element formulations is available in Bathe [19] and Reddy [20].

Step – 1: Discretization of the Domain into Elements

The whole domain is divided into finite number of "sub – domains", a process known as Discretization of the domain. Each sub – domain is termed a "finite element". The collection of elements is designated the "finite element mesh".

Step – 2: Derivation of the element Equations

The derivation of finite element equations $i.e.,$ algebraic equations among the unknown parameters of the finite element approximation, involves the following three steps.

a. Construct the variational formulation of the differential equation.
b. Assume the form of the approximate solution over a typical finite element.
c. Derive the finite element equations by substituting the approximate solution into variational formulation.

These steps results in a matrix equation of the form $\left[K^e\right]\left\{u^e\right\} = \left\{F^e\right\}$, which defines the finite element model of the original equation.

Step – 3: Assembly of Element Equations

The algebraic equations so obtained are assembled by imposing the "inter – element" continuity conditions. This yields a large number of algebraic equations constituting the "global finite element model", which governs the whole flow domain.

Step – 4: Impositions of Boundary Conditions

The physical boundary conditions defined in (12) are imposed on the assembled equations

Step – 5: Solution of the Assembled Equations

The final matrix equation can be solved by a direct or indirect (iterative) method. For computational purposes, the coordinate η is varied from 0 to $\eta_{\max} = 6$, where $\eta_{\max}$ represents infinity $i.e.,$ external to the momentum, energy and concentration boundary layers. The whole domain is divided into a set of 40 intervals of equal length 0.1. At each node 3 functions are to be evaluated. Hence after assembly of the elements we obtain a set of 123 equations. The system of equations after assembly of elements, are non – linear and consequently an iterative scheme is employed to solve the matrix system, which are solved using the Gauss Elimination method maintaining an accuracy of 0.0005.

IV. Results and discussions

The formulation of the problem that accounts for the thermo-diffusion on unsteady MHD natural convective flow past an infinite vertical plate in presence of heat absorption is performed in the preceding sections. The governing equations of the flow field are solved numerically by using a finite element method.

The above-presented equations enable us to carry out numerical computations. The following parameter values are adopted for computations unless otherwise indicated in the figures and table $Gr = 2.0,\ Gc = 1.0,\ M = 0.0,\ K = 0.5,\ \Pr = 0.7,\ S = 1.0,$ $Sc = 0.6,\ U_p = 0.5,\ A = 0.5,\ \varepsilon = 0.2,\ n = 0.1,\ and\ t = 1.0$ The boundary conditions for $\eta \to \infty$ are replaced by those at $\eta_{\max}$ where the value of $\eta_{\max}$ is sufficiently large, so that the velocity at $\eta = \eta_{max}$ is equal to the relevant free stream velocity. We choose $\eta_{max} = 6$. To assess the accuracy of the present method, comparisons between the present results and previously published data Chamkha [17], Table 1 shows the comparison between values of skin- friction coefficient τ, Nusselt number Nu and Sherwood number Sh on Gc. In fact, this results show an excellent agreement.

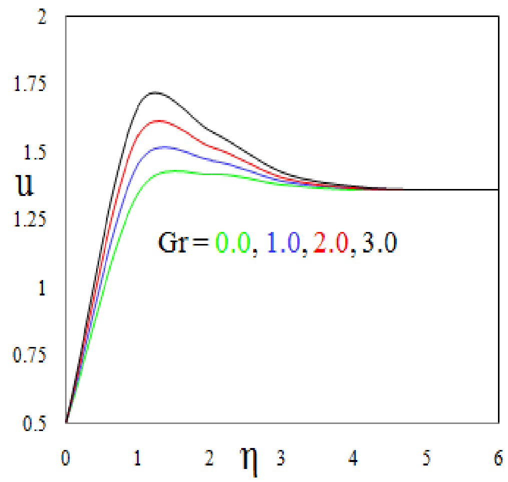

Figure 1. Effect of Gr on velocity profiles

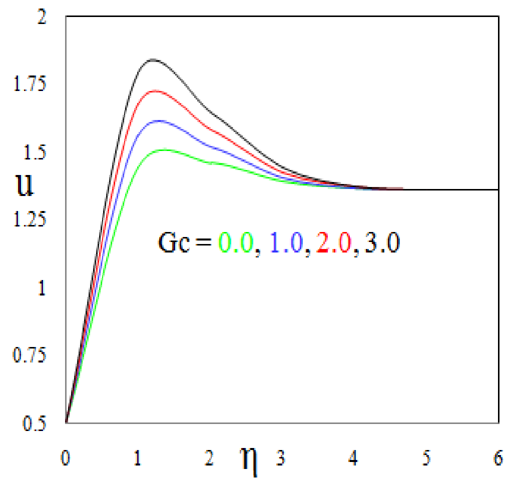

Figure 2. Effect of Gc on velocity profiles

Figures (1) and (2) exhibit the effect of thermal Grashof number and solutal Grashof numbers on the velocity profile with other parameters are fixed. The Grashof number signifies the relative effect of the thermal buoyancy force to the viscous hydrodynamic force in the boundary layer. As expected, it is observed that there is a rise in the velocity due to the enhancement of thermal buoyancy force. Also, as Gr increases, the peak values of the velocity increases rapidly near the porous plate and then decays smoothly to the free stream velocity. The solutal Grashof number defines the ratio of the species buoyancy force to the viscous hydrodynamic force. As expected, the fluid velocity increases and the peak value is more distinctive due to increase in the species buoyancy force. The velocity distribution attains a distinctive maximum value in the vicinity of the plate and then decreases properly to approach the free stream value. It is noticed that the velocity increases with increasing values of the solutal Grashof number. Figures (3) and (4) illustrate the influence of Heat absorption parameter on the velocity and temperature at t = 1.0 respectively. Physically speaking, the presence of heat absorption (thermal sink) effects has the tendency to reduce the fluid temperature. This causes the thermal buoyancy effects to decrease resulting in a net reduction in the fluid velocity. These behaviors are clearly obvious from figures (3) and (4) in which both the velocity and temperature distributions decrease as S increases. It is also observed that the both the hydrodynamic (velocity) and the thermal (temperature) boundary layers decrease as the heat absorption effects increase.

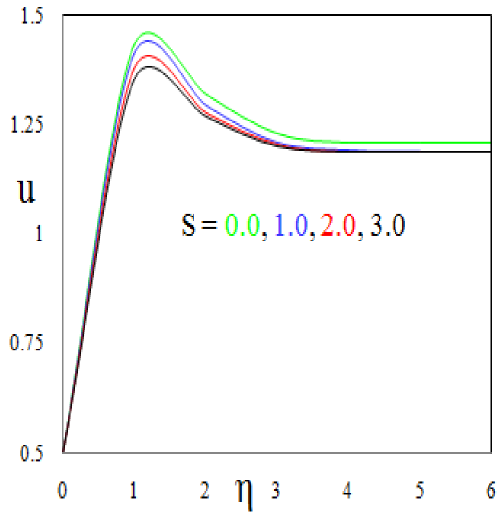

Figure 3. Effect of S on velocity profiles

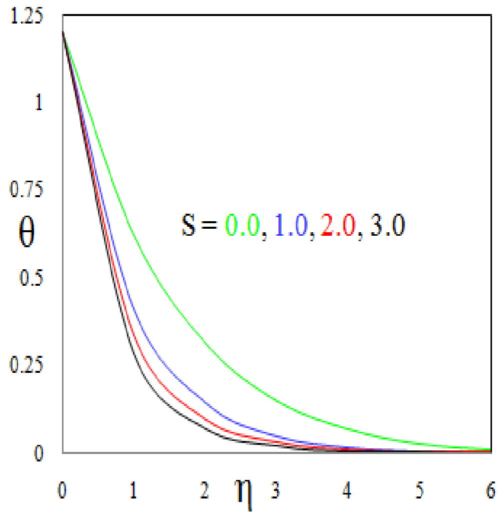

Figure 4. Effect of S on temperature profiles

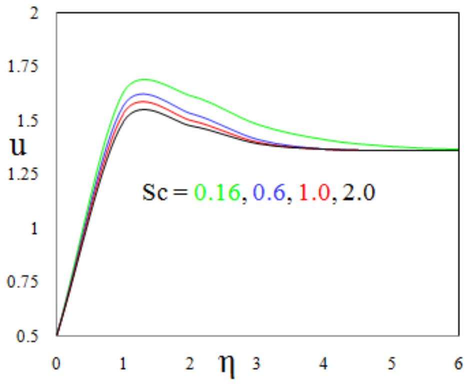

Figure 5. Effect of Sc on velocity profiles

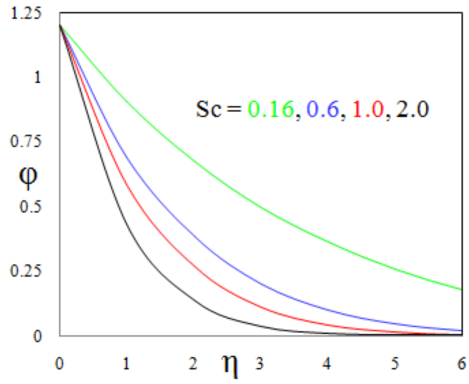

Figure 6. Effect of Sc on concentration profiles

The effect of Schmidt number Sc on the velocity and concentration are shown in figures (5) and (6). As the Schmidt number increases, the velocity and concentration decreases. This causes the concentration buoyancy effects to decrease yielding a reduction in the fluid velocity. Reductions in the velocity and concentration distributions are accompanied by simultaneous reductions in the velocity and concentration boundary layers. Figures (7) and (8) depict the Velocity and Concentration profiles for different values of the Soret number Sr. The Soret number Sr defines the effect of the temperature gradients inducing significant mass diffusion effects. It is noticed that an increase in the Soret number results in an increase in the velocity and concentration within the boundary layer.

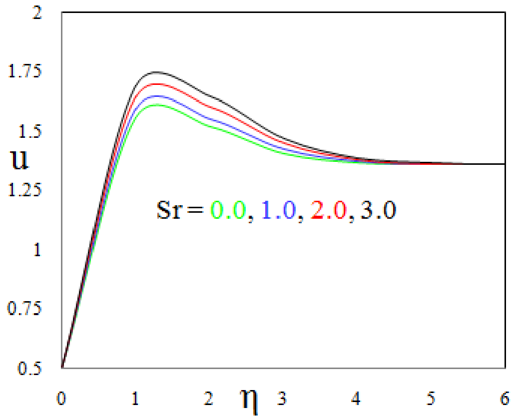

Figure 7. Effect of Sr on velocity profiles

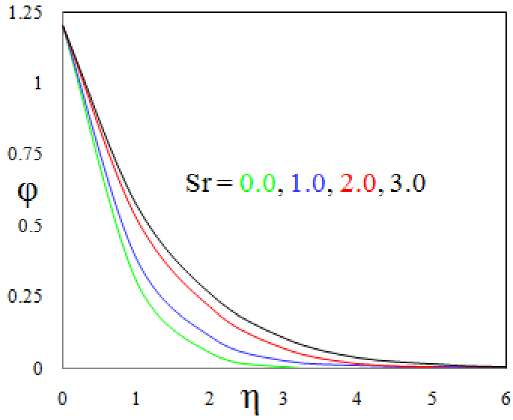

Figure 8. Effect of Sr on concentration profiles

Table 1. Effects of Gr on Skin – friction, Nusselt number and Sherwood number when $Sr = 0$.

	Present results			Previous results Chamka [17]		
Gc	τ	Nu	Sh	τ	Nu	Sh
0.0	2.7200	– 1 .7167	– 0 .8098	2.7200	– 1 .7167	– 0 .8098
1.0	3.2772	– 1 .7167	– 0 .8098	3.2772	– 1 .7167	– 0 .8098
2.0	3.8343	– 1 .7167	– 0 .8098	3.8343	– 1 .7167	– 0 .8098
3.0	4.3915	– 1 .7167	– 0 .8098	4.3915	– 1 .7167	– 0 .8098
4.0	4.9487	– 1 .7167	– 0 .8098	4.9487	– 1 .7167	– 0 .8098

Table 1 depict the effects of the solutal Grashof number on the skin-friction coefficient τ, Nusselt number Nu and the Sherwood number Sh. It is observed from these tables that as Gc increases, the skin-friction coefficient increases whereas the Nusselt and Sherwood numbers remain unchanged.

V. Conclusions

This paper considered thermo-diffusion on unsteady MHD natural convective flow past an infinite vertical plate in presence of heat absorption. The governing equations were non-dimensionalized and transformed into a non-similar form. The transformed equations were solved numerically using a finite element method. A representative set of the obtained results for the velocity, temperature, and concentration profiles was reported graphically for various parametric conditions. The skin-friction coefficient, Nusselt number and the Sherwood number was presented in tabular form. The conclusions of the study are as follows:

1. The velocity increases with the increase thermal Grashof number and solutal Grashof number.
2. Increasing the heat absorption parameter substantially decreases the velocity and the temperature.
3. The velocity as well as concentration decreases with an increase in the Schmidt number.
4. An increase in the Soret number leads to increase in the velocity and concentration.

References

[1] Dursunkaya, Z and Worek,W. M (1992), Diffusion-thermo and thermal-diffusion effects in transient and steady natural convection from vertical surface. *Int. J. Heat Mass Transfer,* Vol. 35(8), pp.2060–2065.

[2] Anghel, M., Takhar, H.S and Pop, I (2000), Dufour and Soret Effects on Free Convection Boundary Layer Over a Vertical Surface Embedded in a Porous Medium. *Mathematics, XI,* Vol. 4, pp. 11–21.

[3] Postelnicu, A (2004), Influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dofour effects. *Int. J. Heat Mass Transfer,* Vol. 47(6–7), pp. 1467–1472.

[4] Abdul El – Aziz, M (2008), Thermal diffusion and diffusion thermo effects on combined heat and mass transfer by hydromagnetic three dimensional free convection over a permeable stretching surface with radiation, *Physics Letters, Section A*, Vol. 372 (3), pp. 263 – 272.

[5] Afify, A. A, (2009), Similarity solution in MHD: Effects of thermal diffusion and diffusion thermo on free convective heat and mass transfer over a stretching surface considering suction or injection, *Communications in Nonlinear Science and Numerical Simulation*, Vol. 14 (5), pp. 2202 – 2214.

[6] Alam, M. S and Rahman, M.M, (2006), Dufour and Soret effects on mixed convection flow past a vertical porous flat plate with variable suction, *Nonlinear Analysis: Modelling and Control*, Vol. 11 (1), pp. 3 – 12.

[7] Alam, S., M. M. Rahman, A. Maleque and 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 International Journal of Science and Technology*, Vol. 11 (2), pp. 1 – 12.

[8] Shivaiah, S and Anand Rao, J, (2012), Chemical reaction effect on an unsteady MHD free convection flow past a vertical porous plate in the presence of suction or injection" *Theoretical and Applied Mechanics,* Vol.39.No.2, pp.185-208.

[9] Chamkha, A. J., 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 effect, *Heat Mass Transfer*, Vol. 44, pp. 845 – 856.

[10] Gaikwad, S. N., M. S. Malashetty and K. Rama Prasad, (2007), An analytical study of linear and non-linear double diffusive convection with Soret and Dufour effects in couple stress fluid, *International Journal of Non – Linear Mechanics*, Vol. 42 (7), pp. 903 – 913.

[11] Anand Rao, J and Shivaiah, S (2011). Chemical reaction effects on an unsteady MHD flow past a semi – infinite vertical porous plate with viscous dissipation", published in *Journal of Applied Mathematics and Mechanics (English Edition)*, Vol. 32, No.8, pp. 1065 – 1078.

[12] Hayat, T., M. Mustafa and I. Pop, (2010), Heat and mass transfer for Soret and Dufour effects on mixed convection boundary layer flow over a stretching vertical surface in a porous medium filled with a viscoelastic fluid, *Communications in Nonlinear Science and Numerical Simulation*, Vol. 15 (5), pp. 1183 – 1196.

[13] Israel – Cookey C., A. Ogulu and V. B. Omubo – Pepple, (2003), Influence of viscous dissipation and radiation on unsteady MHD free convection flow past an infinite heated vertical plate in a porous medium with time – dependent suction, *International Journal of Heat and Mass Transfer*, Vol. 46 pp. 2305 – 2311.

[14] Kinyanjui, M., J. K. Kwanza and S. M. Uppal, (2001), Magnetohydrodynamic free convection heat and mass transfer of a heat generating fluid past an impulsively started infinite vertical porous plate with Hall current and radiation absorption, *Energy Conversion and Management*, Vol. 42 (8), pp. 917 – 931.

[15] Li, M – C., Y – W. Tian and Y – C. Zhai, (2006), Soret and Dufour effects in strongly endothermic chemical reaction system of porous media, *Transactions of Nonferrous Metals Society of China*, Vol. 16 (5), pp. 1200 – 1204.

[16] Lyubimova, T., E. Shyklyaeva, J. Legros, C. Shevtsova, and V. Roux, (2005), Numerical study of high frequency vibration influence on measurement of Soret and diffusion coefficients in low gravity conditions, *Advances in Space Research,* Vol. 36, pp. 70 – 74.

[17] Chamkha, A.J, (2004), Unsteady MHD convective heat and mass transfer past a semi – vertical permeable moving plate with heat absorption. *International Journal of Engineering Science,* 42:217-230.

[18] Shivaiah, S and Anand Rao, J (2011), Soret and Dufour effects on transient MHD flow past a semi- infinite vertical porous plate with chemical reaction", published in *Journal of Naval Architecture Marine Engineering,* Vol. 8, pp.37-48.

[19] Bathe, K.J, (1996) Finite Element Procedures, Prentice – Hall, New Jersey.

[20] Reddy, J. N, (2006). An Introduction to the Finite Element Method, McGraw – Hill Book Company, New York, 3rd Edition.

Nomenclature:

A	Suction parameter
T'	Dimensionless temperature
T_w'	Wall temperature
T_∞'	Reference temperature
U'	Dimensional free stream velocity
t'	Dimensional time
g	Acceleration due to gravity
k	Dimensional porosity parameter
(u', v')	Dimensional velocity components

(x', y') Dimensional Cartesian coordinates
C_p Specific heat capacity
M Magnetic parameter
$\Pr$ Prandtl number
Gr Thermal Grashof number
Gc Solutal Grashof number
Sc Schmidt number
Sr Soret number
D Chemical diffusivity
D_m Molecular diffusivity
C_s Concentration susceptibility
k_T Mean absorption coefficient
C' Concentration
C'_w Concentration near the plate
C'_∞ Concentration in the fluid far away from the plate
U_0 Mean velocity of $U'(t')$
B_o Magnetic field
S_o Non dimensional Heat source
S Heat source parameter
T_m Fluid mean temperature
u'_p Plate velocity
n' Dimensional free stream
U_∞ Free stream velocity
K Permeability parameter
Nu Nusselt number
Sh Sherwood number

Greek symbols

ε Small positive parameter
β Coefficient of Volume expansion
β^* Volumetric coefficient of expansion with concentration
ν Kinematic viscosity
σ Electrical conductivity
ρ Fluid density
θ Temperature of a fluid
ϕ Concentration of a fluid
τ τ Skin – friction coefficient