ISSN: 0975-766X
CODEN: IJPTFI
Available Online through *Research Article*
www.ijptonline.com

STUDY ON MHD BOUNDARY LAYER FLOW OVER A MOVING VERTICAL POROUS PLATE, VISCOUS DISSIPATION AND CHEMICAL REACTION WITH HEAT GENERATION

M.Dhanalakshmi[1], K.Jayaramireddy[2], K.Ramakrishna[3]
[1]Research Scholar, Department of Mathematics, K.L.University, Guntur, A.P, India.
[2]Professor, Department of Mathematics, K.L.University, Guntur, A.P, India.
[3]Professor, Department of Mechanical Engineering, K.L.University, Guntur,A.P., India.
Email: lakshmisyam..lekha@gmail.com

Received on: 12-02-2017 *Accepted on: 20-03-2017*

Abstract:

The aim of the present chapter is to investigate the problem of Soret & Dufour effects on MHD boundary layer flow over a moving vertical porous plate with heat generation and chemical reaction. The governing equations of the flow are transformed into nonlinear ordinary differential equations and then solved by using Runge-Kutta-fourth order along with shooting method. Comparison between the existing literature and the present study was carried out and found to be in excellent agreement. The influence of the various parameters like Magnetic parameter (M), thermal Grashof number (Gr), mass Grashof number (Gc), permeability parameter (K), Prandtl number (Pr), Dufour number (Df), Soret number (Sr), Schmidt number (Sc), Heat generation (B), Radiation Parameter (Ra) and Chemical reaction (Ch) on the flow are analyzed and discussed through graphs in detail. The values of the skin friction coefficient, Nusselt number and the Sherwood number for different physical parameters are also tabulated.

Keywords: Thermal radiation, Heat generation, boundary layer flow, chemical reaction, heat and mass transfer, Soret effect and Dufour effect.

Introduction:

Magnetohydrodynamic (MHD) flows have applications in meteorology, solar physics, cosmic fluid dynamics, astrophysics, geophysics and in the motion of earth’s core. In addition from the technological point of view, MHD free convection flows have significant applications in the field of stellar and planetary magnetospheres, aeronautical plasma flows, chemical engineering and electronics. Chamkha and Khaled [7] investigated the problem of coupled heat and mass transfer by magnetohydrodynamic free convection from an inclined plate in the presence of internal heat generation or absorption. Elabashbeshy [8] studied heat and mass transfer along a vertical plate in the presence of magnetic field. Helmy [11] analyzed MHD unsteady free convection flow past a vertical plate embedded in a porous medium. An excellent summary of applications about electro-magneto fluids is given by Huges and Young [12]. Raptis [20] 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.

Transport processes through porous media play important roles in diverse applications, such as in geothermal operations, petroleum industries, thermal insulation, design of solid-matrix heat exchangers, chemical catalytic reactors, and many others. Alam and Rahman [1] have discussed Dufour and Soret effects on mixed convection flow past a vertical porous flat plate with variable suction. Anwar Hossain*et al.* [3] is studied the effects of radiation on free convection flow of fluid with variable viscosity from a porous vertical plate. Bejan and Khair [4] reported on the natural convection boundary layer flow in a saturated porous medium with combined heat and mass transfer. Makinde [15] considered the MHD boundary-layer flow and mass transfer past a vertical plate in a porous medium with constant heat flux. Raptis*et al.*[18]constructed similarity solutions for boundary layer near a vertical surface in a porous medium with constant temperature and concentration. Vafai and Tien [25]have discussed the importance of inertia effects for flows in porous media. Vempatiand LaxmiNarayanaGari [26] have investigated Soret and Dufour effects on unsteady MHD flow pastan infinite vertical porous plate with thermal radiation.

Many transport processes exist in nature and in industrial applications in which the simultaneous heat and mass transfer occur as a result of combined buoyancy effects of thermal diffusion and diffusion of chemical species. A few representative fields of interest in which combined heat and mass transfer plays an important role are designing of chemical processing equipment, formation and dispersion of fog, distribution of temperature and moisture over an agricultural fields and groves of fruit trees, crop damage due to freezing, and environmental pollution. Alam*et al.* [2] is studied Dufour and Soret effects of steady MHD combined free-forced convective and mass transfer flow past a semi-Infinite vertical plate. Bhupendra*et al.* [5]has studied Soret and Dufour effects on unsteady MHD mixed convection flow past a radiative vertical porous plate embedded in a porous medium with chemical reaction. Callahan and Marner [6] considered the transient free convection flow past a semi-infinite vertical plate with mass transfer. Emad M. Aboeldahab and Elsayed M. E. Elbarbary [9] analyzed hall current effect on magnetohydrodynamic free convection flow past a semi infinite vertical plate with mass transfer. Erickson *et al*. [10] have discussed the effects of heatand mass transfer in the laminar boundary layer flow of a moving flat surface with constant surface velocity and temperature focusing on the effects of suction/injection. Ibrahim and Makinde [13] have discussed the chemically reacting MHD boundary layer flow of heat and mass transfer over a moving vertical plate with suction. Madhusudhana Rao and Viswanatha Reddy [14] is studied Soret and Dufour effects on hydro magnetic heat and mass transfer over a vertical plate in a porous medium with a convective surface boundary condition and chemical reaction. Olajuwon [16] is studied convection heat and mass transfer in an electrically conducting power law flow over a heated vertical porous plate. Olajuwon [17] has discussed convection heat and mass transfer in a hydromagneticcarreau fluid past a vertical porous plate in presence of thermal radiation and thermal diffusion. Raptis and Kafoussias [19] have studied MHD free convective heat and mass transfer flow in a porous medium bounded by an infinite vertical porous plate with constant heat flux. Reddy *et al.* [21] is studied unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical porous plate with variable viscosity and thermal conductivity. Sharma and Singh [22] have discussed unsteady MHD free convective flow and heat transfer along a vertical porous plate with variable suction and internal heat generation. Soundalgekar [24] studied the effects of mass transfer and free convection on the flow past an impulsively started vertical flat plate. Unsteady free convective flow on taking into account the mass transfer phenomenon past an infinite vertical plate was studied by Soundalgekhar and Wavre [23]. Yih [27] studied free convection effect on MHD coupled heat and mass transfer of a moving permeable vertical surface. Vidyasagar *et.al* (28) studied heat and mass transfer effects on MHD boundary layer flow over a moving vertical porous plate. Srinivasa Rao *et.al* (26) investigated effect of thermal radiation on MHD boundary layer flow over a moving vertical porous plate with suction, Srinivasa Rao *et.al* (30) analyzed Soret and Dufour effects on MHD Boundary layer flow over a Moving Vertical porous plate with suction.

In this chapter we analyzed the heat and mass transfer effects on MHD boundary layer flow over a moving vertical porous plate, viscous dissipation and chemical reaction with heat generation. The continuity, momentum, energy and concentration equations are reduced to some parameter problem by introducing suitable transformation variables. The equations that governing the flow are coupled and solved numerically using by shooting method. The effects of various flow controlling parameters such as velocity, temperature and concentration are presented graphically and discussed quantitatively. The skin-friction coefficient and the heat and mass transfer results are illustrated for representative values of the major parameters.

Formulation of the Problem:

Consider a two-dimensional free convection effects on the steady incompressible laminar MHD heat and mass transfer characteristics of a linearly started porous vertical plate, the velocity of the fluid far away from the plate surface is assumed zero for a quiescent state fluid. The variations of surface temperature and concentration are linear. All the fluid properties are assumed to be constant except for the density variations in the buoyancy force term of the linear momentum equation. The magnetic Reynolds number is assumed to be small, so that the induced magnetic field is neglected. No electrical field is assumed to exist and both viscous and magnetic dissipations are neglected. The Hall effects, the viscous dissipation and the joule heating terms are also neglected. Under these assumptions, along with Boussinesq approximations, the boundary layer equations describing this flow as:

Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad 3.1$$

Momentum equation

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=v\frac{\partial^2 u}{\partial y^2}+g\beta(T-T_\infty)+g\beta^*(C-C_\infty)-\frac{\sigma B_o^{\ 2}}{\rho}u-\frac{v}{k'}u \qquad 3.2$$

Energy equation

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho C_P}\frac{\partial q_r}{\partial y}+\frac{Q}{\rho C_P}(T-T_\infty)+\frac{\upsilon}{\rho C_P}\left(\frac{\partial u}{\partial y}\right)^2+\frac{D_M K_T}{C_S C_P}\frac{\partial^2 C}{\partial y^2} \qquad 3.3$$

Concentration equation

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_M\frac{\partial^2 C}{\partial y^2}+D_T\frac{\partial^2 T}{\partial y^2}+K_1(C-C_\infty) \qquad 3.4$$

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

$$u=Bx,\ v=V,\ T=T_w=T_\infty+ax, C=C_w=C_\infty+bx \quad \text{at} \quad y=0$$
$$u\to 0,\ T\to T_\infty,\ \ C\to C_\infty \quad as \quad y\to\infty \qquad 3.5$$

We introduce the following non-dimensional variables are:

$$M = \frac{\sigma B_0^{\,2}}{\rho B},\ K = \frac{\upsilon}{k^{'} B},\ Gr = \frac{g\beta(T_w - T_\infty)}{xB^2},\ Gc = \frac{g\beta^*(C_w - C_\infty)}{xB^2},\ \Pr = \frac{\upsilon}{\alpha},\ Sc = \frac{\upsilon}{D_M}$$

$$\theta = \frac{T - T_\infty}{T_w - T_\infty},\ \varphi = \frac{C - C_\infty}{C_w - C_\infty}, Ra = \frac{4\alpha^2}{B\rho C_P}, Q = \frac{Q_0}{B\rho C_P}, Ec = \frac{B^2 x^2}{\rho C_P (T_w - T_\infty)}, Df = \frac{D_M K_T (C_w - C_\infty)}{C_s C_P \upsilon (T_w - T_\infty)} \quad 3.6$$

$$Sr = \frac{D_M K_T (T_w - T_\infty)}{T_M (C_w - C_\infty)}, Ch = \frac{K_1}{B}$$

$$\eta = \sqrt{\frac{B}{v}}y,\ F(\eta) = \frac{\psi}{x\sqrt{Bv}} \quad 3.7$$

where ψ is the stream function defined as

$$u = \frac{\partial \psi}{\partial y} = xBF^{'}, \quad v = -\frac{\partial \psi}{\partial x} = -\sqrt{Bv}F \quad 3.8$$

In view of (3.6), (3.7) and (3.8) the Equations (3.2) to (3.4) take the form

$$F^{'''} + FF^{''} - (F^{'})^2 + Gr\,\theta + Gc\,\phi - (M + K)F^{'} = 0 \quad 3.9$$

$$\theta'' + \Pr\left[F\theta' - F^{'}\theta\right] - \Pr(Ra - Q)\theta + \Pr Ec\left(f^{''}\right)^2 + \Pr Df\,\phi^{''} = 0 \quad 3.10$$

$$\phi'' + Sc\left[F\phi' - F^{'}\phi\right] + ScSr\theta^{''} + SrCh\phi = 0 \quad 3.11$$

where the primes denote the differentiation with respect to η, M is the magnetic parameter, K is the permeability parameter, Gr is the temperature Grashof number, Gc is the concentration Grashof number, $\Pr$ is the Prandtl number and Sc is the Schmidt number.

The corresponding boundary conditions are

$$F^{'} = 1, F = -F_w,\ \theta = 1,\ \phi = 1 \quad \text{at} \quad \eta = 0$$
$$F^{'} = 0,\ \theta = 0,\ \phi = 0 \quad \text{as} \quad \eta \to \infty \quad 3.12$$

where $F_w = \dfrac{V}{\sqrt{\nu B}}$ is the suction parameter.

Solution of the Problem

The governing boundary layer equations (3.9) to (3.11) subject to boundary conditions (3.12) are solved numerically by using shooting method. First of all higher order non-linear differential equations (3.9) to (3.11) are converted into simultaneous linear differential equations of first order and they are further transformed into initial value problem by applying the shooting technique. From the process of numerical computation, the skin-friction coefficient, the Nusselt number and Sherwood number which are respectively proportional to $F'(0)$, $-\theta(0)$ and $-\phi(0)$ are also sorted out and their numerical values are presented in a tabular form.

Results and Discussion

In order to get a physical insight into the problem, a representative set of numerical results is shown graphically in Figs.1-34, to illustrate the influence of physical parameters viz., the suction parameter *fw*, magnetic parameter M, permeability parameter *K*, Grashof number Gr, modified Grashof number Gc, Prandtl number $\Pr$, Chemical reaction Ch, Soret number Sr, Radiation Parameter Ra and Schmidt number *Sc* on the velocity $f'(\eta)$, temperature $\theta(\eta)$ and concentration $\phi(\eta)$.

The Prandtl number was taken to be *Pr* = 0.72, which corresponds to air, the values of Schmidt number (*Sc*) were chosen to be Sc = 0.24, 0.62, 0.78, 2.62, representing diffusing chemical species of most common interest in air like H_2, H_2O, NH_3, and Propyl Benzene, respectively. Attention is focused on positive values of the buoyancy parameters, that is, Grashof number *Gr* > 0 (which corresponds to the cooling problem) and solutal Grashof number *Gc* > 0 (which indicates that the chemical species concentration in the free stream region is less than the concentration at the boundary surface). The effects of the magnetic parameter *M* on the velocity, temperature and concentration are shown in Figs. 1-3. It is observed that an increase in the magnetic parameter *M* results in a decrease in the velocity. It is observed that the temperature and concentration increases with the increase of magnetic parameter M. Figs. 4-6 shows the dimensionless velocity, temperature and concentration for different values of permeability parameter K. It can be seen that the velocity decreases with the increase of permeability parameter K. It is noticed that the temperature and concentration increases with the increase of permeability parameter K.

For different values of the suction parameter f_w, the velocity, temperature and concentration are shown in Figs.7-9. It is seen that the velocity, temperature and concentration increases with an increase in the suction parameter f_w. The effects of the grashof number Gr on the velocity, temperature and concentration are shown in Figs10-12. It is observed that an increases in the Grashof number Grresults in a decrease in the velocity. It is seen that the temperature and concentration decreases with an increase in the grashof number Gr.

The influence of the modified grashof number Gc on the velocity, temperature and concentration is shown in Figs. 13-15. It is noticed that the velocity profiles increase with the increase of modified Grashof number Gc. It is observed that an increases in the modified Grashof number Gc results in a decrease in the temperature and concentration. The Echet number on the Tempareture is shown in fig. 16. It can be seen that the tempareture increases with the increase of Ec. From figs. 17-18 shown that the velocity and tempareture for different values of radiation parameter Ra. We observed that the velocity and tempareture decreases with the increase of Ra.

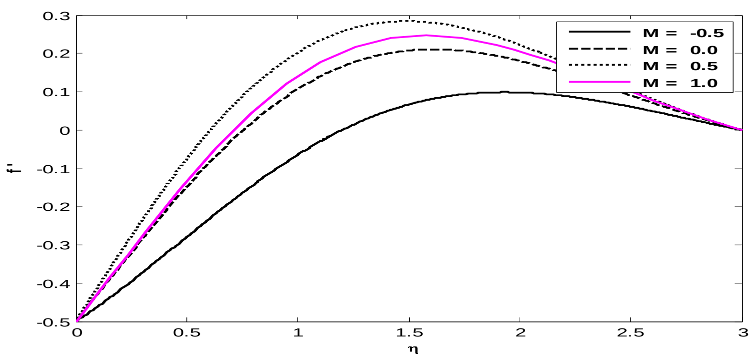
The Dufour effect on the velocity, tempareture and concentration for different values of Dufour effect Df is shown in figs: 19-20. It is noticed that the velocity and tempareture increases with the increase of Df. We observed that the concentration decreases with the increase of Df. From figs. 21-22 shows the velocity and temperature for different values of Prandtl number Pr. We noticed that the velocity and tempareture decreases with the increase of Pr.

Figs. 23-24 shows the dimensionless velocity, temperature and concentration for different values of Schmidt number Sc. It can be seen that the velocity decreases with the increase of Schmidt number Sc. It is noticed that the temperature monotonically increases with the increase of Schmidt number Sc. It is seen that the concentration decreases as Schmidt number Sc increases. The Soret number on the velocity, tempareture and concentration for different values of Sr is shown in figs. 25-26. We observed that the velocity, tempareture and concentration increases with the increase of Sr.

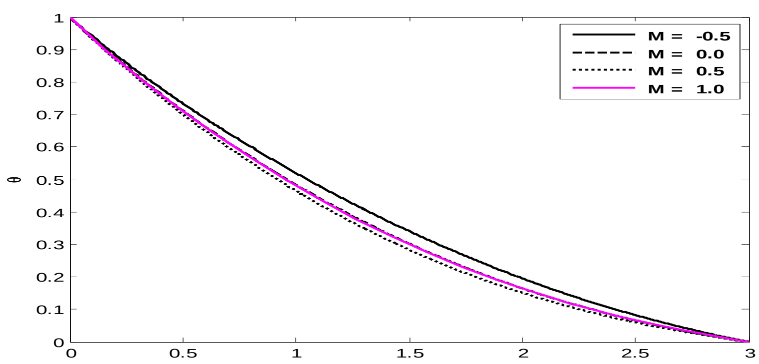
Figs. 28-29 shows the velocity and tempareture for different values of Heat generation B. It is noticed that the velocity and tempareture increases with the increase of B. The velocity, tempareture and concentration for different values of Chemical reaction Ch in shown figs. 30-31. We observed that the velocity, tempareture and concentration increases with the increase of Ch. Numerical results are reported in the Table 1. From Table 1, it is important to note that the skin friction together with the heat and mass transfer rate at the moving plate surface decreases with increase magnitude of fluid suction (*Fw*). The rate of heat and mass transfer at surface of the plate increases with increase intensity of buoyancy forces (*Gr*, *Gc*) and decreases with increasing intensity of magnetic field (M) or permeability parameter (K). Moreover, the skin friction decreases with buoyancy forces and increases with increase magnetic field intensity and Schmidt number (Sc). Furthermore, the surface mass transfer rate increases, while the surface heat transfer rate decreases with an increase in the Schmidt number (Sc). The effects of various governing parameters on the skin-friction coefficient C_f, Nusselt number *Nu* and Sherwood number *Sh* are shown in Table-1. It is observed that the skin-friction, Nusselt number and Sherwood number increases with the increase of unsteadiness parameter A or suction parameter f_w. It is found that the Sherwood number increases as Schmidt number increases. It is noticed that the skin-friction coefficient increases with increasing magnetic parameter M or permeability parameter K, whereas the Nusselt number and Sherwood number decrease with increasing magnetic parameter. It is found that the Nusselt number increases with increasing Prandtl number or heat source parameter.

Table 1. Numerical values of the Skin-friction coefficient (C_f), Nusselt number (Nu) and Sherwood number (Sh) for M, K, Gr, Gc, f_w, Sc.

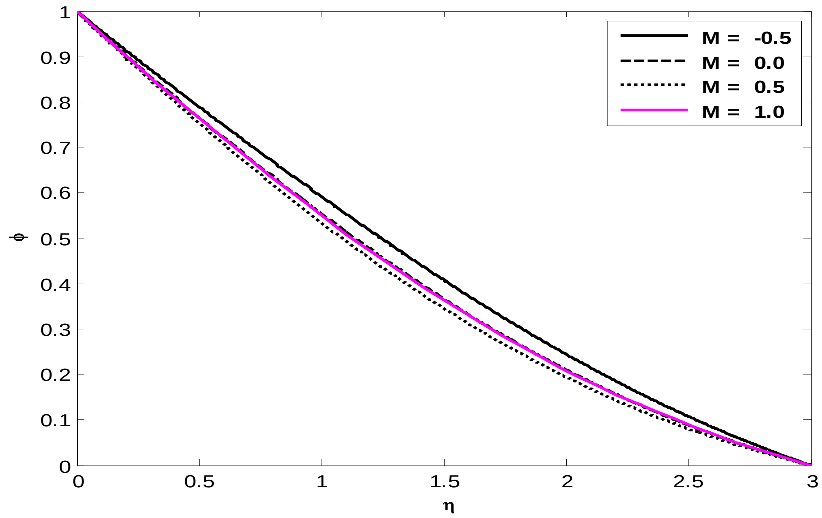
M	K	Gr	Gc	f_w	Sc	$f'(0)$	$-\theta(0)$	$-\phi(0)$
0.1	0.1	0.1	0.1	0.1	0.60	0.86441	0.77525	0.70141
1.0	0.1	0.1	0.1	0.1	0.60	1.02456	0.68920	0.62632
0.1	1.0	0.1	0.1	0.1	0.60	1.68146	0.42517	0.50485
0.1	0.1	0.5	0.1	0.1	0.60	0.68947	0.81724	0.74340
0.1	0.1	0.1	0.5	0.1	0.60	0.649267	0.82420	0.75149
0.1	0.1	0.1	0.1	0.5	0.60	0.67056	0.59178	0.54230
0.1	0.1	0.1	0.1	0.1	0.78	0.87435	0.77912	0.81239



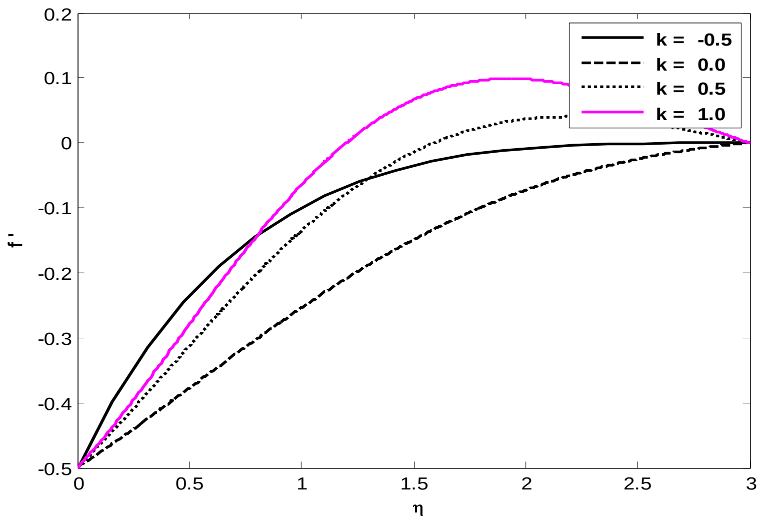
Fig(1): The Velocity profile for different values of M.



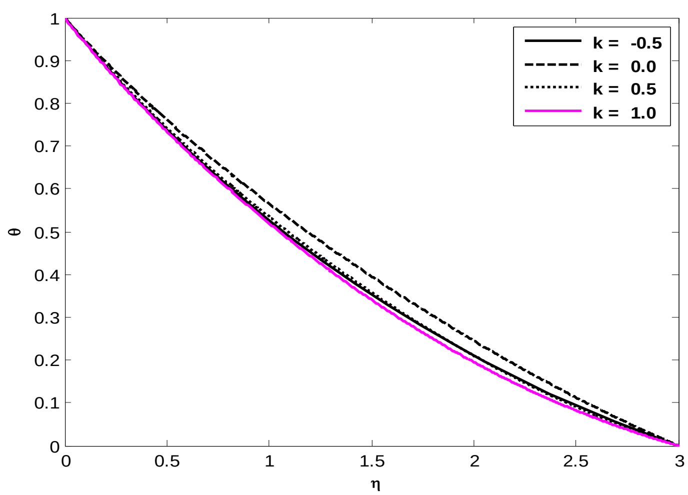
Fig(2): The Temperature profile for different values of M.



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



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



Fig(5): The Temperature profile for different values of K.

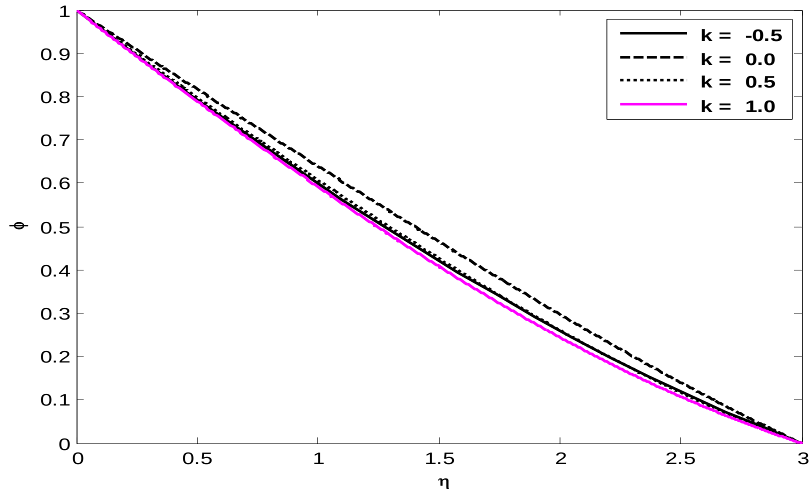
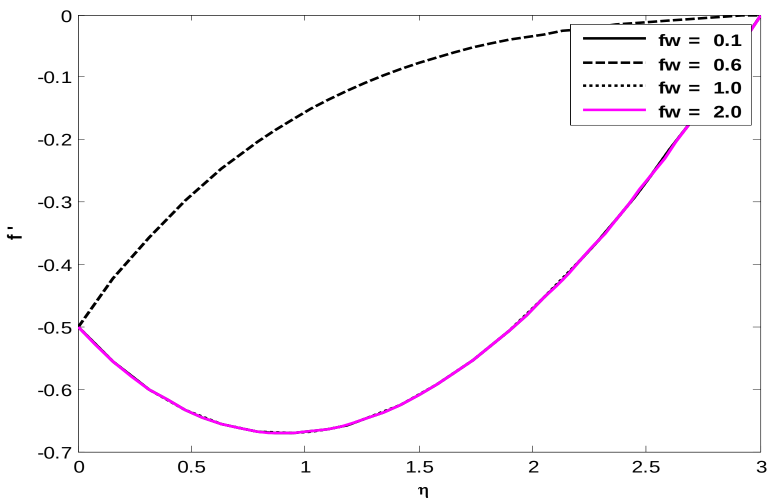
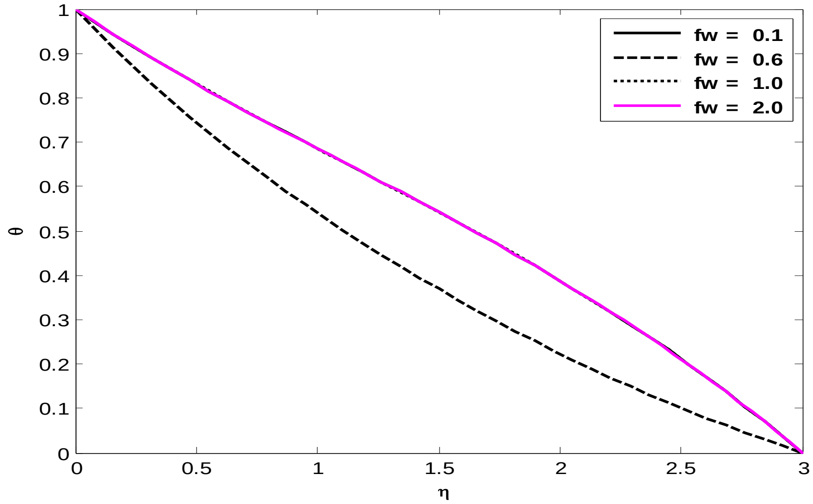


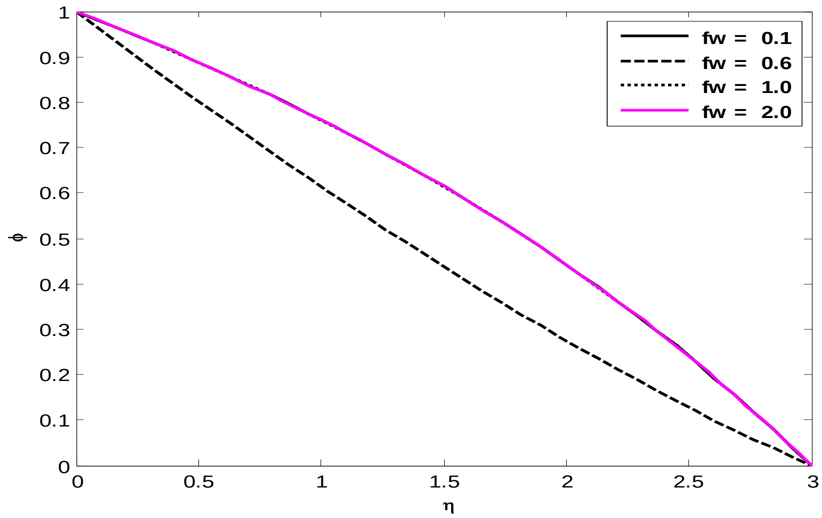
Fig (6): The Concentration profile for different values of K.



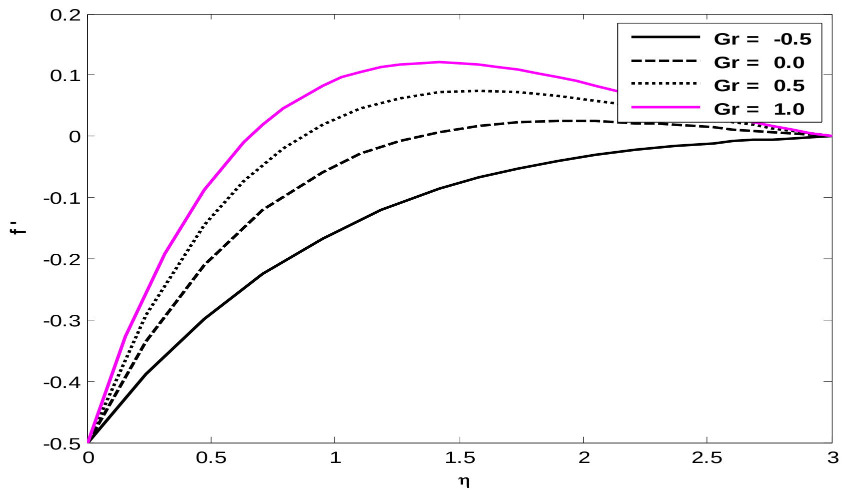
Fig(7): The Velocity profile for different values of fw.



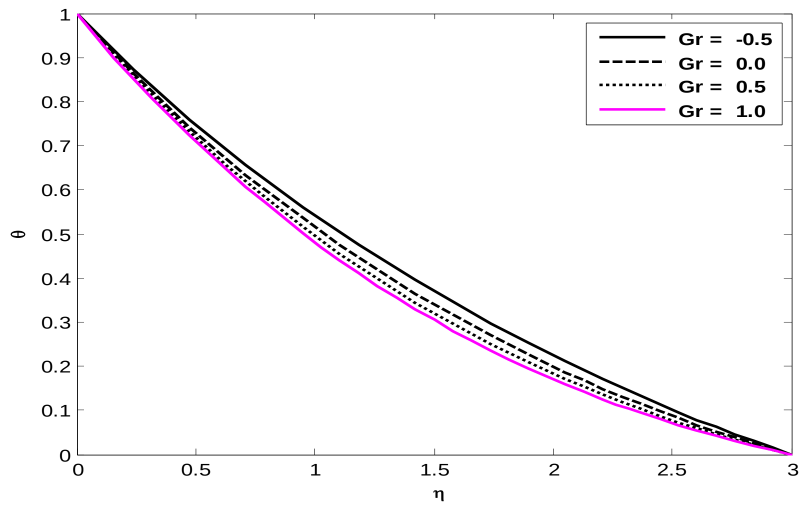
Fig(8): The Temperature profile for different values of fw.



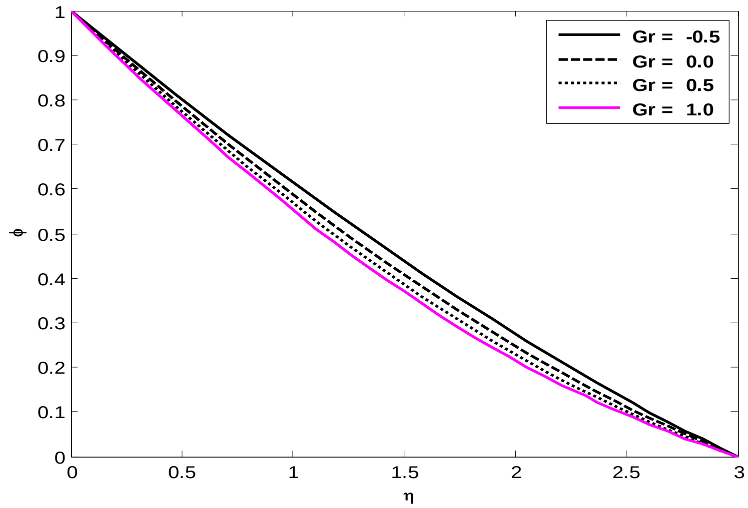
Fig(9): The Concentration profile for different values of fw.



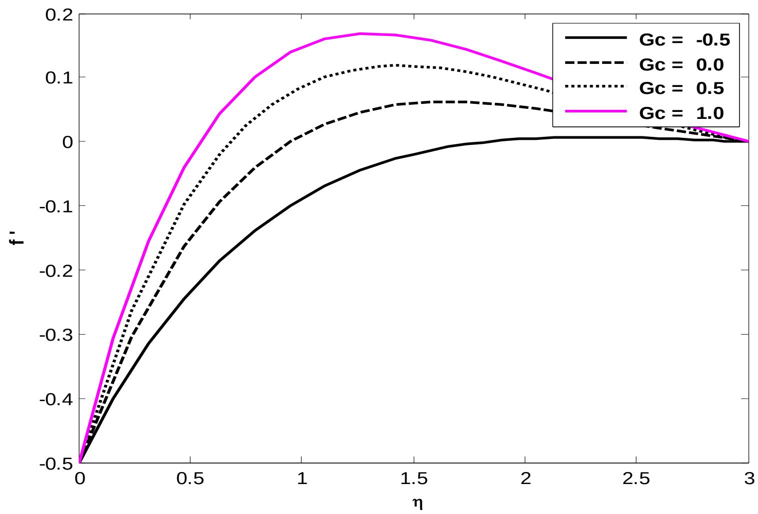
Fig(10): The Velocity profile for different values of Gr.



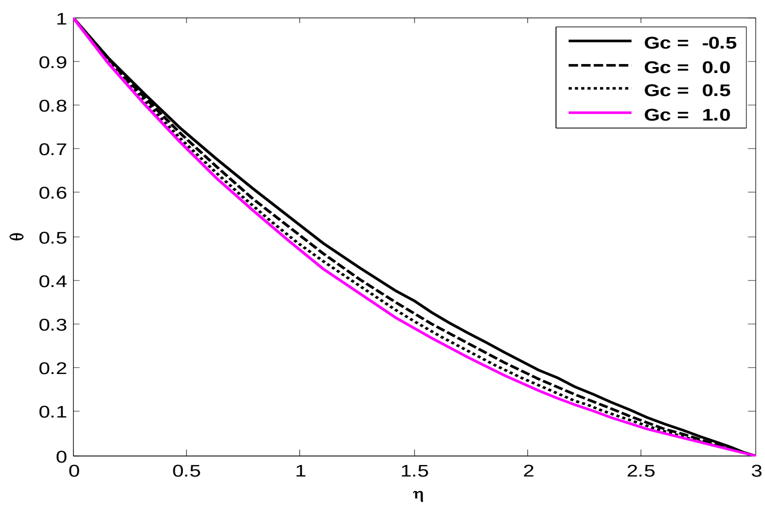
Fig(11): The Temperature profile for different values of Gr.



Fig(12): The Concentration profile for different values of Gr.



Fig(13): The Velocity profile for different values of Gc.



Fig(14): The Temperature profile for different values of Gc.

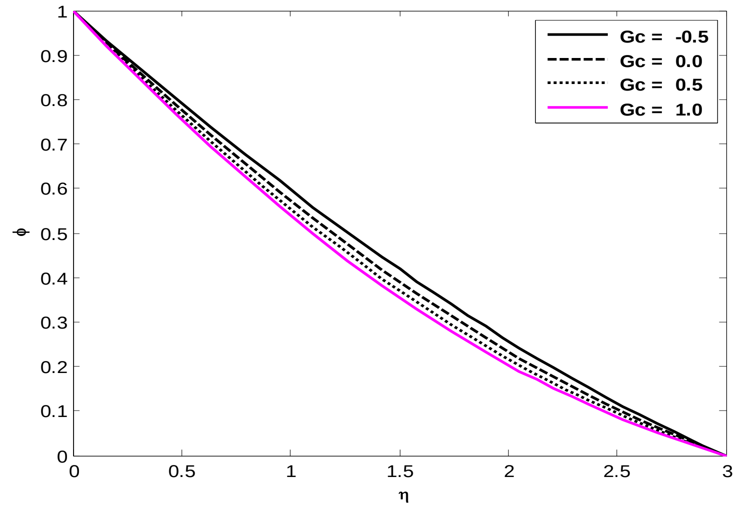
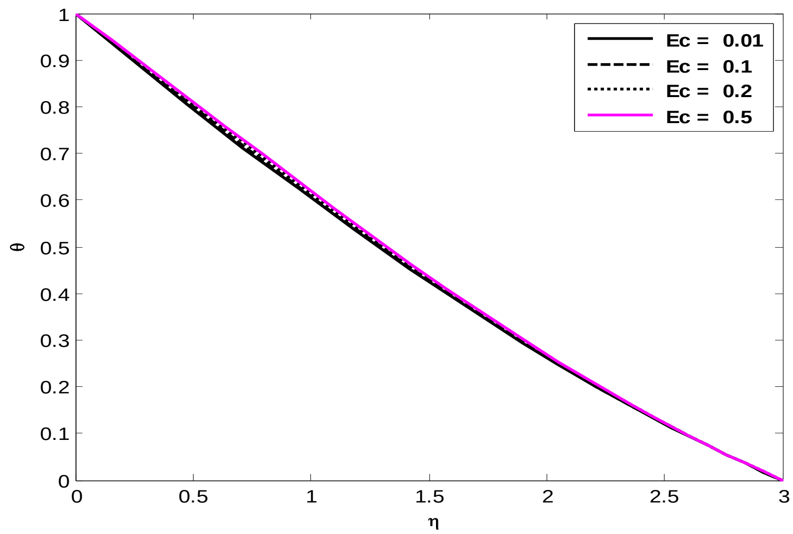
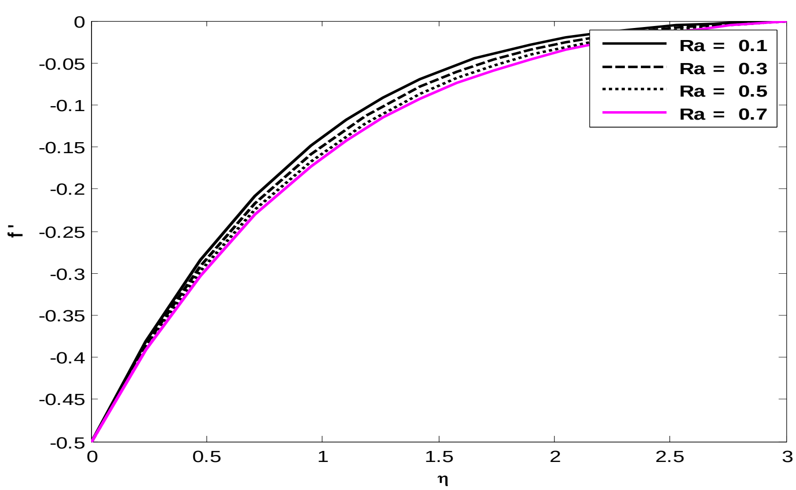


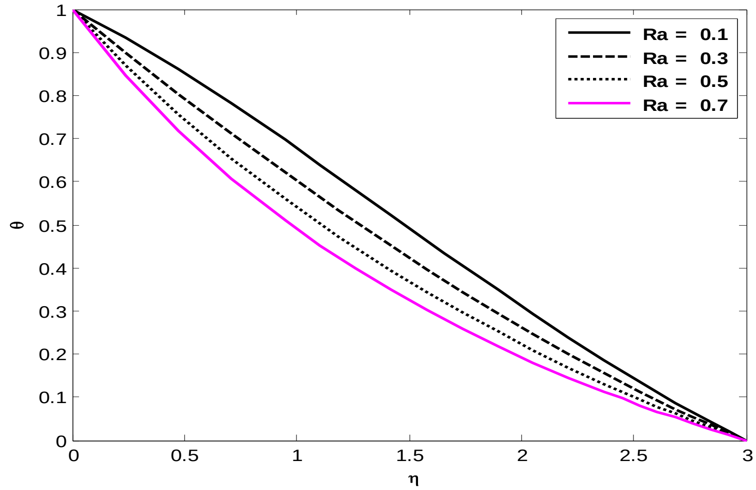
Fig (15): The Concentration profile for different values of Gc.



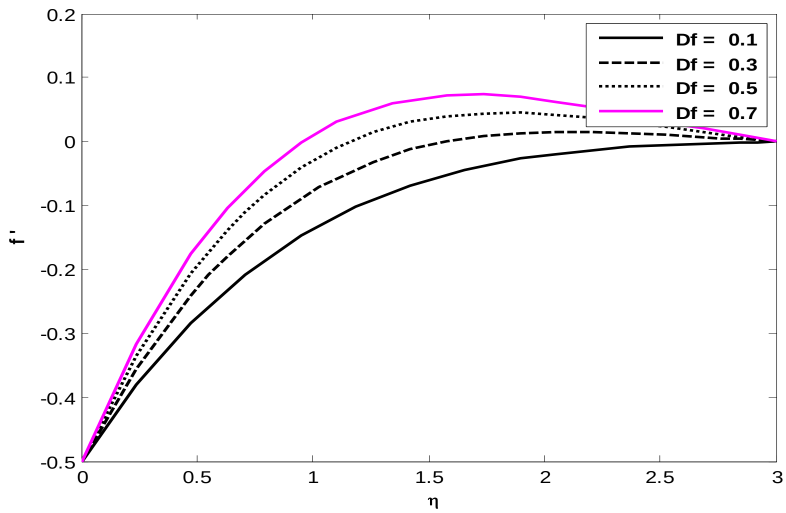
Fig(16): The Temperature profile for different values of Ec.



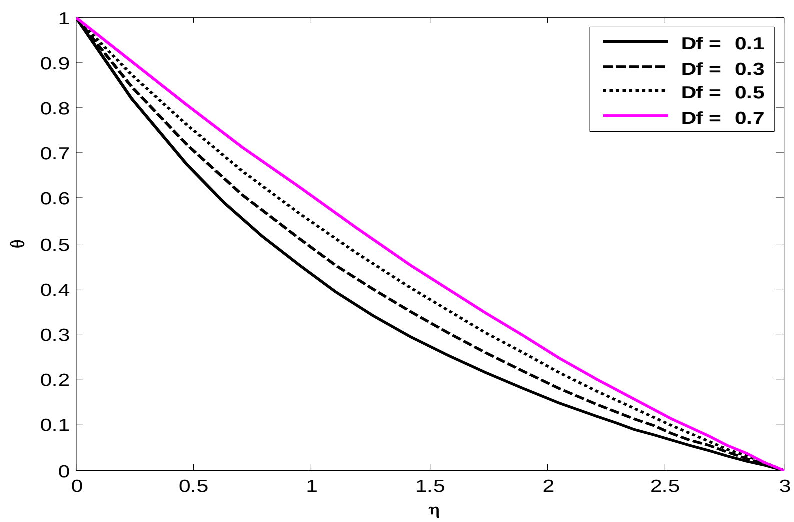
Fig(17): The Velocity profile for different values of Ra.



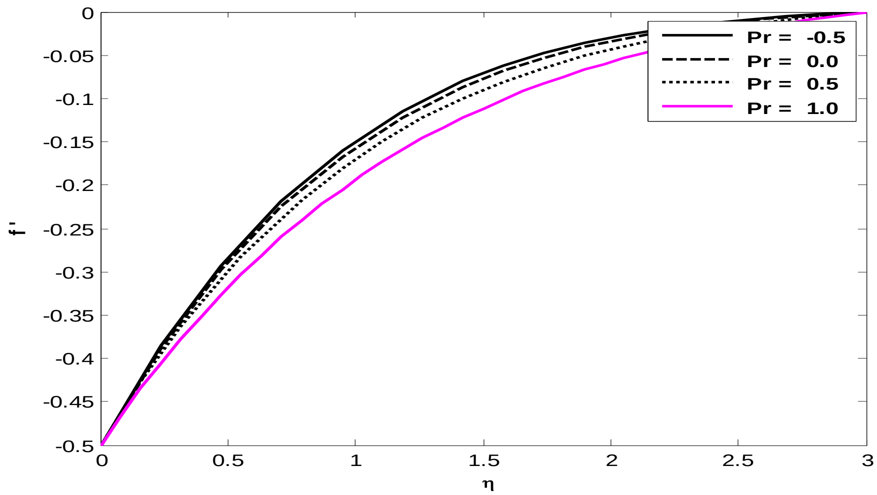
Fig(18): The Temperature profile for different values of Ra.



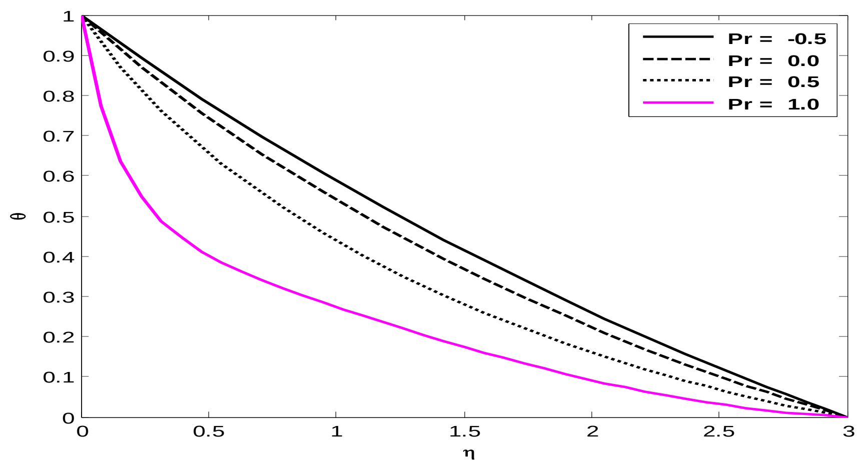
Fig(19): The Velocity profile for different values of Df.



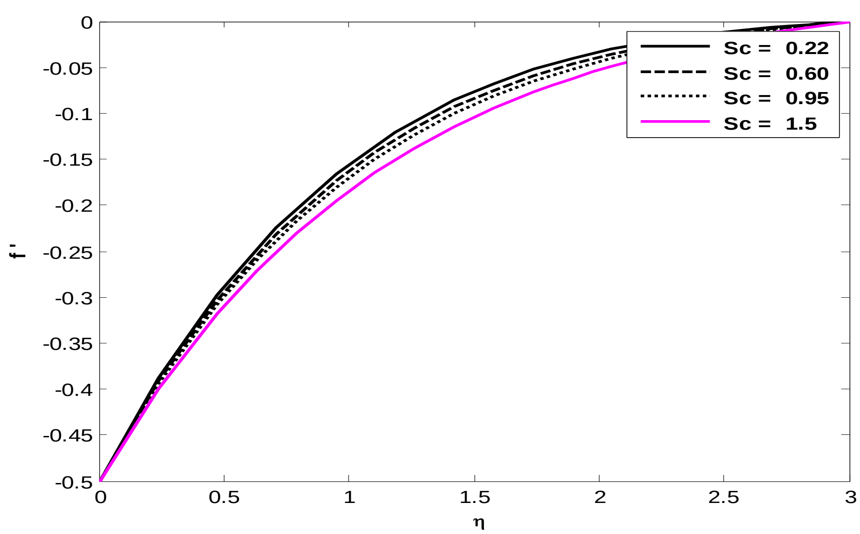
Fig(20): The Temperature profile for different values of Df.



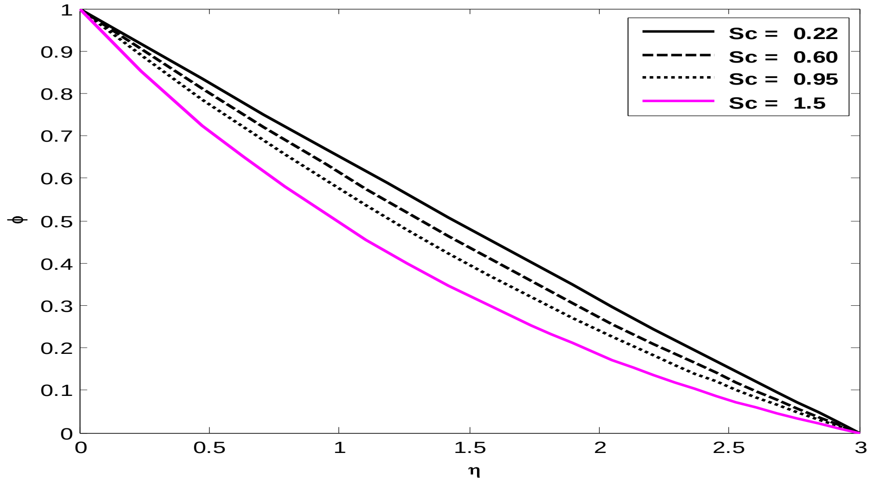
Fig(21): The Velocity profile for different values of Pr.



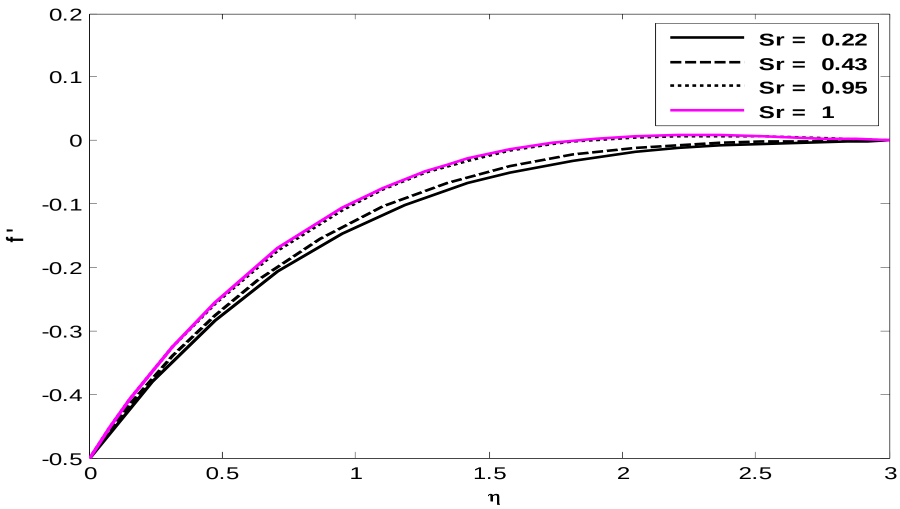
Fig(22): The Temperature profile for different values of Pr.



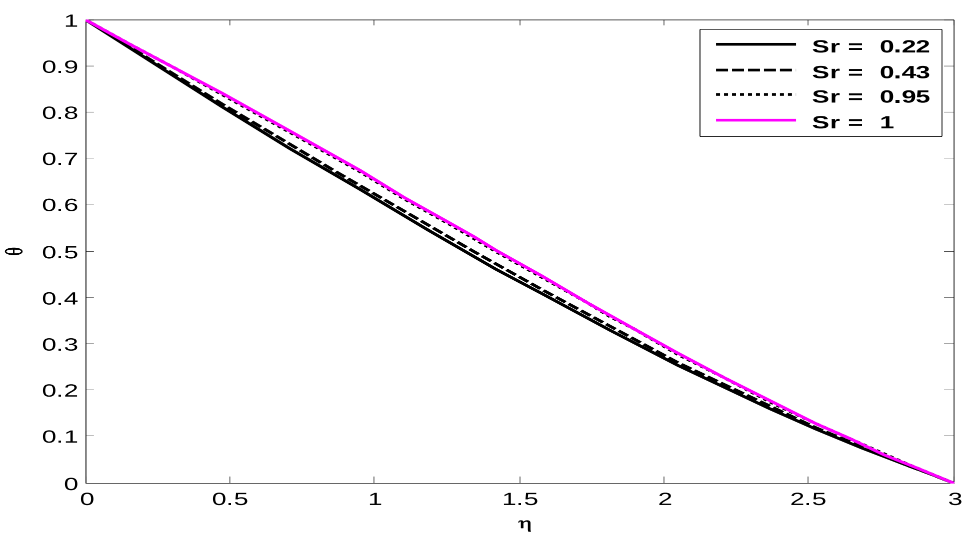
Fig(23): The Velocity profile for different values of Sc.



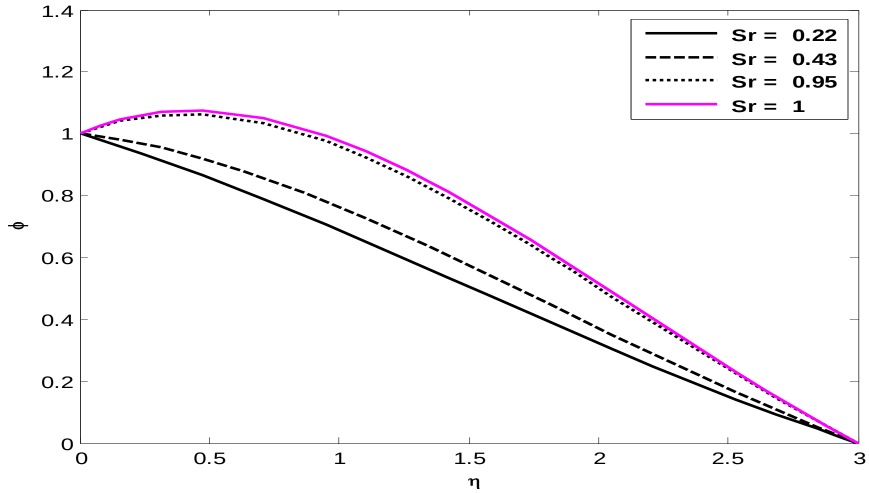
Fig(24): The Concentration profile for different values of Sc.



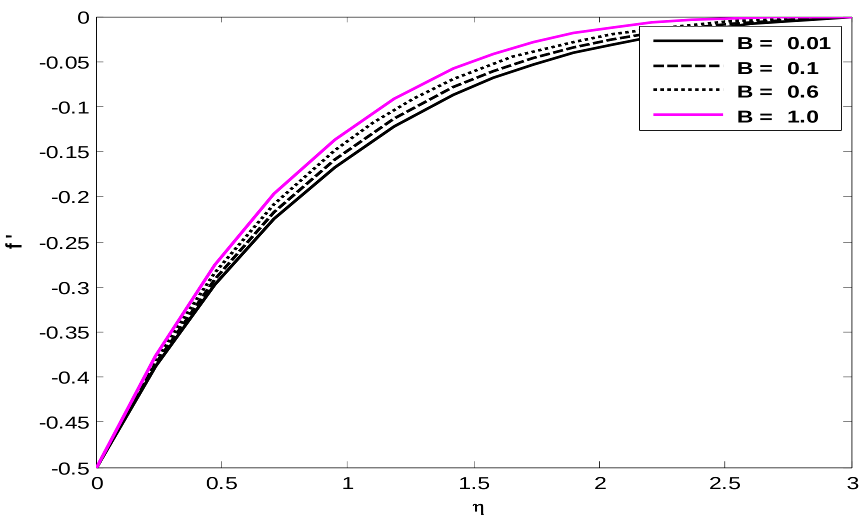
Fig(25): The Velocity profile for different values of Sr.



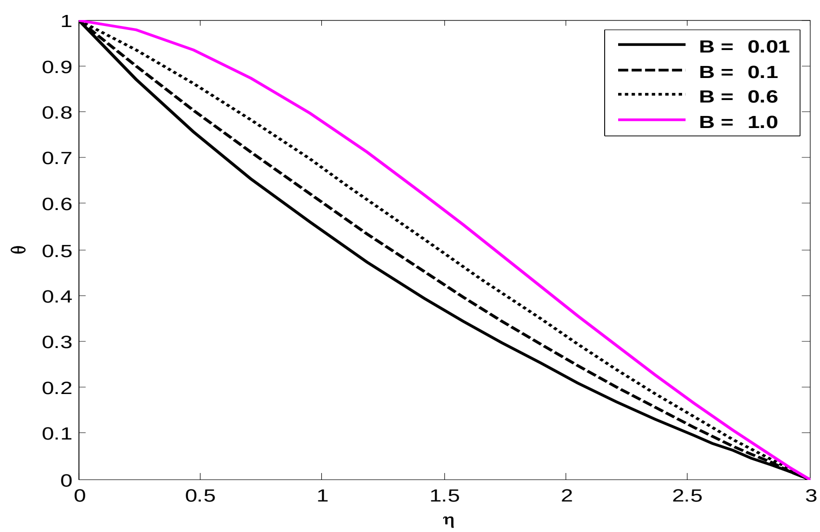
Fig(26): The Temperature profile for different values of Sr.



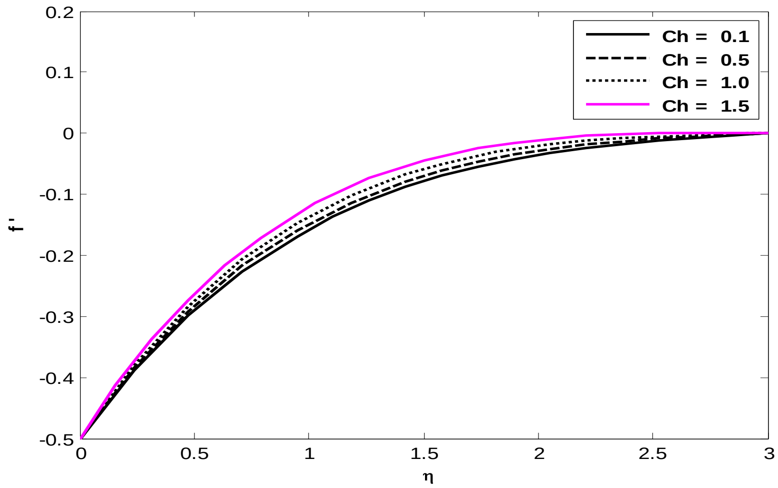
Fig(27): The Concentration profile for different values of Sr.



Fig(28): The Velocity profile for different values of B.



Fig(29): The Temperature profile for different values of B.



Fig(30): The Velocity profile for different values of Ch.

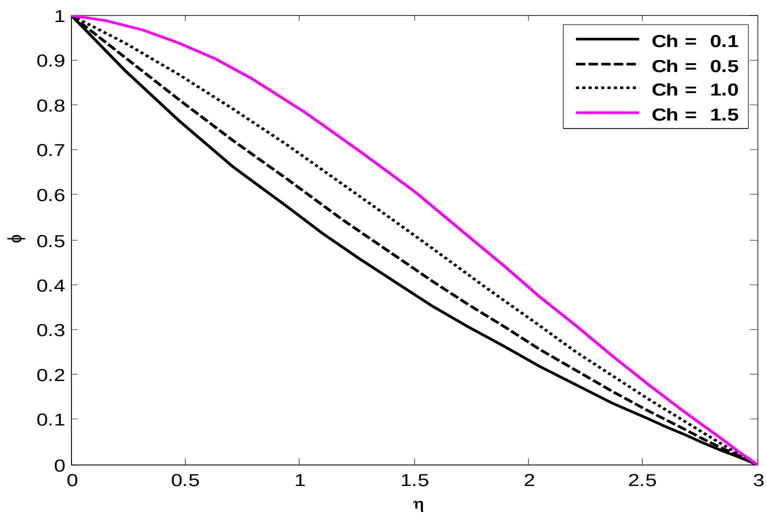


Fig (31): The Concentration profile for different values of Ch.

Conclusions

In this chapter we study the Soret effects on MHD boundary layer flow over a moving vertical porous plate with heat generation in the presence of Chemical reaction. The expressions for the velocity, temperature and concentration distributions are numerically solved by Runge Kutta fourth order along with shooting technique.

- It can be seen that the velocity decreases with the increase of permeability parameter K.
- It is noticed that the temperature and concentration increases with the increase of permeability parameter K.
- We observed that the velocity and temperature decreases with the increase of Ra.
- It is noticed that the velocity and temperature increases with the increase of Df. We observed that the concentration decreases with the increase of Df.

- We observed that the velocity, temperature and concentration increases with the increase of Ch.
- We observed that the velocity, temperature and concentration increases with the increase of Sr.
- The skin friction decreases with buoyancy forces and increases with increasing magnetic field intensity and Schmidt number (Sc).
- The skin-friction, Nusselt number and Sherwood number increases with the increase of suction parameter f_w.
- The surface mass transfer rate increases, while the surface heat transfer rate decreases with an increase in the Schmidt number (Sc).

References

1. Alam M. S. and RahmanM. 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.
2. Alam S., RahmanM. M, MalequeA., and Ferdows M. (2006). Dufour and Soret effects of 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. 112.
3. Anwar Hossain, Khalil Khanafer, KambizVafai (2001). The effect of radiation on free convection flow of fluid with variable viscosity from a porous vertical plate, *Int. J. Thermal Sci*,,vol.40,pp. 115-124.
4. Bejan A. and Khair K.R. (1985). Heat and mass transfer by natural convection in a porous medium, Int.Commun. Heat Mass Transfer, Vol. 28, pp.909–918.
5. Bhupendra K. Sharma1, KailashYadav, Nidhish K. Mishra and, Chaudhary R. C (2012). Soret and Dufour Effects on Unsteady MHD Mixed Convection Flow past a Radiative Vertical Porous Plate Embedded in a Porous Medium with Chemical Reaction, *Applied Mathematics*, 2012, (3)pp. 717-723
6. Callahan G.D. and Marner W.J. (1976). Transient free convection with mass transfer on an isothermal vertical flat plate, *Int. J. Heat Mass Transfer*, Vol.19, pp.165-174.
7. Chamkha A.J. and Khaled A.R.A. (2001). Similarity solutions for hydromagnetic simultaneous heat and mass transfer by natural convection from an inclined plate with internal heat generation or absorption, *Heat Mass Transfer*, Vol. 37, pp.117-123.

8. Elabashbeshy E.M.A. (1997). Heat and mass transfer along a vertical plate with variable temperature and concentration in the presence of magnetic filed, *Int. J. Eng. Sci*., Vol. 34,pp.515-522.
9. Emad M. Aboeldahab and Elsayed M. E. Elbarbary (2001). Hall current effect on magnetohydrodynamic free convection flow past a semi infinite vertical plate with mass transfer, *Int.J. of Eng. Science.*, vol. 39, pp. 1641 – 1652.
10. Erickson L. E, Fan L. T and Fox V. G (1966). Heat and Mass transfer in the laminar boundary layer flow of a moving flat surface with constant surface velocity and temperature focusing on the effects of suction/injection, *Ind. Eng. Chem.*, Vol. 5, pp. 19-25.
11. Helmy K.A. (1998). MHD unsteady free convection flow past a vertical porous plate, *ZAMM*, Vol.78,pp.255-270.
12. Huges W.F. and Young F.J. (1996). The Electro-Magneto Dynamics of fluids, *John Wiley and Sons*, New York.
13. Ibrahim S.Y. and Makinde O.D. (2010). Chemically reacting MHD boundary layer flow of heat and mass transfer over a moving vertical plate with suction, *Scientific Research and Essays*, Vol. 5(19), pp. 2875-2882.
14. Madhusudhana Rao. B. and Viswanatha Reddy. G. (2012). Soret and Dufour effects on hydro magnetic heat and mass transfer over a vertical plate in a porous medium with a convective surface boundary condition and chemical reaction, *Int. J. of Eng. Research and Appl.*Vol. 2 (4), pp.056-076
15. Makinde O.D (2009). On MHD boundary-layer flow and mass transfer past a vertical plate in a porous medium with constant heat flux. *Int. J. Num. Meth. Heat Fluid Flow*, 19(3/4), pp. 546-554.
16. Olajuwon B. I (2010). Convection Heat and Mass Transfer in an Electrically Conducting Power Law Flow over a Heated Vertical Porous Plate, *International Journal of Computational Methods in Engineering Science and Mechanics*, vol. 11(2), pp. 100-108.
17. Olajuwon B.I (2011). Convection heat and mass transfer in a hydromagneticcarreau fluid past a vertical porous plate in presence of thermal radiation and thermal diffusion, *Thermal Science*, vol. 15(2), pp. S241 – S252.
18. Raptis A., Tzivanidis G. and Kafousias N. (1981). Free convection and mass transfer flow through a porous medium bounded by an infinite vertical limiting surface with constant suction, *Letter Heat Mass Transfer*, Vol. 8, pp. 417–424.

19. Raptis A and Kafoussias (1982). MHD free convection flow and mass transfer through porous medium bounded by an infinite vertical porous plate with constant heat flux. *Can. J. Phys., 60 (12),* pp. 1725 – 1729.
20. Raptis A. (1986). Flow through a porous medium in the presence of magnetic field, *Int. J. Energy Res*., Vol.10, pp.97-101.
21. Reddy M. G, Reddy N. B, and Reddy B. R (2009). Unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical porous plate with variable viscosity and thermal conductivity. *Int. J. of Appl. Math and Mech.*, vol. 5 (6), pp. 1–14.
22. Sharma P. R and Singh G (2008). Unsteady MHD free convective flow and heat Transfer along a vertical porous plate with variable suction and internal heat generation. *Int. J. of Appl. Math and Mech.*, 4(5), pp. 1–8.
23. Soundalgekar V.M. and Wavre P.D (1977). Unsteady free convection flow past an infinite vertical plate with constant suction and mass transfer, *Int. J. Heat Mass Transfer,* Vol.20pp.1363-1373.
24. Soundalgekar V.M. (1979). Effects of mass transfer and free convection on the flow past an impulsively started vertical flat plate, *ASME Journal Appl. Mech*, Vol. 46,pp.757-760.
25. Srinivasa Rao G, Ramana B, Rami Reddy B and Vidyasagar G (2014). Effect of thermal radiation on MHD boundary layer flow over a moving vertical porous plate with suction, international journal of mathematics archive, Vol 5, Issue 4, pp. 169-181.
26. 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.
27. Vafai K. and Tien C.L. (1981). Boundary and inertia effects on flow and heat transfer in porous media, *Int. J. Heat Mass Transfer*, Vol. 24, pp.195–203.
28. Vempati S. R. and LaxmiNarayanaGari A. B. (2010). Soret and Dufour effects on unsteady MHD flow pastan infinite vertical porous plate with thermal radiation," *Applied Mathematics and Mechanics*, vol. 31,(12), pp. 1481–1496.

29. Vidyasagar G, Sugunamma V and Ramana B (2013). Heat and Mass transfer effects on MHD boundary layer flow over a moving vertical porous plate, Annals of faculty engineering hunedoara-international journal of engineering tome XI, fascucle 3, pp.181-186.

30. Yih KA. (1999). Free convection effect on MHD coupled heat and mass transfer of a moving permeable vertical surface. *Int. Commun. Heat Mass Transfer*, Vol. 26 (1)pp. 95-104.