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Chemically Reacting and Thermal Radiating Effects On Magnetohydrodynamic Flow Over A Vertical Plate CumDufour And Soret Effects

K. K. Asogwa

Department of Physical and Computer Sciences, College of Natural and Applied Sciences, McPherson University, PM B 2094 Abeokuta. Ogun State Nigeria.

Abstract

An analysis of chemically reacting and thermal radiating effects on MHD flow over a vertical plate in the presence of Dufour and Soret effects. The governing equations are solved using perturbation method. The velocity, temperature, and concentration profiles are studied for different values of Dufour Du and Soret Sr numbers, thermal Grashof number Gr, mass Grash of number Gc, Prandtl number Pr, Magnetic parameter M, Chemical term K and thermal radiation R. It is observed that the velocity increases with increase in M, K and Gc. but the trend is reversed to other parameters present. It is also observed that temperature and concentration increases with decrease in R and K respectively.

Key words: MHD flow, Vertical plate, Thermal Radiation, Chemical reaction, Dufour and Soret effect.

1.0 Introduction

The magnetic hydrodynamics (MHD) continues to attract the interest of engineering science and applied Mathematics researches owing to extensive applications of such flows in the context of aerodynamics, engineering, geophysics and aeronautics. The magnetic hydrodynamic flow of a viscous incompressible fluid past an impulsively started infinite horizontal plate was studied by stokes [1], and because it's practical importance. In the above stated papers, the diffusion-thermo and thermal-diffusion term were neglected from the energy and concentration equations respectively. But when heat and mass transfer occurs simultaneously in a moving fluid, the relation between the fluxes and the driving potentials are of intricate nature. It has been found that an energy flux can be generated not only by temperature gradient but by composition gradients as well. The energy flux caused by composition gradient is called the Dufour or diffusion-thermal effect. The diffusion-thermo (Dufour) effect was found to be of considerable magnitude such that it cannot be ignored Eckert and Drake [2]. In view of the importance of this diffusion-thermo effect, Ibrahim *et al.* [3] very recently reported computational solutions for transient reactive magnetohydro dynamic heat transfer with heat source land wall mass flux effects. This study did not consider transfer over an inclined plate or Soret and Dufour effects, Asogwa and Ofudje [4] studied radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate cum mass flux. Very recently, Alam and Rahmam [5] studied the Dufour and Soret effects on study MHD free convective heat and mass transfer flow past a semi-infinite vertical porous plate embedded in a porous medium. Sedeek [6]has considered thermal-diffusion and diffusion-thermo effects on mixed free-forced convective flow and mass transfer over accelerating surface with a heat source in the presence of suction and blowing in the case of variable viscosity. Dufour and Soret effects on steady MHD free convection and mass transfer fluid flow through a porous medium in a rotating system were studied recently by Nazmul and Mahmud [7]. Kafoussias and Williams [8] presented thermal-diffusion and diffusion-thermo effects on mixed free forced convective and mass transfer boundary layer flow with temperature dependent. Ananda *et al.* [9] studied thermal diffusion and chemical effects with simultaneous thermal and mass diffusion in MHD mixed convection flow with ohmic heating. Oladapo [10]obtained the numerical solution of Dufour and Soret effects of a transient free convective flow with radiative heat transfer past a flat plate moving through a binary mixture. Anghel *et al.* [11] investigated Dufour and Soret effects on free convection boundary layer over a vertical surface embedded in a porous medium. Ibrahim and Makinde [12] examined chemically reacting MHD boundary layer flow of heat and mass transfer past a low-heat-resistant sheet moving vertically downwards

Corresponding author: K.K. Asogwa, E-mail: kanasogwa@yahoo.com, Tel.: +2349097346775.

Very recently, Postelnicus [13] studied numerically the influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dofour effects. Dursunkaya *et al.* [14] analyzed diffusion-thermo and thermal-diffusion effects in transient and steady natural convection from vertical surface. Mansour et al. [15] studied the effects of chemical reaction and thermal stratification on magnetohydrodynamics free convective heat and mass transfer over a vertical stretching surface embedded in a porous media. Ibrahim *et al*[16] studied radiation fluid flow over a vertical porous channel under optically thick approximation in the presence of MHD. Uwanta*et al* [17] examined MHD fluid flow over a vertical plate with Dufour and Soret effects.Hence, this research is to study the behaviour of chemically reacting and thermal radiating effects on MHD flow over a vertical plate cum Dufour and soret effects.

2.0 Mathematical Model

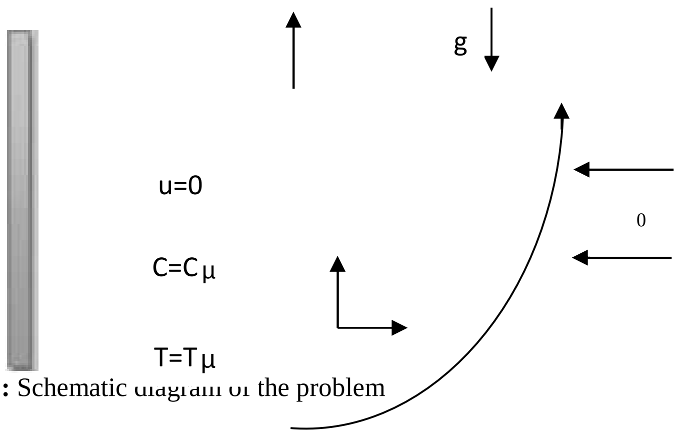

Figure 1: Schematic diagram of the problem

Consider the unsteady chemically reacting and thermal radiating effects on MHD flow of a viscous, incompressible, electrically-conducting fluid over a vertical plate moving with constant velocity cum Dufour and soret effects is considered. The surface temperature of the plate oscillates with small amplitude about a non-uniform mean temperature. The system representation (see figure 1) is such that the x-axis is taken along the plate and y-axis is normal to the plate. The governing equations for the momentum, energy and concentration are as follows;

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

$$\frac{\partial T'}{\partial t'} = \frac{k}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y} + \frac{D_m k_T}{C_s C_p}\frac{\partial^2 C'}{\partial y'^2} \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} + \frac{D_m k_T}{T_m}\frac{\partial^2 T'}{\partial y'^2} - K'C' \tag{3}$$

where u' is the velocity of the fluid, t' is time, ν is the kinematics viscosity, g is the gravitational constant, β and β^* are the thermal expansions of fluid and concentration, T' is the temperature of the fluid, k is thermal conductivity, ρ is density, C_p is the specific heat capacity at constant pressure, C_s is the concentration susceptibility, k_T is the thermal diffusion, T_m is the mean fluid temperature, C' is the mass concentration, y' is distance, q_r is the radiative heat flux, B_0 is the magnetic field, D is the molecular diffusivity and D_m is the coefficient of mass diffusivity and K' is the chemical term. The mathematical formulation is an extension of Uwanta *et al* [17]chemical reaction term was added to the existing equations. The fluid is assumed to have constant properties except for the influence of the density variations with temperature and concentration, which are considered only in the body force term. under the above assumptions the physical variables are functions of y and t.

By Rosseland approximation, we assume that the temperature differences within the flow are such that T^{*4} may be expressed as a linear function of the temperature T^*. This is accomplished by expanding Taylor series about T_d^* neglecting higher order terms.

The boundary conditions are:

$$\left.\begin{array}{l} u' = 0, \quad T' = T'_{μ} + £(T'_{μ} - T'_{\infty})e^{iμt},\ C' = C'_{μ} + £(C'_{μ} - C'_{\infty})e^{iμt}, at\ \ y = 0 \\ u' \to 0, \quad ¯' \to 0,\ T' \to 0 \quad C' \to 0 \qquad as \qquad y \to \infty \end{array}\right\} \tag{4}$$

Introducing the dimensionless quantities

$$\left.\begin{array}{l} u = \frac{u'}{U},\ y = \frac{y'U}{¬}, t = \frac{t'U^2}{¬}, \\ Gr = \frac{g\ ¬(T'_{μ} - T'_{\infty})}{U^3}, M = \frac{±_0^2 ¬}{°U^2},\ Du = \frac{D_m k_T}{C_s C_p}\frac{(C'_{μ} - C'_{\infty})}{¬(T'_{μ} - T'_{\infty})} \\ R = \frac{16a± *¬^2 T'^3}{kU^2}, \Pr = \frac{«C_{\circ}}{K}, Sc = \frac{¬}{D},\ \ Sr = \frac{D_m k_T (T'_{μ} - T'_{\infty})}{T_m ¬(C'_{μ} - C'_{\infty})} \\ ¯ = \frac{T' - T'_{\infty}}{T'_{μ} - T'_{\infty}}, C = \frac{C' - C'_{\infty}}{C'_{μ} - C'_{\infty}}, Gc = \frac{g^{\ *}¬(C'_{μ} - C'_{\infty})}{U^3} \end{array}\right\} \tag{5}$$

The thermal radiation flux gradient smay be expressed as follows

$$-\frac{\partial q_r}{\partial y'} = 4a± *(T'^4_{\infty} - T'^4) \tag{6}$$

Considering the temperature difference by assumption within the flow are sufficiently small such that T'^4 may be expressed as a linear function of the temperature.this is attained by expanding in T'^4 taylor series about T'_{∞} and ignoring higher orders terms.

$$T'^4 = 4T'^3_{\infty}T' - 3T'^4_{\infty} \tag{7}$$

Substituting the dimensionless variables (5) into (1) to (3) and using equation (6) and (7) equation (2) reduces to (9)

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr¯ + GcC - Mu \tag{8}$$

$$\frac{\partial ¯}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 ¯}{\partial y^2} - R¯ + Du\frac{\partial^2 C}{\partial y^2} \tag{9}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + Sr\frac{\partial^2 ¯}{\partial y^2} - KC \tag{10}$$

where

$$\left.\begin{array}{l} u = 0,\ C = 1 + £e^{iμt}, ¯ = 1 + £e^{iμt}, y = 0 \\ u \to 0, C \to 0, ¯ \to 0, y \to \infty \end{array}\right\} \tag{11}$$

Where Gr is thermal Grashof number, M is the Hartmann number, Gc is the mass Grashof number, R is the thermal radiation conduction number ,Sc is the Schmidt number, Pr is the Prandtl number, Sr *and* Du represent the Soret and Dufour numbers respectively

3.0 Method of Solution

Perturbation approach.

We assume that £ is small, therefore, we seek the solutions to (12), (13) and (14) having the form

$$u(y,t) = u_0(y) + £u_1(y)e^{iμt} \tag{12}$$

$$¯(y,t) = ¯_0(y) + £¯_1(y)e^{iμt} \tag{13}$$

$$C(y,t) = C_0(y) + £C_1(y)e^{iμt} \tag{14}$$

where $u_0(y), C_0(y), \theta_0(y), u_1(y), C_1(y)$ and $\theta_1(y)$ are to be determined.

$$u_0'' - Mu_0 = -GcC_0 - Gr\theta_0 \tag{15}$$

$$\theta_0'' - \Pr R\theta_0 = D_3^* C_0'' \tag{16}$$

$$C_0'' = D_2^* \theta_0'' + D_a C_0 \tag{17}$$

$$u_1'' - (M + i\mu)u_1 = -GcC_1 - Gr\theta_1 \tag{18}$$

$$\theta_1'' - (R + i\mu)\Pr\theta_1 = D_3^* C_1'' \tag{19}$$

$$C_1'' - Sci\mu C_1 = D_2^* \theta'' + D_a C_1' \tag{20}$$

All primes denote differentiation with respect to y

The boundary conditions are:

$$\left.\begin{array}{ll} u_0 = 0, \theta_0 = 1, C_0 = 1 & \text{on } y = 0 \\ u_1 = 0, \theta_1 = 1, C_1 = 1 & \text{on } y = 0 \\ u_0 \to 0, \theta_0 \to 0, C_0 \to 0 & \text{as } y \to \infty \\ u_1 \to 0, \theta_1 \to 0, C_1 \to 0 & \text{as } y \to \infty \end{array}\right\} \tag{21}$$

Solving equation (15) to (17) subject to the boundary conditions (21) we obtain

$$u_0 = \left[Gr\left(\frac{1}{f^2 - M} + \frac{1}{g^2 - M} \right) + Gc\left(\frac{1}{p^2 - M} + \frac{1}{q^2 - M} \right) \right] e^{-(M)^{0.5} y} - Gc\left(\frac{1}{p^2 - M} e^{-py} + \frac{1}{q^2 - M} e^{-qy} \right)$$
$$-Gr\left(\frac{1}{f^2 - M} e^{-fy} + \frac{1}{g^2 - M} e^{-gy} \right) \tag{22}$$

$$C_0(y) = e^{-fy} + e^{-gy} \tag{23}$$

$$\theta_0(y) = e^{-py} + e^{-qy} \tag{24}$$

Solving equation (18) to (20) subject to the boundary conditions (21) we obtain

$$\therefore u_1 = \left[Gr\left(\frac{1}{a^2 - (M + i\mu)} + \frac{1}{b^2 - (M + i\mu)} \right) + Gc\left(\frac{1}{c^2 - (M + i\mu)} + \frac{1}{d^2 - (M + i\mu)} \right) \right] e^{-(M + i\mu)^{0.5} y}$$
$$-Gc\left(\frac{1}{c^2 - (M + i\mu)} e^{-cy} + \frac{1}{d^2 - (M + i\mu)} e^{-dy} \right) - Gr\left(\frac{1}{a^2 - (M + i\mu)} e^{-ay} + \frac{1}{b^2 - (M + i\mu)} e^{-by} \right) \tag{25}$$

$$C_1(y) = e^{-cy} + e^{-dy} \tag{26}$$

$$\theta_1(y) = e^{-ay} + e^{-by} \tag{27}$$

where

$$a = (0.5\P_1 + \P_3)^{0.5} \quad b = (0.5\P_1 - \P_3)^{0.5} \quad \P_1 = \frac{(R + i\mu)\Pr + Sci\mu + D_a}{1 - D_2^* D_3^*}, \quad \P_2 = \frac{Sci\mu(R + i\mu)\Pr + D_a(R + i\mu)\Pr}{1 - D_2^* D_3^*}$$

$$D_a = ScK, \quad \Psi_1 = \frac{D_a + \Pr R}{1 - D_2^* D_3^*}, \quad \Psi_2 = \frac{\Pr R D_a}{1 - D_2^* D_3^*}$$

$$D_2^* = -ScSr, \quad D_3^* = -\Pr Du, \quad ¤_1 = \frac{(Sci\mu + D_a) + (R + i\mu)\Pr}{1 - D_2^* D_3^*}, \quad ¤_2 = \frac{(R + i\mu)\Pr(Sci\mu + D_a)}{1 - D_2^* D_3^*}$$

$$f=\left(0.5\Psi_1+\Psi_3\right)^{0.5},\quad g=\left(0.5\Psi_1-\Psi_3\right)^{0.5}\ \text{¢}_1=\frac{\Pr R+D_{\text{a}}}{1-D_2^*D_3^*}\ ,\quad \text{¢}_2=\frac{D_{\text{a}}\Pr R}{1-D_2^*D_3^*}$$

$$p=\left(0.5\text{¢}_1+\text{¢}_3\right)^{0.5},\quad q=\left(0.5\text{¢}_1-\text{¢}_3\right)^{0.5}\ c=\left(0.5\text{¤}_1+\text{¤}_3\right)^{0.5}\quad d=\left(0.5\text{¤}_1-\text{¤}_3\right)^{0.5}$$

$$\text{¢}_3=\left(\left(\text{¢}_1^{\,2}+4\text{¢}_2\right)/4\right)^{0.5},\ \text{¶}_3=\left(\left(\text{¶}_1^{2}+4\text{¶}_2\right)/4\right)^{0.5},\ \text{¤}_3=\left(\left(\text{¤}_1^{2}+4\text{¤}_2\right)/4\right)^{0.5},\ \Psi_3=\left(\left(\Psi_1^{2}+4\Psi_2\right)/4\right)^{0.5}$$

Substituting equation (22) and (25), (23) and (26), (24)and (27)into (12),(13) and (14) respectively gives

$$u(y,t)=\left[Gr\left(\frac{1}{f^2-M}+\frac{1}{g^2-M}\right)+Gc\left(\frac{1}{p^2-M}+\frac{1}{q^2-M}\right)\right]e^{-(M)^{0.5}y}$$
$$-Gc\left(\frac{1}{p^2-M}e^{-py}+\frac{1}{q^2-M}e^{-qy}\right)-Gr\left(\frac{1}{f^2-M}e^{-ey}+\frac{1}{g^2-M}e^{-fy}\right)$$
$$+\text{£}\left[\left[Gr\left(\frac{1}{a^2-(M+i\mu)}+\frac{1}{b^2-(M+i\mu)}\right)+Gc\left(\frac{1}{c^2-(M+i\mu)}+\frac{1}{d^2-(M+i\mu)}\right)\right]e^{-(M+i\mu)^{0.5}y}\right.$$
$$\left.-Gr\left(\frac{1}{a^2-(M+i\mu)}e^{-ay}+\frac{1}{b^2-(M+i\mu)}e^{-by}\right)-Gc\left(\frac{1}{c^2-(M+i\mu)}e^{-cy}+\frac{1}{d^2-(M+i\mu)}e^{-dy}\right)\right]e^{i\mu t}\qquad(28)$$

$$C(y)=e^{-fy}+e^{-gy}+\text{£}\left(e^{-cy}+e^{-dy}\right)e^{i\mu t}\qquad(29)$$

$$\overline{\ }(y)=e^{-py}+e^{-qy}+\text{£}\left(e^{-ay}+e^{-by}\right)e^{i\mu t}\qquad(30)$$

4.0 Results and Discussion

An investigation of chemically reacting and thermal radiating effects on MHD flow over a vertical plate in the presence of Dufour and Soret effects In order to understand the nature of the flow problem, computations are performed for different parameters such as Hartmann number M, Dufour number Du, Soret number Sr,thermal radiation conduction R, Prandtl number Pr Schmidtl number Sc, Chemical term K

Figures 2-10 represent the velocity profiles with varying parameters, while figures 11 to 15 and 16 to 20 represent temperature and concentration distributions respectively.

The effect of velocity for different values of Hartmann number (M = 5, 8, 10) is presented in Figure 2. The graph shows velocity increases with increasing M. The effect of velocity for different values of Dufour number (Du = 0.03, 0.06,0.3) is presented in Figure 3. The graph shows that velocity decreases with increasing Du. The effect of velocity for different values of thermal radiation conduction (R = 2, 5, 8) is presented in Figure 4.The graph shows that velocity decreases with increasing R.

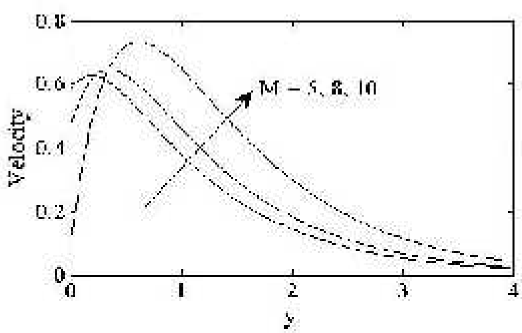

Figure 2: Velocity profiles for different values of M

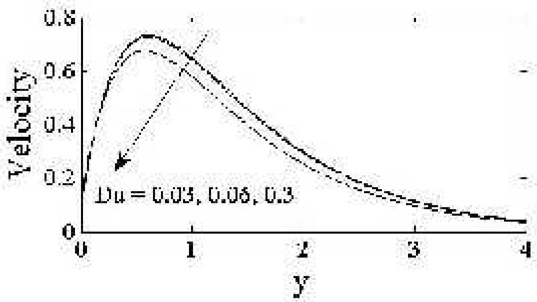

Figure 3: Velocity profiles for different values of Du

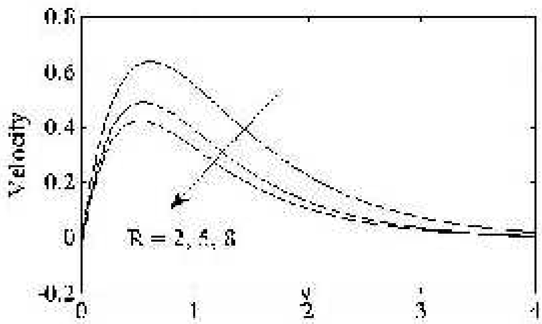

Figure 4: Velocity profiles for different values of R

The velocity profiles is studied for different values of mass and thermal Grash of number (Gc = 2, 5, 10) and (Gr = 3, 5, 10) are presented in Figure 5 and 6 respectively. It is observed that velocity increases with increasing Gc. and decreases with Gr. respectively. The velocity profiles is studied for various values of Prandtl number (Pr =0.71, 1, 7) and is presented in Figure 7. It is observed that velocity increases with decreasing values of Pr.

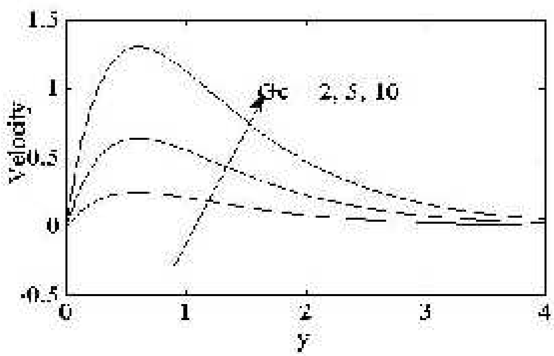

Figure 5: Velocity profiles for different values of Gc

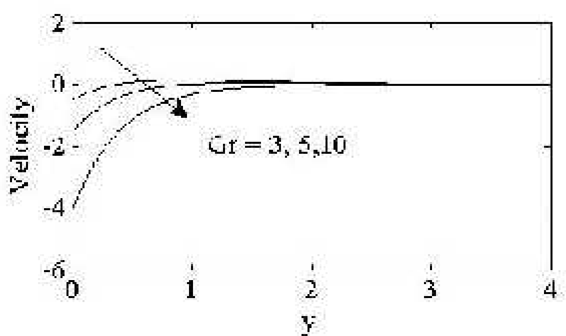

Figure 6: Velocity profiles for different values of Gr

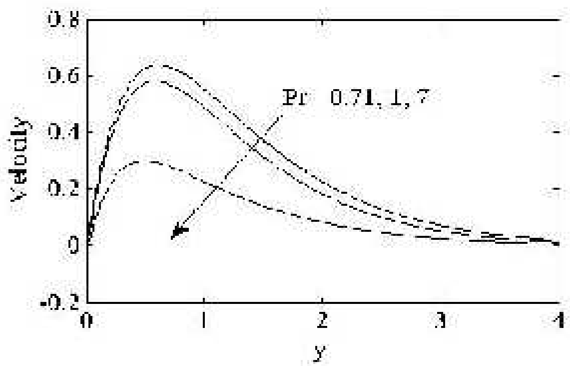

Figure 7: Velocity profiles for different values of Pr

The velocity profiles is studied for various values of Chemical term(K = 2, 5, 10) and is presented in Figure 8. It is observed that velocity increases with increasing values of K. The effects of velocity for different values of Soret number (Sr = 0.2, 5, 10) is presented in Figure 9. From the graph it shows that velocity increases with decreasing Sr. The velocity profiles is studied for various values of Schmidt number (Sc = 0.16, 0.3, 0.6) and is presented in Figure 10. It is observed that velocity increases with decreasing values of Sc

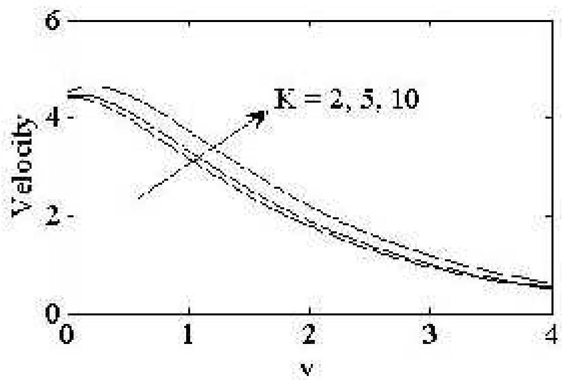

Figure 8: Velocity profiles for different values of K

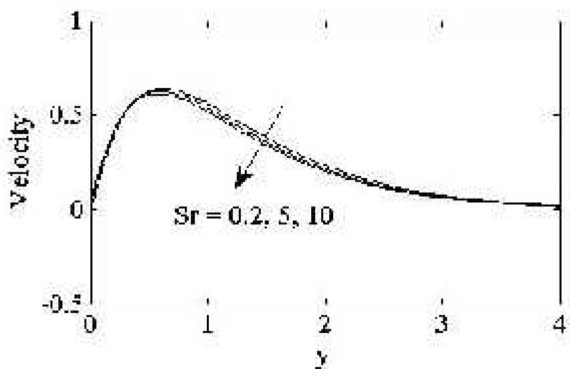

Figure 9: Velocity profiles for different values of Sr

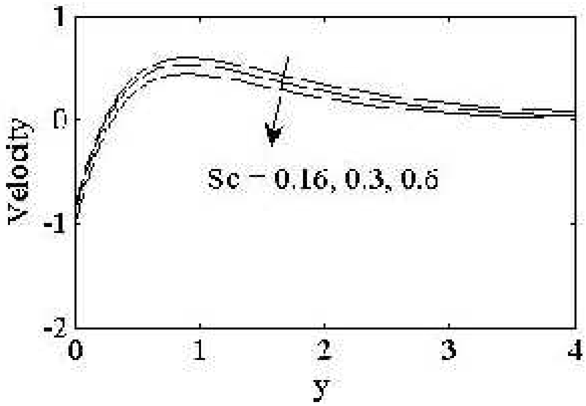

Figure 10: Velocity profiles for different values of Sc

The effects of temperature for different values of Dufour number (Du = 0.03, 0.06, 0.3) is presented in Figure 11. From the graph it shows that temperature increases with decreasing Du. The effects of temperature for different values of thermal radiation conduction (R = 2, 5, 8) is presented in Figure 12 From the graph it shows that temperature increases with decreasing R. The effects of temperature for different values of Soret number (Sr = 0.2, 2, 5) is presented in Figure 13.From the graph it shows that temperature increases with decreasing Sr. The temperature profiles is studied for various values of Prandtl number (Pr =0.71, 0.85, 1) and is presented in Figure 14. It is observed that velocity increases with decreasing values of Pr. The temperature profiles is studied for various values of Schmidt number (Sc = 0.16, 0.3, 0.6) and is presented in Figure 15. It is observed that velocity increases with decreasing values of Sc

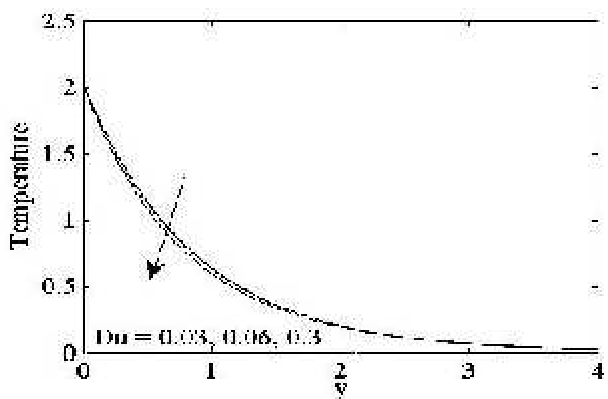

Figure 11: Temperature profiles for different values of Du

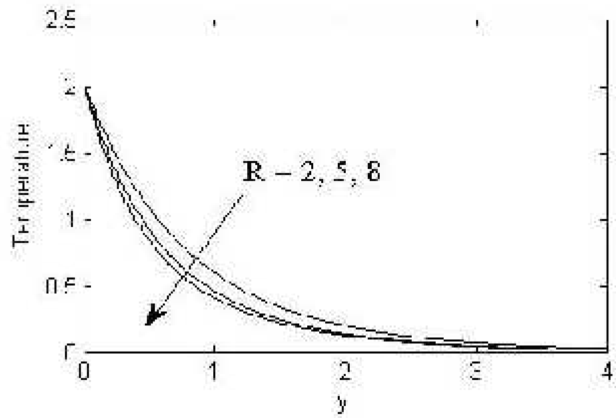

Figure 12: Temperature profiles for different values of R

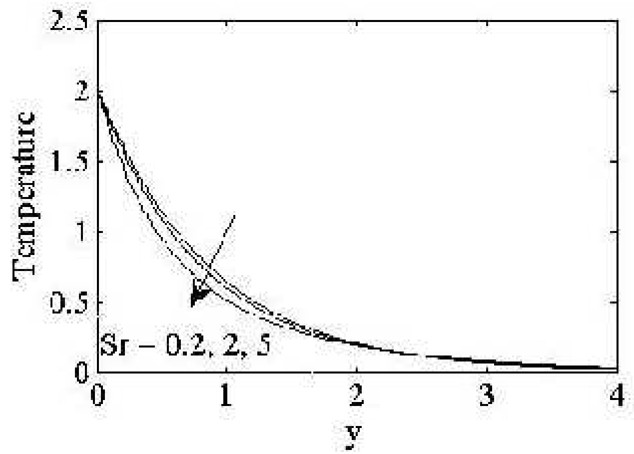

Figure 13: Temperature profiles for different values of Sr

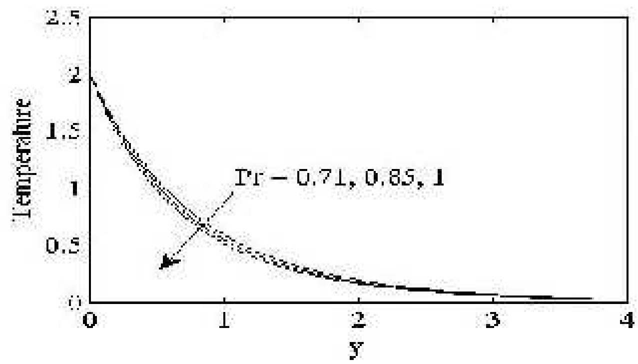

Figure 14: Temperature profiles for different values of Pr

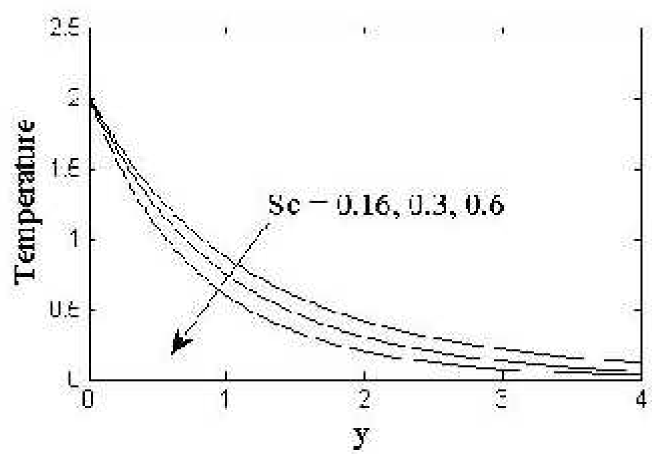

Figure 15: Temperature profiles for different values of Sc

The concentration profiles for different values of Dufour number (Du = 0.03, 0.06, 0.3) is presented in Figure 16. It is observed that the concentration increases with decreasing Du. the concentration profiles for different values of thermal radiation conduction (R = 2, 5, 8) is presented in Figure 17. It is observed that the concentration increases with decreasing R.

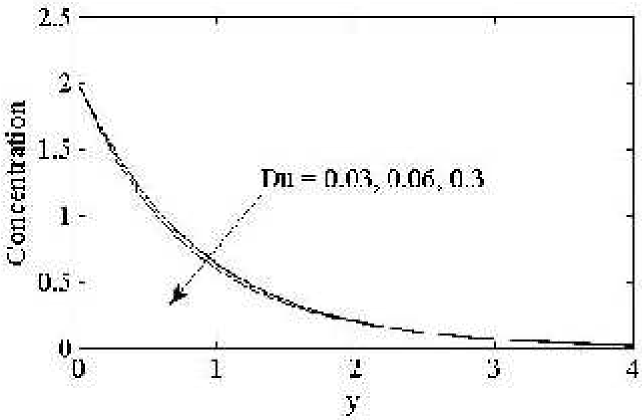

Figure 16: Concentration profiles for different values of Du

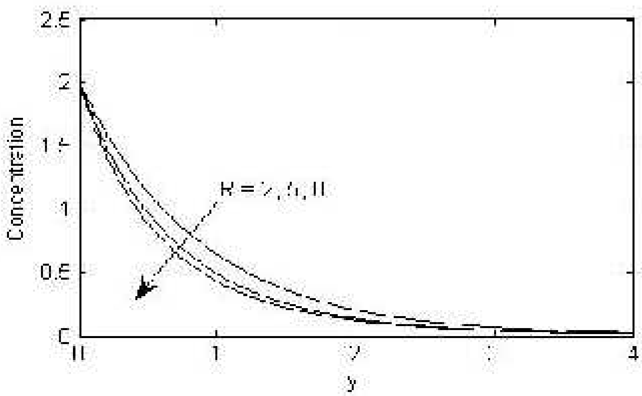

Figure 17: Concentration profiles for different values of R

The effects of concentration for different values of Chemical term (K = 2, 5, 8) is presented in Figure 18. From the graph it shows that concentration increases with decreasing K. The concentration profiles for different values of Prandtl number(Pr = 0.71, 0.85, 1) is presented in Figure 19. It is observed that the concentration increases with decreasing Prandtl number. The concentration profiles for different values of Schmidt number (Sc = 0.16, 0.3, 0.6) is presented in Figure 20. It is observed that the concentration increases with decreasing Schmidt number.

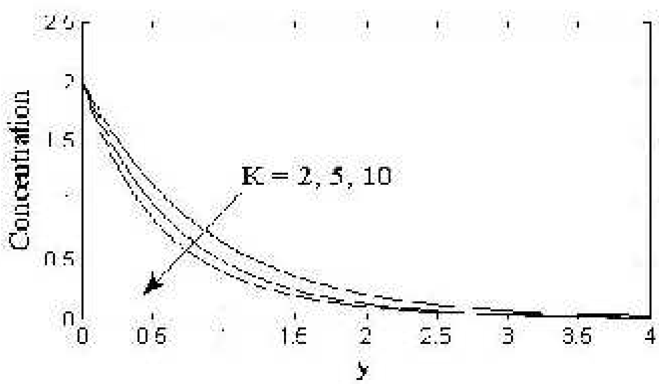

Figure 18: Concentration profiles for different values of K

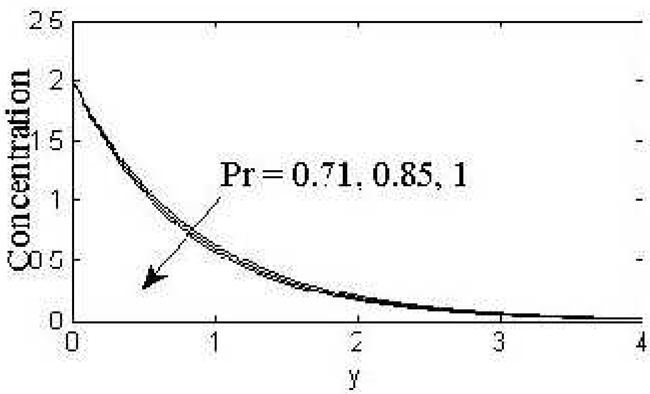

Figure 19: Concentration profiles for different values of Pr

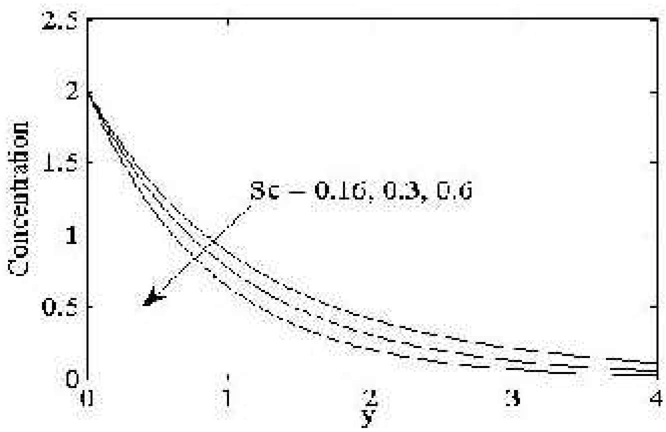

Figure 20: Concentration profiles for different values of Sc

5.0 Conclusion

Chemically reacting and thermal radiating effects on MHD over a vertical plate cum Dufour and Soret effects has been formulated, solved and analysed. The governing equations are solved using perturbation method. The velocity, temperature, and concentration profiles are studied for different values of Dufour Du and Soret Sr numbers, Grashof number Gr, mass Grashof number Gc, Prandtl number Pr, Magnetic parameter M, Chemical term K and thermal radiation R. It is observed that the velocity increases with increase in M, K and Gc. but the trend is reversed with respect to Gr, Du, Sr, Sc, R and Pr. it is also observed that temperature and concentration increases with decrease in R and K respectively.

6.0 References

[1] G. G. Stokes, On the effects of internal friction of fluids on the motion of pendulum, Thammasat International Journal of Science and Technology 9(1856) 8-106.

[2] E. R. G. Eckert, and R.M. Drake, Analysis of Heat and Mass Transfer, Mc. Graw-.Hill, New York, 1972.

[3] F. S. Ibrahim, A. M. Elaiw and A.A. Bakr, Effects of the chemical reactions and radiations absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction, Cambridge Journal Physics 78 (2008)255-270.

[4] K. K. Asogwa and E. A. Ofudje, Radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate cum mass flux. International Journal of Mathematical Archive-5(10), (2014) 81-89.

[5] M.S. Alam and M.M. Rahman, Dufour and Soret effects on MHD free convective heat and mass transfer flow past a vertical flat plate embedded in porous medium, Journal Naval Architecture and Marine Engineering 2(1). (2005) 55-65.

[6] M. A. Sedeek, Thermal-diffusion and diffusion-thermo effects on mixed free- forced convective flow and mass transfer over accelerating surface with a heat source in the presence of suction and blowing in the case of variable viscosity, Acta Mechanica 172 (2004) 83-94.

[7] I. Nazmul and A. Mahmud, Dufour and Soret effects on steady MHD free convection and mass transfer fluid flow through a porous medium in a rotating system, Journal of Naval Architecture and Marine Engineering 4(1) (2007) 119.

[8] N.G.Kafoussias and E.M.Williams, Thermal-diffusion and diffusion-thermo effects on mixed free forced convective and mass transfer boundary layer flow with temperature dependent, International Journal of Engineering Science 33(9) (1995) 1369-1384.

[9] R. N. Ananda, V.K. Varma and M.C.Raju., Thermal diffusion and chemical effects with simultaneous thermal and mass diffusion in MHD mixed convection flow with ohmic heating, Journal of Naval Architecture and Marine Engineering6 (2009) 84-93.

[10] P.O.Oladapo, Dufour and Soret effects of a transient free convective flow with radiative heat transfer past a flat plate moving through a binary mixture, Pacific Journal of Science and Technology 11(1) (2010)163-172

[11] M. Anghel, H.S. Takhar and I. Pop, Dufour and Soret effects on free convection boundary layer over a vertical surface embedded in a porous medium, Journal Heat and Mass Transfer 43 (2000)1265-1274

[12] S. Y. Ibrahim and O. D. Makinde, Chemically reacting Magnetohydrodynamics (MHD) boundary layer flow of heat and mass transfer past a low-heat-resistant sheet moving vertically downwards. Scientific Research and Essays 6(22), (2011), 4762-4775.

[13] A Postelincus, Influence of a magnetic field on heat and mass transfer by a natural convection from vertical surfaces in porous media considering Soret and Dufour effects, International Journal Heat mass transfer47 (6-7) (2004) 1467-1472.

[14] Z. Dursunkaya, W. M. Worek, Diffusion thermo and thermal-diffusion effects in transient and steady natural convection from vertical surface, International Journal Heat mass transfer 35(8) (1992) 2060-2065.

[15] M. A. Mansour, N. F. El-Anssary, A.M. Aly, Effect of chemical reaction and thermal stratification on MHD free convective heat and mass transfer over a vertical stretching surface embedded in a porous media considering Soret and Dufour number, Chemical Engineering Journal145 (2008) 340-345.

[16] Ibrahim M. O., Asogwa K. K., Uwanta I. J. and A. O. Jos, Radiation fluid flow over a vertical porous channel under optically thick approximation in the presence of MHD. Journal of the Nigerian Association of Mathematical Physics. Volume 27: (2014) 159-170.

[17] I.J. Uwanta, K.K. Asogwa, Ali U.A., MHD fluid flow over a vertical plate with Dufour and Soret effects, International Journal of Computer Application. (2012), Vol.45-No.2,.