Soret effect and Thermal Radiation on MHD free convective flow over a permeable stretching surface with suction, viscous dissipation and Chemical Reaction in the presence of heat generation

M. Dhanalakshmi* G. Vidyasagar[1] K. Jaya Rami Reddy** B. Ramana[1]
**Research Scholar, Dept. of Mathematics, K.L. University, Vijayawada, A.P., India.*
[1]Asst.Prof., Dept. of S&H, QIS College of Engineering and Technology, Ongole, A.P., India.
***Professor, Dept. of Mathematics, K.L. University, Vijayawada, A.P., India.*
Date of Publication: 25 January 2017

Abstract

In this paper we study for the steady two dimensional MHD free convection flow over a permeable stretching surface with suction, viscous dissipation and chemical reaction with heat generation. The governing systems of partial differential equations are converted to ordinary differential equations by using the similarity transformations numerically by Range Kutta fourth order along with shooting method. The dimensionless velocity, temperature and concentration are computed for different physical parameters and finally discussed with the graphs.

Keywords: *Free convection, viscous dissipation, heat generation, permeable parameter, stretching surface, chemical reaction, thermal radiation, Soret effect.*

INTRODUCTION

The study of unsteady MHD free convection flow with mass transfer along a vertical porous plate is receiving considerable attention of many researchers because of its various applications. Permeable porous plates are used in the filtration processes and also for a heated body to keep its temperature constant and to make the heat insulation of the surface more effective. Sometimes along with the free convection currents caused by difference in temperature the flow is also affected by the differences in concentration or material constitution. This type of flow has applications in many branches of science and engineering. Flow of an incompressible viscous fluid over a stretching surface is a classical problem in fluid dynamics and important in various process. It is used to create polymers of fixed cross-sectional profiles, cooling of metallic and glass plates. Aerodynamics shaping of plastic sheet by forcing through die and boundary layer along a liquid film in condensation processes are among the other areas of application. The production of sheeting material, which includes both metal and a polymer sheet arises in a number of industrial manufacturing processes. The pioneering work of Sakiadis [28] extensive literature is available on this topic for a linearly stretching sheet. A broad effort has been made to gain information regarding the stretching flow problems in various situations. Such situations include consideration of non-Newtonian fluids, MHD fluid, heat transfer; mass transfer, porous medium, slip effects, etc. A vast body of literature is now available on the topic. Some very recent attempts in this direction have been made in the investigations. Abbas and Hayata [1] studied radiation effects on MHD flow in a porous space. Afify [2] have investigated 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. Andersson [3] is studied MHD flow of a viscoelastic fluid past a stretching surface. Awang Kechil and Hashim [4] is studied Series solution of flow over nonlinearly stretching sheet with chemical reaction and magnetic field. Carragher and Crane [5] have discussed heat transfer on a continuous stretching sheet. Chakrabarti and Gupta [6] have discussed hydromagnetic flow and heat transfer over a stretching sheet. Chen [7] is studied marangoni effects on forced convection of power-law liquids in a thin film over a stretching surface. Chiam [8] is studied stagnation-point flow towards a stretching plate. Chiam [9] is studied hydromagnetic flow over a surface stretching with a power-law velocity. Cortell [10] reported as flow and heat transfer of a fluid through a porous medium over a stretching surface with internal heat generation/absorption and suction/blowing. Cortell [11] had studied the effects of viscous dissipation and work done by deformation on the MHD flow and heat transfer of a viscoelastic fluid over a stretching sheet, and considered with internal heat generation or absorption. Cortell [12] have investigated similarity solutions for flow and heat transfer of a quiescent fluid over a nonlinearly stretching surface.

Cortell [13] is studied viscous flow and heat transfer over a nonlinearly stretching sheet. Cortell [14] has studied the effects of viscous dissipation and radiation on the thermal boundary layer over a nonlinearly stretching sheet. Crane [15] had studied flow past a stretching plate. . Dutta *et al.* [16] have discussed temperature field in flow over a stretching sheet with uniform heat flux. El-Aziz [17] is studied 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. Khaled and Vafai [18] is studied the role of porous media in modeling flow and heat transfer in biological tissues. Liao [19] investigation on the proposed homotopy analysis techniques for nonlinear problems and its application. Liao [20] had studied unsteady boundary-layer flows caused by an impulsively stretching plate. Nazar *et al.* [21] had studied stagnation point flow of a micropolar fluid towards a stretching sheet. Puvi Arasu *et al.* [22] have discussed lie group analysis for thermal diffusion and diffusion-thermo effects on free convective flow over a porous stretching surface with variable stream conditions in the presence of thermophoresis particle deposition. Rajagopal *et al.* [23] studied flow of a viscoelastic fluid over a stretching sheet. Ray Mahapatra and Gupta [24] investigation heat transfer in stagnation-point flow towards a stretching sheet. Ray Mahapatra and Gupta [25] had studied stagnation-point flow of a viscoelastic fluid towards a stretching surface. Robert *et al.* [26] has discussed convective heat transfer in a conducting fluid over a permeable stretching surface with suction and internal heat generation/ absorption. Sadeghy *et al.* [27] studied realistic viscoelastic fluid models such as a Maxwell model should be invoked in the analysis. Indeed, this fluid model has recently been used to study the flow of viscoelastic fluids. Sakiadis [28] is studied boundary layer behavior on continuous solid surfaces. Vajravelu [29] studied viscous flow over a nonlinearly stretching sheet. Xu [30] had studied an explicit analytic solution for convective heat transfer in an electrically conducting fluid at a stretching surface with uniform free stream.Vidyasagar *et.al.* (31) studied MHD Convective heat and mass transfer flow over a permeable stretching surface with suction and internal heat generation/absorption. Srinivasa Rao.G *et. al.* (32) investigated Soret and Dufour effects on MHD Boundary layer flow over a Moving Vertical porous plate with suction. Sattar *et.al.* (33) studied Similar Solutions of an MHD Free Convection and Mass Transfer Flow with Viscous Dissipation.

In the present investigation a study of MHD free convective heat and mass transfer in a conducting fluid over a permeable stretching surface with suction, viscous dissipation and heat generation/absorption in the presence of chemical reaction. The basic equations governing the flow are in the form of partial differential equations and have been reduced to a set of non-linear ordinary differential equations by applying suitable similarity transformations. The equations governing the flow are solved numerically by Runge Kutta fourth order along with shooting technique. The expressions for velocity, temperature and concentration are obtained graphically. The effects of Grashof number (Gr), modified Grashof number (Gc), Suction parameter (S), Porosity parameter (K), heat generation\ absorption parameter (B), Prandtl number (Pr), Stretching parameter (C), Schmidt number (Sc), Radiation Parameter (Ra), Echet number (Ec), Soret effect (Sr) and Chemical reaction (Ch) are studied graphically.

Nomenclature:

u,v	:	Velocity components along the x and y axes
T	:	Fluid temperature inside the boundary layer
T_∞	:	Ambient temperature for away from the plate
T_w	:	Uniform constant temperature at the wall
C	:	Species concentration inside the boundary layer
C_∞	:	Species concentration of the ambient fluid
C_p	:	Specific heat at constant pressure
g	:	Acceleration due to gravity
$k^{'}$	:	Permeability of the porous medium
B_0	:	Uniform magnetic field
μ	:	Viscosity of fluid
Pr	:	Prandtl number
M	:	Magnetic parameter
Gr	:	Grashof number
Gc	:	Modified Grashof number
Sc	:	Schmidt number
K	:	Darcy permeability
D	:	Molecular diffusivity of the species concentration

K	:	Porosity parameter
C	:	Stretching parameter
k	:	Thermal conductivity
Q	:	Heat generation or absorption
s	:	Suction parameter

Greek Symbols:

θ	:	Dimensionless temperature
B	:	Dimensionless heat generation or absorption parameter
ρ	:	Fluid density
υ	:	Kinematics viscosity
σ	:	Electrical conductivity
β, β^*	:	Thermal and concentration expansion coefficient
α	:	Thermal diffusivity

INTRODUCTION

We consider the steady two dimensional stagnation point flow of a viscous incompressible electrically conducting fluid near a stagnation point at a surface coinciding with the plane y = 0, with the flow being restricted to y > 0. Two equal and opposing forces are applied along the x-axis so that the surface is stretched (while keeping the origin fixed). The potential flow that arrives from the y-axis (impinges on the flat wall at y = 0), divides into two streams on the wall and leaves in both directions. The flow is through a porous medium where the Darcy model is assumed. The viscous flow must adhere to the wall, whereas the potential flow slides along it. We denote the components of the fluid velocity by (u, v) at any point (x, y) for the viscous flow, while (U, V) denote the velocity components for the potential flow. We consider the case in which there may be a suction velocity (-W) on the stretching surface. Also, we denote the fluid temperature by T. The velocity distribution of the frictionless flow in the neighborhood of the stagnation point is becomes

$$U(x) = ax, \quad V(x) = -ay \qquad 5.1$$

where the parameter a > 0 is proportional to the free stream velocity. The continuity and momentum equations for the two dimensional steady flow, using the usual boundary layer approximations reduces to

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad 5.2$$

Momentum equation

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = -\frac{\partial p}{\partial x} + \mu\frac{\partial^2 u}{\partial y^2} + g\beta\rho(T - T_\infty) + g\beta^*\rho(C - C_\infty) - \sigma B_o^2 u - \frac{\mu}{K}u \qquad 5.3$$

Where $-\frac{\partial p}{\partial x} = U\frac{dU}{dx} + \frac{\sigma B_o^2}{\rho}U + \frac{\upsilon}{K}U$ 5.4

Energy equation

$$\rho c_p\left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = k\frac{\partial^2 T}{\partial y^2} + Q(T - T_\infty) - \frac{\partial q_r}{\partial y} + \mu\left(\frac{\partial u}{\partial y}\right)^2 \qquad 5.5$$

where $\frac{\partial q_r}{\partial y} = 4\alpha^2(T - T_\infty)$

Concentration equation

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_M\frac{\partial^2 C}{\partial y^2} + D_T\frac{\partial^2 T}{\partial y^2} + K_1(C - C_\infty) \qquad 5.6$$

Substitute the equation (5.4) in equation (5.3) then the equation (5.3) reduces to

$$\rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = U\frac{dU}{dx} + \mu\frac{\partial^2 u}{\partial y^2} + g\beta\rho(T - T_\infty) + g\beta^*\rho(C - C_\infty) + \sigma B_o^2(U - u) + \frac{\mu}{K}(U - u)$$

5.7

The corresponding boundary conditions are

$$u = cx,\ v = 0, T = T_w, C = C_w \quad at \quad y = 0$$
$$u = ax, T \to T_\infty, C \to C_\infty \quad as \ y \to \infty \qquad 5.8$$

where c > 0.

We introduce the following non-dimensional variables:

$$M = \frac{\sigma B_0^{\,2}}{\rho},\ B = \frac{Q}{c\rho C_p},\ \Pr = \frac{\rho\upsilon C_p}{k},\ K = \frac{\upsilon}{ck'},\ Sc = \frac{\upsilon}{D_M},\ s = \frac{W}{\sqrt{cv}},\ Gr = \frac{g\beta(T-T_\infty)}{xc^2}$$

$$Gc = \frac{g\beta^*(C-C_\infty)}{xc^2},\ \theta = \frac{T-T_w}{T_w-T_\infty}, \theta = \frac{C-C_w}{C_w-C_\infty}, Ra = \frac{4\alpha^2}{c\rho C_p}, B = \frac{Q}{c\rho C_p}, Ec = \frac{c^2x^2}{C_p(T-T_\infty)}$$

$$Sr = \frac{D_T(T_w-T_\infty)}{(C_w-C_\infty)}, Ch = \frac{K_1}{c} \qquad 5.9$$

$$\eta = \sqrt{\frac{c}{v}}y,\ \psi = \sqrt{cv}xf(\eta) \qquad 5.10$$

where ψ is the stream function defined as

$$u(x,y) = \frac{\partial\psi}{\partial y} = xcf'(\eta), \quad v(x,y) = -\frac{\partial\psi}{\partial x} = -\sqrt{cv}f(\eta) \qquad 5.11$$

In view of (5.9), (5.10) and (5.11) the Equations (5.5) to (5.7) take the form

$$f''' + ff'' - (f')^2 + Gr\theta + Gc\phi + (M+K)(C-f') + C^2 = 0 \qquad 5.12$$

$$\theta^{11} + \Pr f\theta^1 - \Pr(Ra-B)\theta + \Pr Ec(f'')^2 = 0 \qquad 5.13$$

$$\phi'' + Sc\, f\phi' + SrSc\theta'' + ScCh\phi = 0 \qquad 5.14$$

where the primes denote the differentiation with respect to η, K is the porosity parameter, M is the magnetic parameter, C = a/c > 0 is the stretching parameter, B is the dimensionless heat generation or absorption parameter, $\Pr$ is the Prandtl number, Sc is the Schmidt number, Sr is the Soret effect, Ecet number Ec, Radiation Parameter Ra and Chemical Reaction Ch.

The corresponding boundary conditions are

$$f' = 1, f = s,\ \theta = 1, \phi = 1 \quad \text{at} \quad \eta = 0$$
$$f' = C,\ \theta = 0, \phi = 0 \quad \text{as} \quad \eta \to \infty \qquad 5.15$$

SOLUTION OF THE PROBLEM

The governing boundary layer equations (5.12) to (5.14) subject to boundary conditions (5.15) are solved numerically by using shooting method. First of all higher order non-linear differential equations (5.12) to (5.14) are converted into simultaneous linear differential equations of first order and they are further transformed into initial value problem by applying Runge Kutta fourth order along with shooting technique.

RESULTS AND DISCUSSION

The problem under consideration has been solved numerically and the behavious of velocity, temperature and concentration have been computed for various in the governing parameters Grashof number(free convection parameter) Gr, modified Grashof number Gc, suction parameter *S*, porosity parameter K, magnetic parameter M, heat generation/absorption parameter *B*, Prandtl number $\Pr$, stretching parameter *C*, Schmidt number Sc, Chemical Reaction Ch, Soret effect Sr, Radiation parameter Ra and Echet number Ec are depicted in Figs.1-30, on the velocity $f'(\eta)$, temperature $\theta(\eta)$ and concentration $\phi(\eta)$. The effects of the grashof number (free convection parameter) *Gr* on the velocity, temperature and concentration are shown in Figs. 1-3. The velocity in the y direction decreases in magnitude with an increase in the free convection parameter *Gr* for air and an increase in *Gr* yields a uniform increases in temperature and concentration. Figs. 4-6 shows the dimensionless velocity, temperature and concentration for different values of modified grashof number *Gc*. It can be seen that the velocity decreases with the increase of modified grashof number *Gc*. It is noticed that the temperature and concentration increases with the increase of modified grashof number *Gc*. The various values of the suction/injection parameter S profiles for velocity, temperature and concentration are shown in Figs. 7-9. We find that the velocity increases with the increase of suction parameters. We notice that increases in S results in a uniform increase in the temperature and concentration. The effects of the porosity parameter *K* on velocity is shown in Fig. 10. It is observed that an increases in the permeability parameter *K* results in a decrease in the velocity. From fig. 11-13 we observed that the dimensionless Velocity, temperature and Concentration for different values of *B*. we observe that the velocity decreases with the increase of B. It is noticed that the temperature and Concentration increases with the increase of *B*. The influence of the Prandtl number *Pr* the temperature is shown in Fig. 14. It is noticed the temperature decreases with the increase of Prandtl number *Pr*. We plot the change in the velocity, temperature and concentration on the stretching parameter C is shown in Figs. 15-17. An increase in the stretching parameter results in an increases in the velocity. Meanwhile, an increase in the stretching parameter results in a decreases in the temperature or concentration. Figs. 18-20 shows the dimensionless velocity, temperature and concentration for different values of magnetic parameter M. It can be seen that the velocity decreases with the increase of magnetic parameter M. It is noticed that the temperature and concentration increases with the increase of magnetic parameter M. Figs. 21-22 shown that the velocity and concentration for different values of chemical reaction Ch. It can be seen that the velocity decreases with the increase of Ch it can be take the reverse action. We observe that the concentration increases with the increase of Ch. Figs. 23 shown that the temperature for different values of Echet number Ec. It is observed that the temperature increases with the increase of Ec. The effect of the radiation parameter on Tempareture is shown in fig. 24. It can be seen that the radiation parameter decreases with the increase of Ra. Figs. 25-26 shows that the velocity and concentration for different values of Soret number Sr. We seen that the velocity increases with the increase of Sr. It can be seen that the concentration decreases with the increase of Sr. The effects of the Schmidt number Sc on Velocity and concentration is shown in Fig. 27-28. We observed that the velocity increases with the increase of Sc. It is noticed that the concentration decreases with the increase of Schmidt number Sc.

I. FIGURES AND TABLES

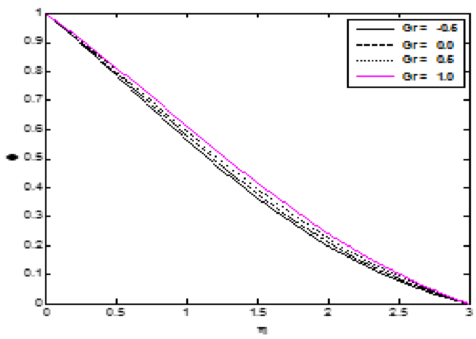


Fig (1) : The velocity profile for différent values of Gr

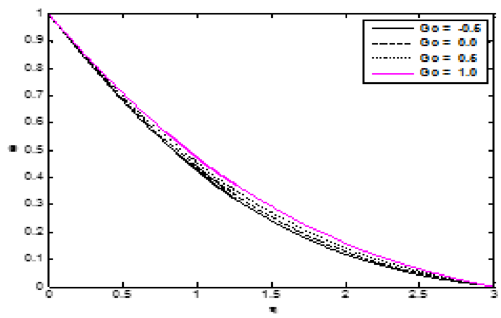


Fig (2) : The Température profile for différent values of Gr.

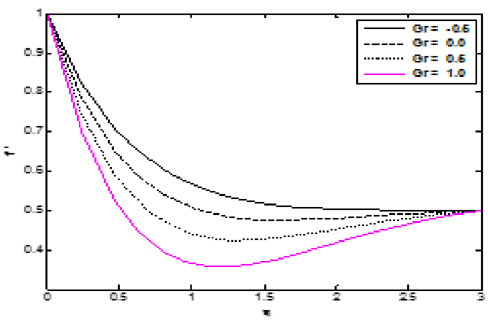


Fig (3) : The Concentration profile for different values of Gr

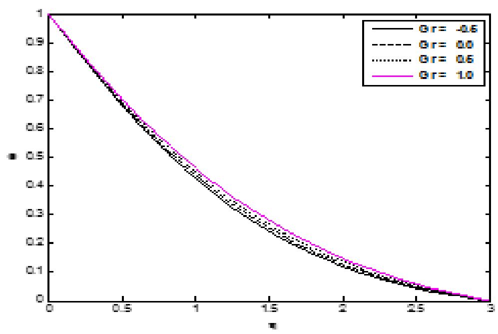


Fig (4) :The Velocity profile for different values of Gc

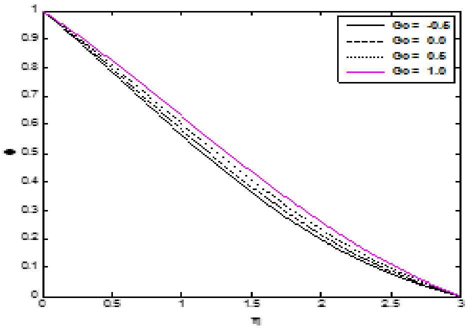
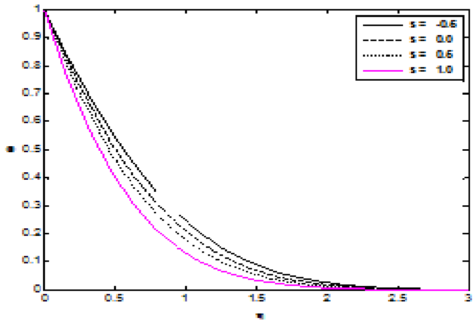
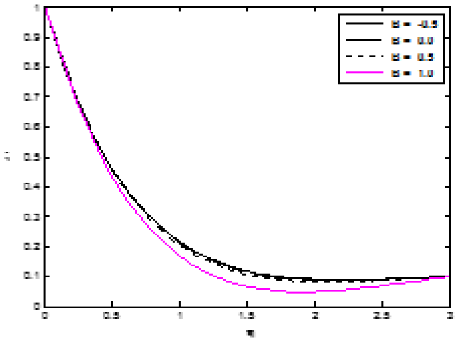


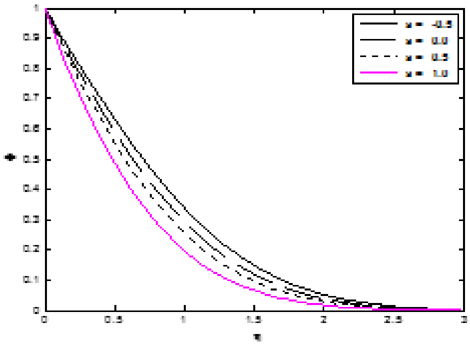
Fig (5) : The Temprature profile for different values of Gc



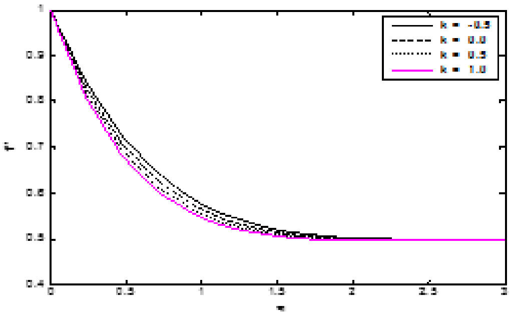
Fig(6) : The Concentration profile for different values of Gc



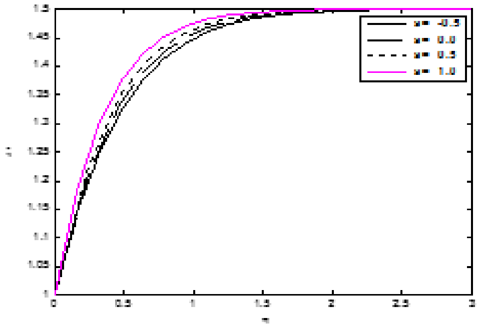
Fig(7) : The Velocity profile for different values of s



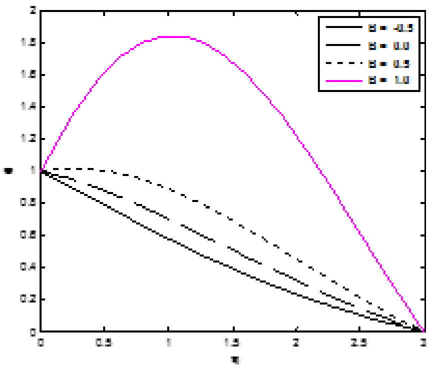
Fig(8) : The Temprature profile for different values of s



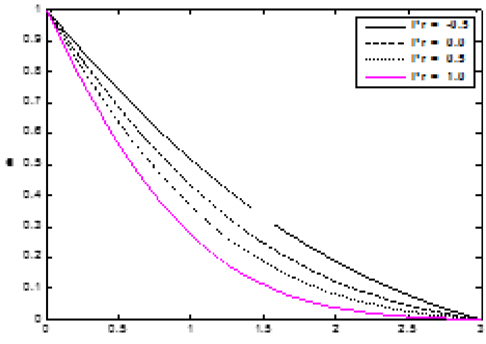
Fig(9) : The concentration profile for different values of s



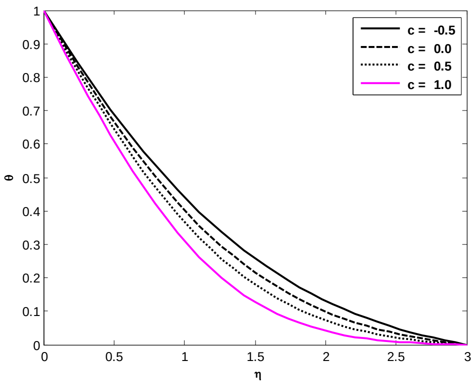
Fig(10) : The Velocity profile for different values of K



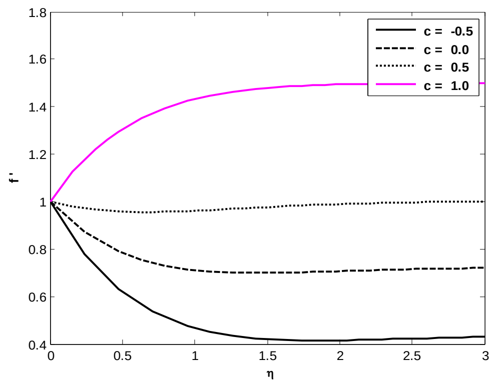
Fig(11) : The Velocity profile for different values of B



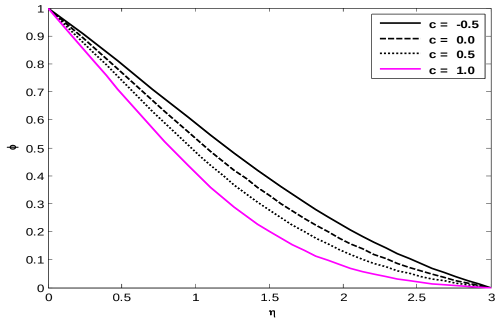
Fig(12) : The Temprature profile for different values of B



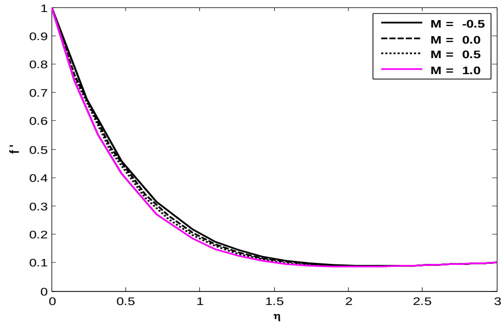
Fig(14) : The Temprature profile for different values of Pr



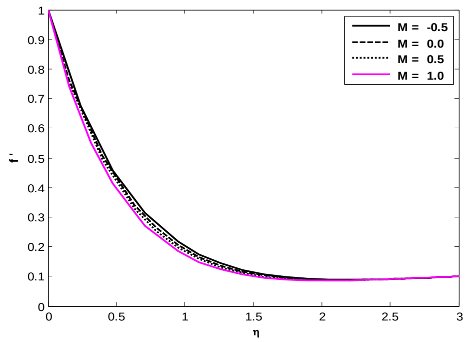
Fig(15) : The Velocity profile for different values of C



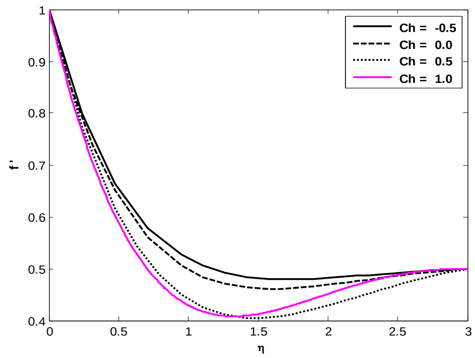
Fig(16) : The Temprature profile for different values of C



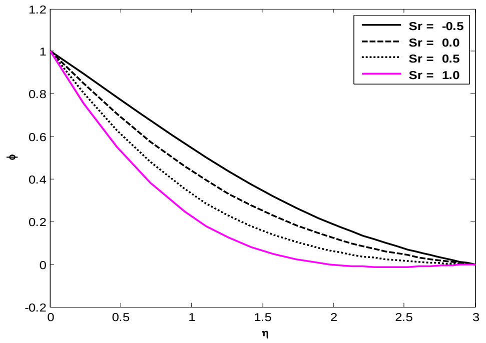
Fig(17) : The Concentration profile for different values of C



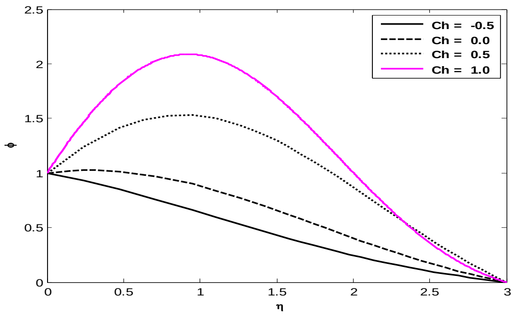
Fig(18) : The Velocity profile for different values of M



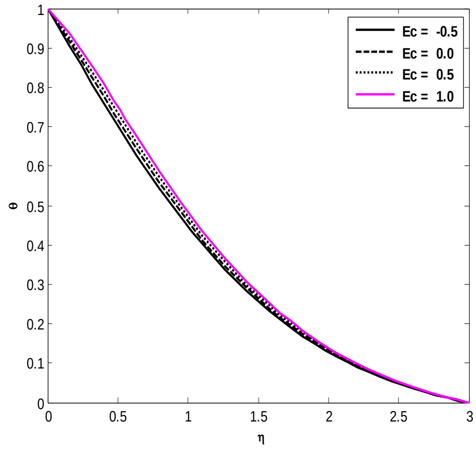
Fig(19) : The Temprature profile for different values of Ec



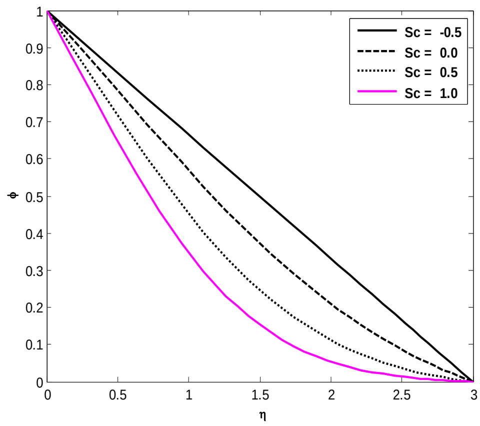
Fig(20) : The Velocity profile for different values of Ch



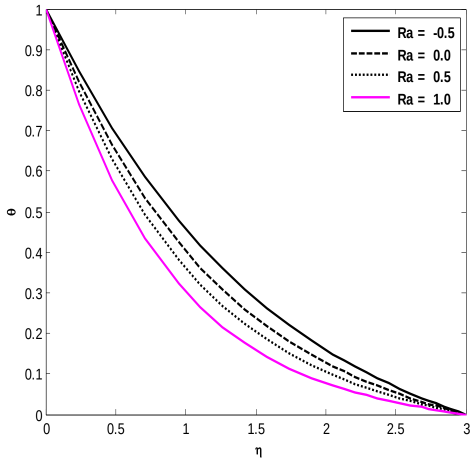
Fig(21) : The Concentration profile for different values of Ch



Fig(22) : The Temprature profile for different values of Ec



Fig(23) : The Concentration profile for different values of Sc



Fig(24) : The Concentration profile for diffèrent values of Sr

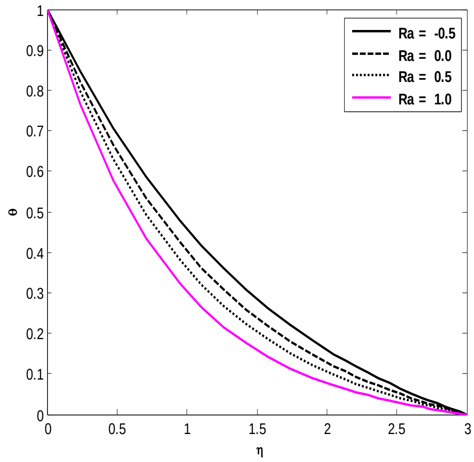


Fig. (25) : The Temperature profile for different values of Ra

CONCLUSION

In this chapter we study of MHD free convective heat and mass transfer in a conducting fluid over a permeable stretching surface with suction, viscous dissipation and heat generation/absorption in the presence of chemical reaction. The expressions for the velocity, temperature and concentration distributions are the equations governing the flow are numerically solved by Runge Kutta fourth order along with shooting technique.

- It can be seen that the velocity decreases with the increase of magnetic parameter M. It is noticed that the temperature and concentration increases with the increase of magnetic parameter M.
- An increase in the stretching parameter results in an increases in the velocity. Meanwhile, an increase in the stretching parameter results in a decreases in the temperature or concentration.
- It can be seen that the velocity decreases with the increase of magnetic parameter M. It is noticed that the temperature and concentration increases with the increase of magnetic parameter M.
- It is observed that an increases in the permeability parameter *K* results in a decrease in the velocity.
- It is noticed that the concentration decreases with the increase of Schmidt number Sc.
- It can be seen that the velocity decreases with the increase of Ch it can be take the reverse action. We observe that the concentration increases with the increase of Ch.
- It can be seen that the radiation parameter decreases with the increase of Ra.
- It is observed that the temperature increases with the increase of Ec.
- We seen that the velocity increases with the increase of Sr. It can be seen that the concentration decreases with the increase of Sr.

REFERENCES

[1] Abbas Z and Hayata T (2008). Radiation effects on MHD flow in a porous space, *Int. J. of Heat and Mass Transfer*, Volume 51, Issues 5-6, March, Pages 1024-1033.

[2] 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, no. 5, pp. 2202–2214,.

[3] Andersson H.I. (1992). MHD flow of a viscoelastic fluid past a stretching surface. *Acta Mechanica*, vol. 95, pp. 227-230.

[4] Awang Kechil R and Hashim I (2007). Series solution of flow over nonlinearly stretching sheet with chemical reaction and magnetic field, *Physics Letters a*, In Press,.

[5] Carragher P and Crane L J. (1982). Heat transfer on a continuous stretching sheet, *ZAMM,* vol. 62, pp. 564 – 565.

[6] Chakrabarti A. and Gupta A. S. (1979). Hydromagnetic flow and heat transfer over a stretching sheet, *Q. Appl. Math*, vol. 37, pp. 73-78.

[7] Chen C. H. (2007). Marangoni effects on forced convection of power-law liquids in a thin film over a stretching surface, *Physics Letters A*, vol. 370 (1), pp. 51–57.

[8] Chiam T.C. (1994). Stagnation-point flow towards a stretching plate, *J. Phys. Soc. Jpn*. Vol. 63 2443–2444

[9] Chiam, T. C (1995). Hydromagnetic flow over a surface stretching with a power-law velocity, *Int. J. Engg. Sci*. vol. 33, pp. 429-435.

[10] Cortell R (2005). Flow and heat transfer of a fluid through a porous medium over a stretching surface with internal heat generation/absorption and suction/blowing, *Fluid Dyn. Res.* Vol. 37, pp. 231–245.

[11] Cortell R (2006). Effects of viscous dissipation and work done by deformation on the MHD flow and heat transfer of a viscoelastic fluid over a stretching sheet, *Phys. Lett. A,* vol. 357, pp. 298–305.

[12] Cortell Bataller R (2007). Similarity solutions for flow and heat transfer of a quiescent fluid over a nonlinearly stretching surface, *Journal of Materials Processing Technology*, In Press.

[13] Cortell R (2007). Viscous flow and heat transfer over a nonlinearly stretching sheet, *Applied Mathematics and Computation*, Volume 184, Issue 2, pp. 864-873.

[14] Cortell R (2008). Effects of viscous dissipation and radiation on the thermal boundary layer over a nonlinearly stretching sheet, *Physics Letters A*, Vol 372, (5), pp. 631-636.

[15] Crane L J (1970). Flow past a stretching plate, *ZAMP,* vol. 21, pp. 645–647.

[16] Dutta B.K, Roy P and Gupta A S (1985). Temperature field in flow over a stretching sheet with uniform heat flux, *Int. Commun. Heat and Mass Transfer.* Vol. 12, pp 89– 94.

[17] . El-Aziz M. A. (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 a,* vol. 372, (3), pp. 263–272.

[18] Khaled A.R.A and Vafai K (2003). The role of porous media in modeling flow and heat transfer in biological tissues, *Int. J. Heat Mass Transf.* vol. 46, pp. 4989–5003.

[19] Liao S.J. (1992). On the proposed homotopy analysis techniques for nonlinear problems and its application, Shanghai Jiao Tong University.

[20] Liao S J (2006). An analytic solution of unsteady boundary-layer flows caused by an impulsively stretching plate, Commun. *Non-linear Sci. Numer. Simul*. Vol. 11, pp. 326–339.

[21] Nazar R, Amin N and Filip D. I. Pop (2004). Stagnation point flow of a micropolar fluid towards a stretching sheet, *Int. J. Nonlinear Mech*. Vol. 39, pp. 1227–1235.

[22] Puvi Arasu P., Loganathan P., Kandasamy R., and Muhaimin I. (2011). Lie group analysis for thermal diffusion and diffusion-thermo effects on free convective flow over a porous stretching surface with variable stream conditions in the presence of thermophoresis particle deposition, *Nonlinear Analysis: Hybrid Systems*, vol. 5 (1), pp. 20–31.

[23] Rajagopal K.R., Na T.Y and Gupta A.S. (1984). Flow of a viscoelastic fluid over a stretching sheet, Rheol. *Acta.* Vol. 23, pp. 213–215.

[24] Ray Mahapatra. T and Gupta A.S. (2002). Heat transfer in stagnation-point flow towards a stretching sheet, *Heat Mass Transfer*. vol. 38, pp. 517–521.

[25] Ray Mahapatra T and Gupta A.S. (2004). Stagnation-point flow of a viscoelastic fluid towards a stretching surface, *Int. J. Nonlinear Mech*. Vol. 39, pp. 811–820.

[26] Robert .A, Van Gorder and Vajravelu K. (2011). Convective heat transfer in a conducting fluid over a permeable stretching surface with suction and internal heat generation/ absorption. *J. of Appl. Math. and Comp. (Elsevier)*, vol. 217, pp 5810 - 5821.

[27] Sadeghy K, Najafi A N and Saffaripour M (2005). Sakiadis flow of an upper-convected Maxwell fluid, *Int. J. Non-Linear Mech*. Vol. 40, pp. 1220 – 1228.

[28] Sakiadis B.C. (1966). Boundary layer behavior on continuous solid surfaces, *AICHE J.* vol. 7, pp 26 - 28.

[29] Sattar, M.A., Rahman M.M. and Samad M.A. (2001). Similar Solutions of an MHD Free Convection and Mass Transfer Flow with Viscous Dissipation, *Dhaka Univ. J. Sci.* 49, 67-78.

[30] Srinivasa Rao.G, Ramana B, Rami Reddy B and Vidyasagar G *(*2014). Soret and Dufour effects on MHD Boundary layer flow over a Moving Vertical porous plate with suction, International Journal of Emerging Trends in Engineering and Development, Vol.2, Issue 4, pp. 215-226.

[31] Vajravelu K (2001),. Viscous flow over a nonlinearly stretching sheet, *Appl. Math. and Comp.*, Vol 124 (3), pp. 281-288.

[32] Vidyasagar G, Ramana B and Bala Anki Reddy (2013). MHD Convective heat and mass transfer flow over a permeable stretching surface with suction and internal heat generation/absorption, International Journal of Advanced Engineering Technology, Vol 4, Issue 1, pp. 41-45.

[33] Xu H (2005). An explicit analytic solution for convective heat transfer in an electrically conducting fluid at a stretching surface with uniform free stream, *Int. J. Eng. Sci*. 43, pp. 859–874.