International Journal of Engineering, Science and Mathematics
Vol. 7Issue 2, February 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

INFLUENCE OF VISCOUS DISSIPATION AND VARIABLE SUCTION ON STEADY MHD MIXED CONVECTION FLOW PAST A VERTICAL POROUS FLAT PLATE WITH DUFOUR AND SORET EFFECTS

J VENKATA MADHU
Department of Mathematics, SNIST, Ghatkesar, Hyderabad-501301, Telangana State, INDIA.

ABSTRACT:

This work is focused on the influence of Viscous dissipation and variable suction on free-combined flow past a semi-infinite vertical flat plate with Dufour and soret effects under the influence of transversely applied magnetic field, have been studied numerically. The resulting governing equations are transformed into non linear ordinary differential equations using similarity transformation. The set of non linear ordinary differential equations are first linearized by using Quasi-linearization technique and then solved numerically by using implicit finite difference scheme. Then the system of algebraic equations is solved by using Gauss-Seidal iterative method. Numerical results of hydrogen-air mixture fluid for the velocity, temperature and concentration are shown graphically for various values of the parameter entering into the problem.

Keywords : Magnetic field effects, Soret and Dufour effects, variable suction and viscous dissipation.

INTRODUCTION:

In the process of involving high temperatures, the radiation heat transfer in combination with conduction, convection and mass transfer plays very important role in the design of pertinent equipments in the areas such as nuclear power plants, gas turbines and the various propulsion devices for air craft, missiles, satellites and space vehicles. A comprehensive reviews on this area have been made by many researchers some of them are Nield and Bejan [1], Ingham and Pop [2,3], Bejan and Khair [4] and Trevisan and Bejan [5].

The previous studies, the diffusion-thermo (Dufour) and thermal-diffusion (Soret) terms were neglected from the energy and concentration equations respectively. But when heat and mass transfer occur simultaneously in a moving fluid, the relations between the fluxes and the driving potentials are of a more intricate nature. It has been found that an energy flux can be generated not only by temperature gradients but by composition gradients as well. The energy flux caused by a composition gradient is called the Dufour or diffusion-thermo effect. On the other hand, mass fluxes can also be created by temperature gradients and this is the Soret or thermal diffusion effect. In general, the thermal-diffusion (Dufour) and the diffusion thermo (Soret) effects are of a smaller order of magnitude than the effects described by Fourier's or Fick laws and are often neglected in heat and mass-transfer processes. For medium molecular weight (N_2, air), the dufour effect was to be of considerable magnitude such that it cannot be neglected Eckert and Drake [6]. In view of the importance of these above effects, Kafoussias and Williams [7] studied thermal-diffusion and diffusion-thermo effects on mixed free-forced convective and mass transfer boundary layer flow with temperature dependent viscosity. Recently, Angel *et al*. [8] investigated the Dufour and Soret effects on free convection in a porous medium. Very recently, Postelnicu [9] used an implicit finite difference method to study the influence of a magnetic field on heat and mass transfer by natural convection from vertical surface in a porous media considering Soret and Dufour effects. Therefore, the objective of this paper is to investigate the Dufour and Soret effects on steady combined free-forced convective and mass transfer flow past a vertical porous flat plate with variable suction in the presence of a uniform transverse magnetic field.

Viscous dissipation which, appears as a source term in the fluid flow generates appreciable temperature, gives the rate at which mechanical energy is converted into heat in a viscous fluid per unit volume. However in the existing convective heat transfer literature the effect of the viscous dissipation has been generally disregarded. J. Venkata Madhu, M. N. Rajasekhar and B. Shashidar Reddy[10] have studied Effects of viscous dissipation and thermal stratification on chemical reacting fluid flow over a vertical stretching surface with heat source. Kishan and Shashidar Reddy [11] have studied the MHD effects on non-Newtonian power-law fluid past a continuously moving porous flat plate with heat flux and Viscous Dissipation.

MATHEMATICAL FORMULATION:

We consider the combined free-forced convective and mass transfer flow of a viscous, incompressible and electrically conducting fluid over an isothermal semi-infinite vertical flat plate under the influence of a transversely applied magnetic field is considered. The flow is assumed to be in the x-direction, which is taken along the vertical plate in the upward direction and the y-axis is taken normal to the plate. The surface of the plate is maintained at a uniform constant temperature T_w and a uniform constant concentration C_w, which are higher than the corresponding values T_∞ and C_∞ respectively, sufficiently far away from the flat surface. The magnetic Reynolds number of the flow is taken to be small enough so that the induced magnetic field is assumed to be negligible in comparison with the applied magnetic field so that $\boldsymbol{B}$ = (0, B_o, 0), where B_o is the uniform magnetic field action normal to the plate. The equation of conservation of electric charge $\nabla\cdot\boldsymbol{J} = 0$ gives J_y = constant, where $\boldsymbol{J}=(J_x, J_y, J_z)$ since the plate is electrically non-conducting, this constant is zero and hence $J_y = 0$ everywhere in the flow. Under the boundary layer and Darcy-Boussinesq approximations, the basic boundary layer equations are given by

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

(1)

$$u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y} = \nu\frac{\partial^2 v}{\partial y^2} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\sigma B_0^2 u}{\rho} - \frac{\nu u}{k}$$

... (2)

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} + \frac{(T_p - T_\infty)h^2}{C_p}\left(\frac{\partial u}{\partial x}\right)^2 + \frac{D_m k_T}{c_s c_p}\frac{\partial^2 C}{\partial y^2}$$

... (3)

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_m\frac{\partial^2 C}{\partial y^2} + \frac{D_m k_T}{T_m}\frac{\partial^2 T}{\partial y^2}$$

... (4)

The appropriate boundary conditions for the above problem are as follows

$$\left.\begin{array}{l} u=0,\ v=\pm V(x),\ T=T_w,\ C=C_w,\quad at \quad y=0 \\ u\to U_\infty,\ T\to T_\infty,\ C\to C_\infty,\quad at \quad y\to\infty \end{array}\right\}$$ …

(5)

We now introduce the following dimensionless variables:

$$\left.\begin{array}{l} \eta = y\sqrt{\dfrac{U_\infty}{\nu x}} \\ \psi = \sqrt{\nu x U_\infty}\, f(\eta) \\ \theta(\eta) = \dfrac{T-T_\infty}{T_w-T_\infty} \\ \phi(\eta) = \dfrac{C-C_\infty}{C_w-C_\infty} \end{array}\right\}$$ …

(6)

From the continuity equation (1), we have

$$\frac{\partial v}{\partial y} = -\frac{\partial u}{\partial x}$$ …

(7)

Integrating both sides of (7) with respect to *y*, we get

$$v = -\frac{1}{2}\sqrt{\frac{U_\infty \upsilon}{x}}\ \left[f(\eta)-\eta f'(\eta)\right]$$ …

(8)

Introducing the relations (6) and (8) into the equations (2) – (4), we get the following dimensionless equations which are locally similar:

$$f''' + \frac{1}{2} ff'' + g_s\theta + g_c\phi - \left[M+\frac{1}{Da\,\mathrm{Re}^2}\right] f' = 0$$

… (9)

$$\theta'' + \frac{1}{2}\Pr f\theta' + \Pr D\phi'' + P_r E_c \left(f''(y)\right)^2 = 0$$

... (10)

$$\phi'' + \frac{1}{2} Scf\phi' + ScSr\theta'' = 0$$ ...

(11)

The relevant boundary conditions in dimensionless form are:

$$\left.\begin{aligned} f = f_w,\ f' = 0,\ \theta = 1,\ \phi = 1 \quad at \quad \eta = 0 \\ f' = 1,\ \ \theta = 0,\ \ \phi = 0 \quad as \quad \eta \to \infty \end{aligned}\right\}$$ ...

(12)

Where primes denote differentiation with respect to the variable η

NUMERICAL PROCEDURE:

To solve the system of transformed governing equations (9) - (11) with the boundary conditions (12), we first linearized equation (9) by using Quasi linearization technique. Then by using implicit finite difference scheme, these equations are transformed to matrix equation form.

Now the computation procedure is employed to obtain the numerical solutions in which first the momentum equation is solved to obtain the values of f using which the solution of energy and concentration equations are solved under the given boundary conditions using Thomas algorithm[12] for various parameters entering into the problem and computations were carried out by using C programming.

The numerical solutions of f are considered as $(n+1)^{th}$ order iterative solutions and F are the n^{th} order iterative solutions. After each cycle of iteration the convergence check is performed, and the process is terminated when $|F - f| < 10^{-4}$.

RESULTS AND DISCUSSIONS:

Numerical computations have been carried out for different values of S_r, *D* and for fixed values of Pr, *Sc*, g_s, g_c, *Da* and Re. The dimensionless parameter g_s is used to represent the free, forced and combined(free-forced) convection regime, and the corresponding parameter g_c takes the value 0.1 for low concentration. The case $g_s \ll 1$ corresponds to pure forced convection, g_s=1 corresponds to combined free-forced convection and g_s>>1 corresponds to pure free convection.

The numerical results for the velocity, temperature and concentration profiles are shown in Figures 1 – 7.

In Figure 1, velocity profiles are shown for different values of g_s and g_c. It is seen from this figure that the velocity profiles increases with the increase of g_s. And the velocity reaches maximum inside the boundary layer.

The variation of temperature and concentration fields for different values of g_s and g_c are displayed in Figures 2 and 3 respectively. As would be expected, both fields exhibit the same behavior. The influence of g_c on the temperature and concentration field is not so much evident for higher values of g_s.

The effects of Soret and Dufour numbers on the velocity field are shown in Figure 4. We observe that quantitatively when η = 2.0 and *Sr* decreases from 2.0 to 0.4 (or *D* increases from 0.03 to 0.15) there is increase in the velocity value, whereas the corresponding increase is 3.38% when *Sr* decreases from 0.4 to 0.08.

The effects of Soret and Dufour numbers on the temperature field are shown in Figure 5. We observe that quantitatively when η = 2.0 and *Sr* decreases from 2.0 to 0.4 (or *D* increases from 0.03 to 0.15) there is increase in the temperature value, whereas the corresponding increase is 15.49%, when *Sr* decrease from 0.4 to 0.08.

The effects of Soret and Dufour numbers on the concentration field are shown in Figure 6. We observe that quantitatively when η = 2.0 and *Sr* decreases from 2.0 to 0.4 (or *D* increases from 0.03 to 0.15) there is 33.62% decrease in the concentration value, whereas the corresponding decrease is 3.34%, when *Sr* decrease from 0.4 to 0.08.

The dimensionless temperature profiles for different values of Eckert number with fixed values of S_r, *D* ,Pr, *Sc*, g_s, g_c, and uniform magnetic field are demonstrated in Figure 7. It is seen that the temperature of the fluid rises with the increase of Eckert number.

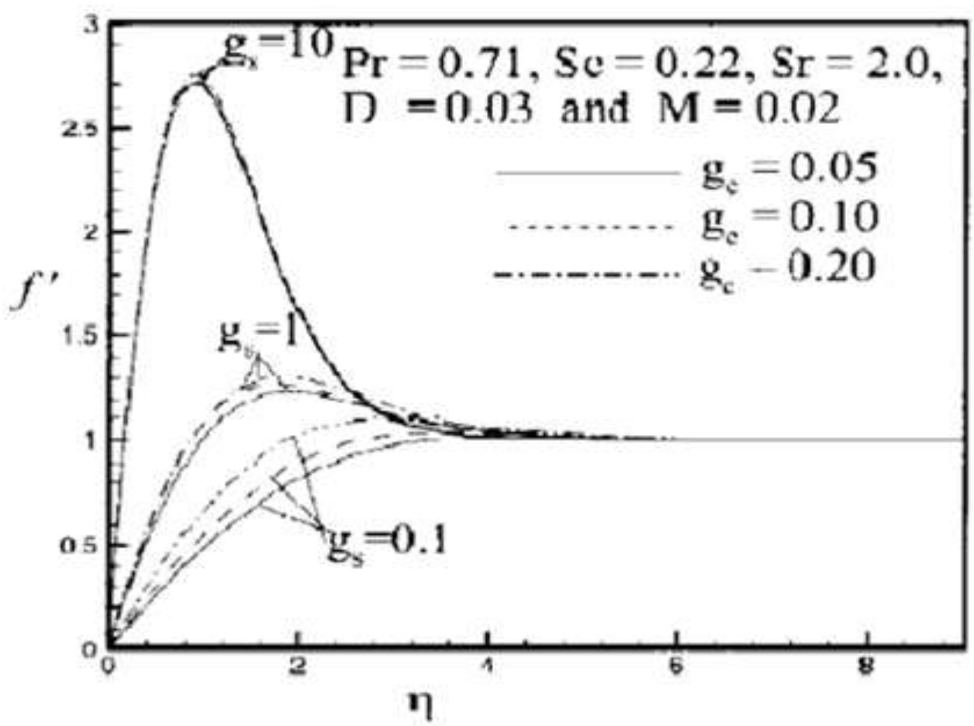

Fig 1 velocity profiles for different values of g_s and g_c

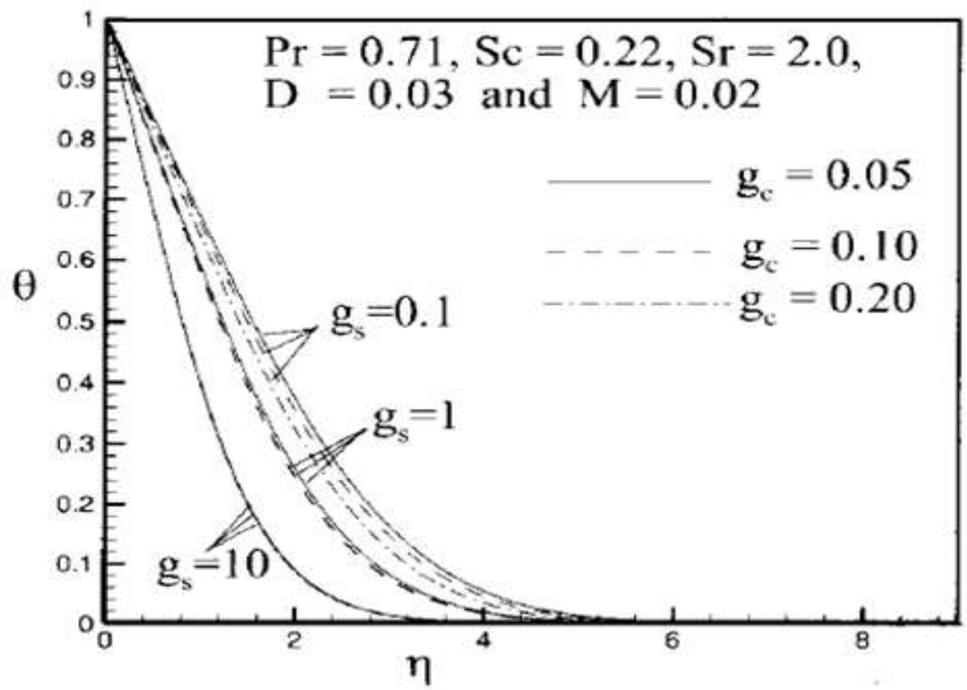

Fig 2 Temperature profiles for different values of g_s and g_c

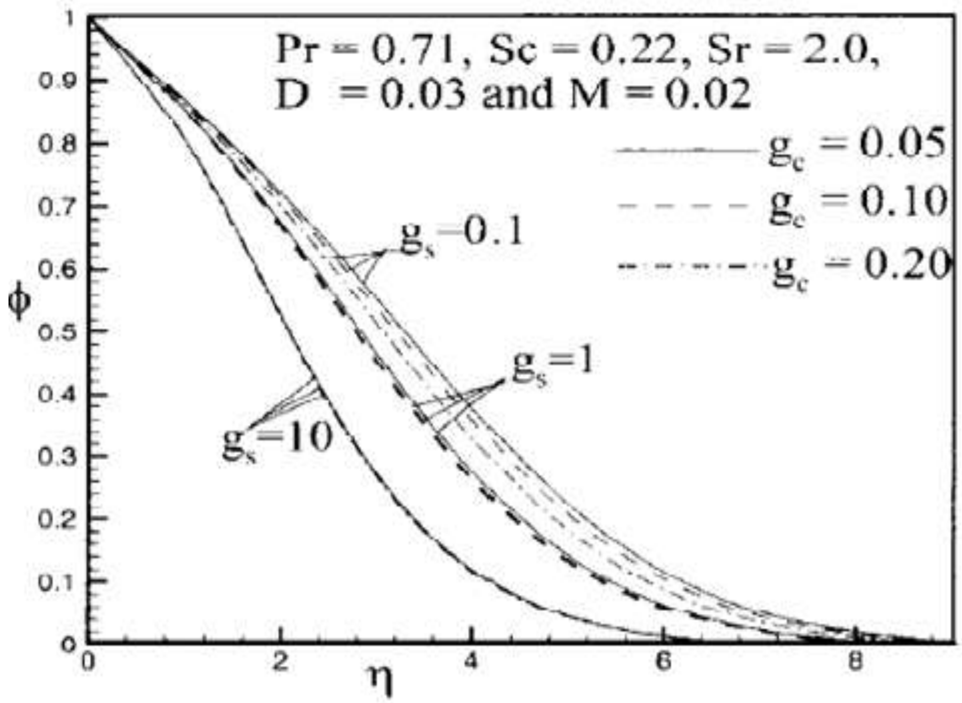

Fig 3 Concentration profiles for different values of g_s and g_c

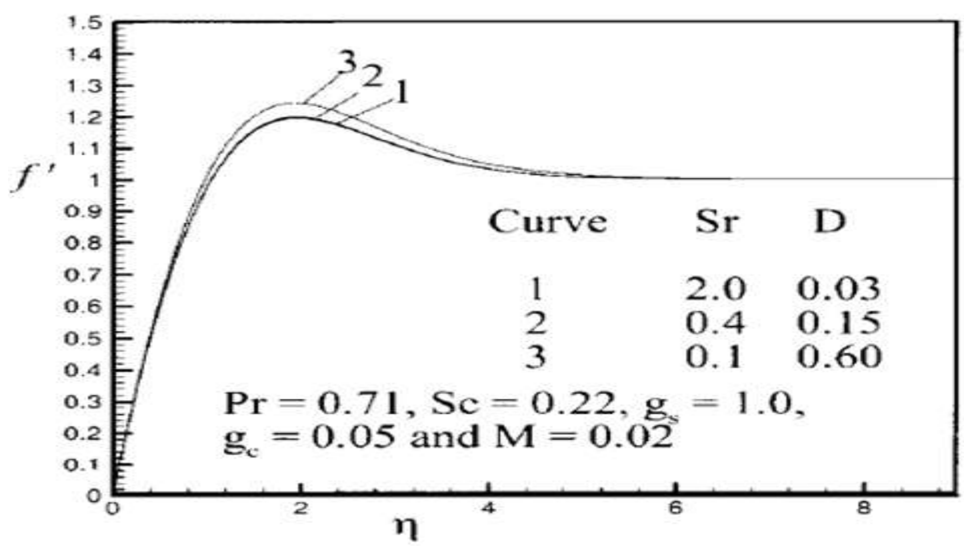

Fig 4 velocity profiles for different values of Sr and D

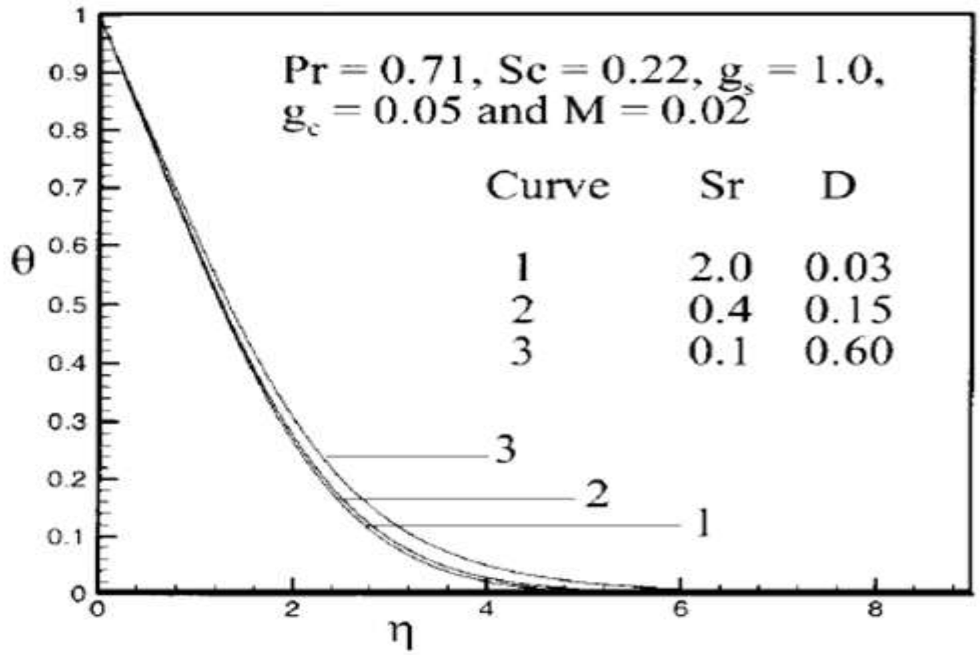

Fig 5 Temperature profiles for different values of Sr and D

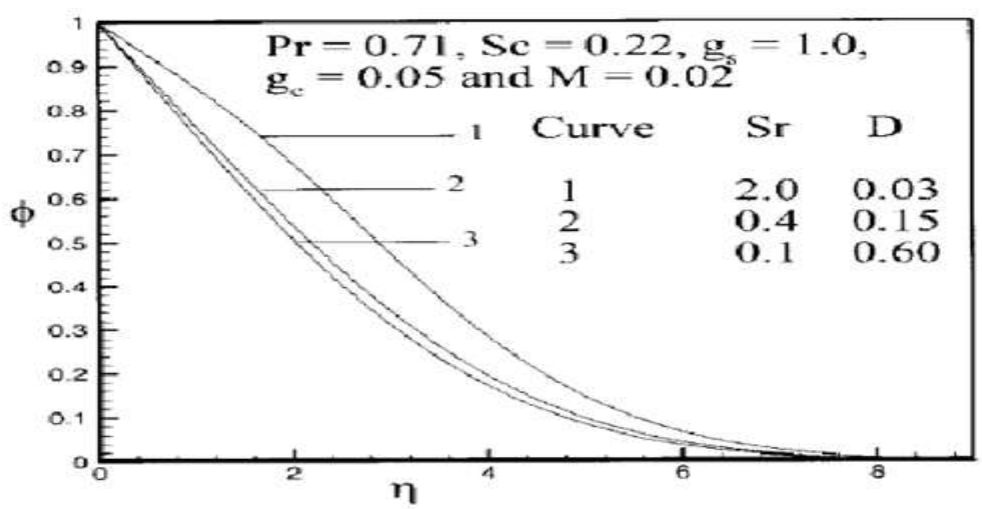

Fig 6 Concentration profiles for different values of Sr and D

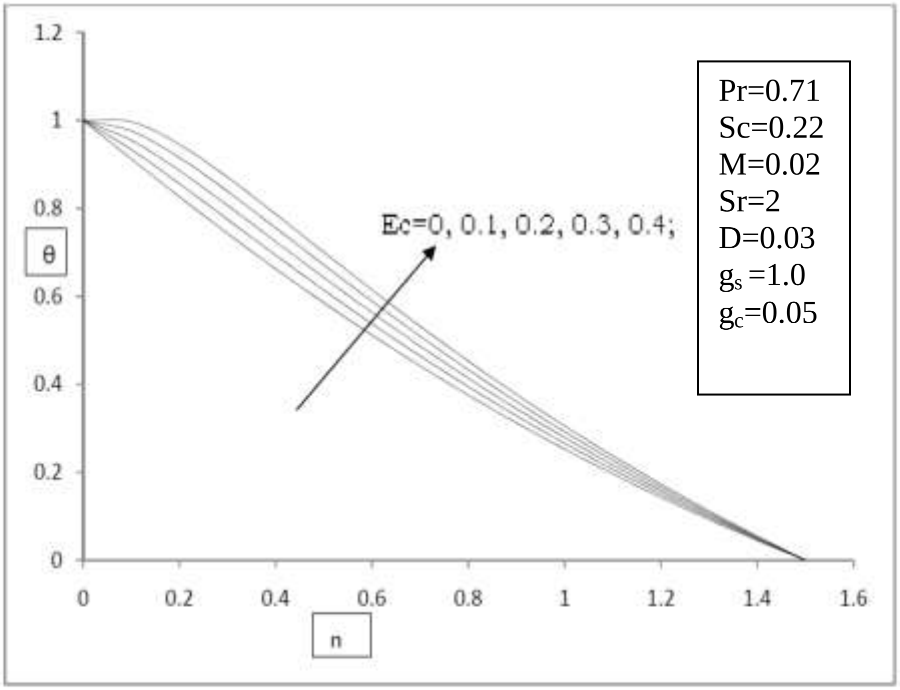

Fig 7 temperature profiles for different values of Ec

REFERENCES:

[1] Neild, D. A.; Bejan, A. (1999): Convection in Porous Media, 2nd edition, Springer, New York.

[2] Ingham, D. B.; Pop, I. (1998): Transport Phenomena in Porous Media I, Pergamon, Oxford.

[3] Ingham, D. B.; Pop, I. (2002): Transport Phenomena in Porous Media II, Pergamon, Oxford.

[4] Bejan, A.; Khair, K. R. (1985): Heat and mass transfer by natural convection in a porous medium, Int. J. Heat and Mass Transfer, 28, pp.

909-918.

[5] Trevisan, O. V.; Bejan, A. (1990): Combined heat and mass transfer by natural convection in a porous medium, Adv. Heat Transfer, 20, pp. 315-352.

[6] Eckert, E. R. G.; Drake, R. M. (1972): Analysis of Heat and Mass Transfer, McGraw-Hill, New York.

[7] Kafoussias, N. G.; Williams, E. M. (1995): Thermal-diffusion and diffusion-thermo effects on mixed free-forced convective and mass transfer boundary layer flow with temperature dependent viscosity, Int. J. Engng. Sci., 33, pp. 1369-1384.

[8] Angel, M.; Takhar, H. S.; Pop, I. (2000): Dufour and Soret effects on free convection boundary-layer over a vertical surface embedded in a porous medium, Studia Universitatis Babes-Bolyai, Mathematica, XLV(4), pp. 11-21.

[9] 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 Dufour effects, Int. J. Heat and Mass transfer, 47, pp. 1467-1472.

[10] J. Venkata Madhu, M. N. Rajasekhar, B. Shashidar Reddy 'Effects of Viscous Dissipation and Thermal Stratification on Chemical Reacting Fluid Flow over a Vertical Stretching Surface with Heat Source '*Pelagia Research Library,Advances in Applied Science Research,* **2015***,* vol.6(1), pp59-65

[11] Kishan, N., Shashidar Reddy, B. "MHD effects on non-Newtonian power-law fluid past a continuously moving porous flat plate with heat flux and viscous dissipation", *International journal*

of Applied mechanics and engineering, **2012**, Vol. 1(4), pp.425-445.
[12] Thomas, L. H. (1949): Walson Scientific Computing Lab., Columbia University, New York.