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Influence of Chemical Reaction And Magnetic Field on Heat and Mass Transfer by Natural Convection From Vertical Stationary Flat Plate in Porous Media Considering Soret and Dufour Effects

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ABSTRACT *Heat and mass transfer characteristics of MHD natural convection about a vertical stationary flat plate embedded in a porous medium saturated by a binary fluid mixture subjected to a chemical reaction is investigated numerically by taking into account the Soret and Dufour effects. The concentration profile is drawn for various values of magnetic,Lewis,Dufour,Soret ,Sustentation and chemical reaction parameters by taking first, second and third order chemical reactions.*

KEYWORDS : Binary fluid mixture, Soret effect, Dufour effect, Magnetic field, Chemical reaction,Porous media.

INTRODUCTION

Coupled heat and mass transfer due to natural convection in a fluid saturated porous medium has attracted considerable attention in the last several decades due to its many important engineering, environmental and geophysical applications. Recent books by Nield and Bejan(1999), Ingham and Pop (1998 , 2002) present a comprehensive account of the available information in the field. Ibrahim and Makinde(2011) studied free convection heat and mass transfer problems neglecting Dufour and Soret effects on the basis that they are of smaller order of magnitudes. Benano-Melly(2001) analyzed the problem of thermal diffusion in binary fluid mixtures, lying within a porous media and subjected to a horizontal thermal gradient. Afifi(2006) presented an analysis of non-Darcy MHD free convective heat and mass transfer past a vertical isothermal surface embedded in a porous medium with thermal dispersion and temperature-dependent viscosity. In their work Anjalidevi and Kandasamy(1999) considered the chemical reaction between species A and B to be of first order, homogenous and with a constant rate. Chamka(2003) has analyzed MHD flow over a uniformly stretched vertical permeable surface in presence of heat generation/absorption and a chemical reaction. Afifi(2004) analyzed the MHD free convective flow and mass transfer over a stretching sheet with homogenous chemical reaction of order n (where n was taken to be 1,2 and 3) and with a constant rate. Seddeek(2005) took into account the homogenous chemical reaction of first-order in boundary layer hydromagnetic flow with heat and mass transfer over a heat surface. Various other effects have been included in his analysis such as thermopheresis, variable viscosity and heat generation absorption. A diffusion equation with a chemical reaction source term was included by Abo-Eldahad and Salem(2005) in the analysis of flow and heat transfer of an electrically conducting non-Newtonian fluid over a moving cylinder in presence of uniform magnetic field. Postelnicu(2007) has analyzed the effect of chemical reaction on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour Effects neglecting the effect of magnetic field.Sharma(2011-2012) has analyzed the Soret and Dufour effects on separation of a binary fluid mixture in MHD natural convection in porous media neglecting the effect of chemical reaction term.

The objective of this paper is to study simultaneous heat and mass transfer by natural convection from a vertical stationary flat plate embedded in a binary fluid mixture of incompressible viscous fluids using Darcy Boussingesq model considering the plate to be soluble in the fluid in the presence of a chemical reaction and magnetic field perpendicular to the plate including Soret and Dufour effects..

2.Mathematical Formulation

We consider the steady two-dimensional natural convection in a porous medium saturated with a Newtonian binary fluid mixture bounded by a vertical stationary flat plate with constant wall temperature and constant concentration in presence of weak uniform magnetic field intensity applied in a direction perpendicular to the plate. The temperature of the ambient medium is where and is the concentration of rarer and lighter component of binary fluid mixture far away from the plate. The x- coordinate is measured along the plate from its leading edge, and y-coordinate normal to it. Under the boundary-layer and Boussinesq approximation, the basic boundary layer equations describing the conservation of mass, momentum, energy and concentration can

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 , \qquad \ldots(1)$$

$$u\left(1+\frac{k\sigma\mu_e^2H_0^2}{\mu}\right) = \frac{gk}{\vartheta}\left[\beta_T(T-T_\infty)+\beta_C(C-C_\infty)\right] , \qquad \ldots(2)$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha_m\frac{\partial^2 T}{\partial y^2} + \frac{D_m k_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2} \qquad \ldots(3)$$

and

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_m\frac{\partial^2 C}{\partial y^2} + \frac{D_m k_T}{T_m}\frac{\partial^2 T}{\partial y^2} - K_1(C - C_\infty)^n \qquad \ldots(4)$$

where $u$and v are fluid velocity components along x and y axes, ϑ is the kinematic viscosity, g is acceleration due to gravity, ρ is the density,β_T is the coefficient of thermal expansion, β_C is coefficient of concentration expansion, k is the Darcy permeability,α_m is thermal diffusivity,T_m is the mean fluid temperature,$k_T$is the thermal diffusion ratio and C_s is the concentration susceptibility, C is the concentration of the rarer and lighter component of the binary fluid mixture and T denotes the temperature of the fluid, K_1 is the rate constant of chemical reaction. The boundary conditions of the problem are

$$u = v = 0,\ T = T_w,\ C = C_w \ \ldots\ at\ y = 0$$
$$\text{and } T \to T_\infty,\ C \to C_\infty \quad \ldots\ at\ y \to \infty \qquad \ldots(5)$$

and

We now introduce the following dimensional variables:

$$\eta = \frac{y}{x} Ra_x^{\frac{1}{2}},\ \psi = \alpha_m Ra_x^{\frac{1}{2}} f(\eta), \qquad \ldots(6)$$
$$\theta = \frac{T - T_\infty}{T_w - T_\infty} \text{ and } \phi = \frac{C - C_\infty}{C_w - C_\infty}$$

where ψ is stream function defined in the usual way

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

$$\text{and } Ra_x = \frac{g k \beta_T (T_w - T_\infty) x}{\vartheta \alpha_m}$$

is the local Rayleigh number.

If we introduce the relations (6) into the equations (2),(3)and(4),we have

$$(1 + M^2) f' = \theta + N\phi, \qquad \ldots(7)$$

$$\theta'' + \frac{1}{2} f\theta' + D_f \phi'' = 0 \qquad \ldots(8)$$

and

$$\frac{1}{Le}\phi'' + S_r \theta'' + \frac{1}{2} f\phi' - \gamma \phi^n = 0 \qquad \ldots(9)$$

where M, N, D_f ,L_e, S_r and γ are respectively magnetic, sustentation parameter, Dufour, Lewis, Soret numbers and chemical reaction parameter and are defined as

$$M^2 = \frac{k\sigma \mu_e^2 H_0^2}{\mu},\ N = \frac{\beta_c (C_w - c_\infty)}{\beta_T (T_w - T_\infty)},$$
$$D_f = \frac{D_m k_T (C_w - c_\infty)}{C_s C_p \alpha_m (T_w - T_\infty)},\ Le = \frac{\alpha_m}{D_m},$$
$$S_r = \frac{D_m k_T (T_w - T_\infty)}{T_m \alpha_m (C_w - C_\infty)} \text{ and } \gamma = \frac{K_1 x^2}{\alpha_m Ra_x} \qquad \ldots(10)$$

N is positive for thermally assisting flows, negative for thermally opposing flows and zero for thermal-driven flows.

The boundary conditions (5) in terms of dimensional variables ,are transformed to

$$f = 0,\ \theta = 1, \phi = 1 \quad \ldots \quad at\ \eta = 0$$
$$\text{and } \theta \to 0,\ \phi \to 0 \quad \ldots \quad at\ \eta \to \infty \qquad \ldots(11)$$

The equations (7)-(9) are coupled ordinary non-linear differential equations and so their solution in closed form cannot be obtained. Hence, the set of equations (7), (8) and (9) under the boundary conditions (11) have been solved numerically by using MATLAB's built in solver bvp4c.

3.Results and Discussion:

Numerical results of equations (7), (8) and (9) under boundary conditions (11) are obtained for various values of parametersSeveral cases are considered:

CaseI: $N = 1,\ n = 2, Le = 1,\ D_f = 0.5,\ \gamma = 0.5, M = 1,\ S_r = (0.1, 0.3, 0.5)$

CaseII: $N = 1,\ n = 2, Le = 1, D_f = 0.5,\ S_r = 0.5,\ \gamma = 0.5,\ M = (0, 0.5, 1)$

CaseIII: $N = 1,\ \gamma = 0.5, Le = 1, D_f = 0.5, S_r = 0.5,\ M = 1,\ n = (1, 2, 3)$

CaseIV: $N = 1,\ n = 2,\ Le = 1,\ D_f = 0.5,\ S_r = 0.5,\ M = 1, \gamma = (0, 0.5, 1)$

CaseV: $n = 2,\ \gamma = 0.5,\ Le = 1, D_f = 0.5,\ S_r = 0.5,\ M = 1, N = (0, 0.5, 1)$

CaseVI: $N = 1,\ n = 2, Le = 1,\ \gamma = 0.5,\ S_r = 0.5, M = 1, D_f = (0.1, 0.3, 0.5)$

CaseVII: $N = 1,\ n = 2, D_f = 0.5,\ S_r = 0.5, M = 1,\ \gamma = 0.5$, Le=(0.5,1,1.5)

The numerical results for concentration profile are displayfor above mentioned cases in Fig. 1 to Fig. 7.

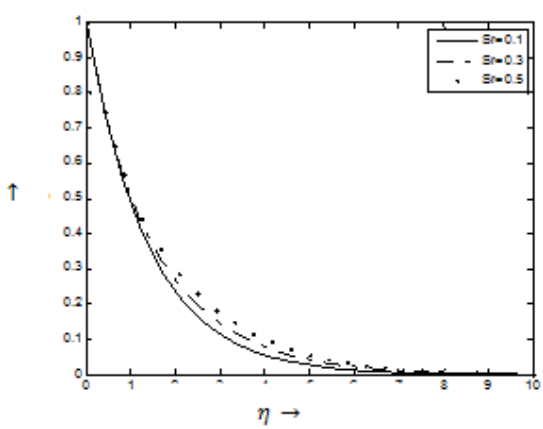


Fig.1: Variation of concentration across the boundarylayer for N=1,n=2, Le=1,D_f=0.5,γ=0.5 ,M=1

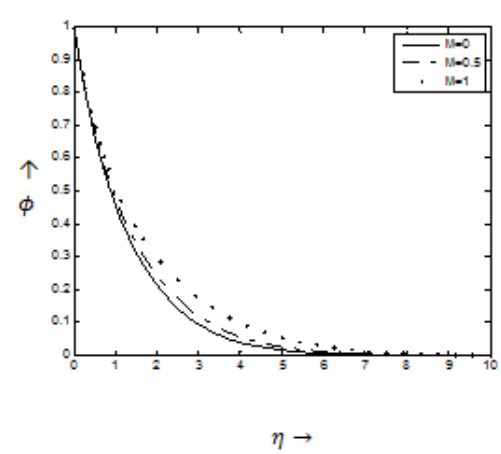


Fig. 2: Variation of concentration across the boundarylayer for, N=1,n=2, Le=1,D_f=0.5 ,S_r=0.5 ,γ=0.5

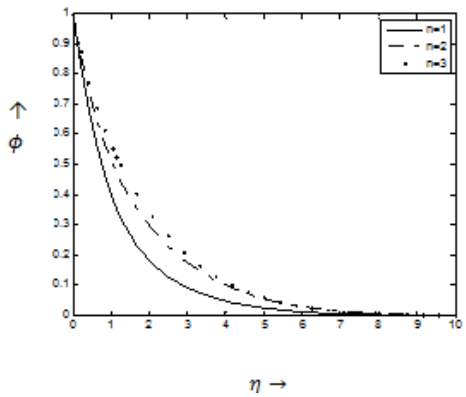


Fig. 3: Variation of concentration across the boundary layer for N=1,γ=0.5,Le=1,D_f=0.5 ,S_r=0.5 ,M=1

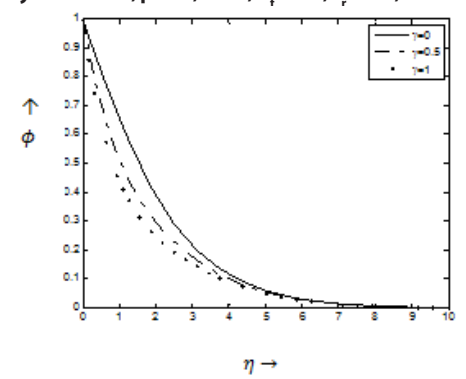


Fig .4:Variation of concentration across the boundary layer for, for N=1,n=2, Le=1, D_=0.5 ,S_=0.5 ,M=1

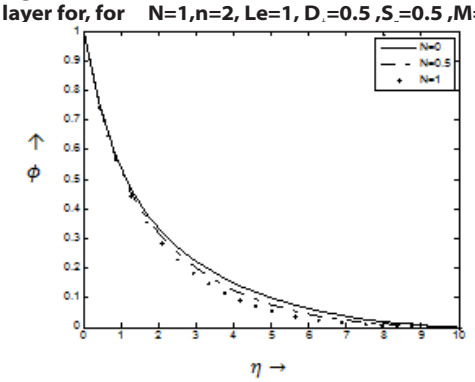


Fig. 5: Variation of concentration across the boundary layer for n=2,γ=0.5,Le=1, D_f=0.5 ,S_r=0.5 ,M=1

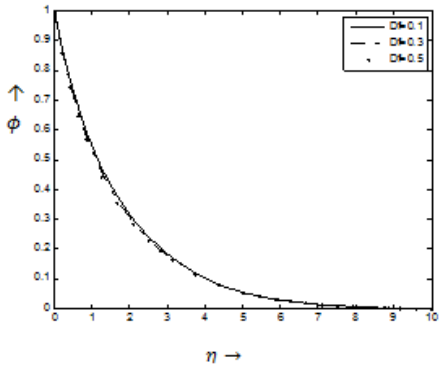


Fig. 6: Variation of concentration across the boundary layer for, N=1,n=2,Le=1,γ=0.5, S_r=0.5 ,M=1

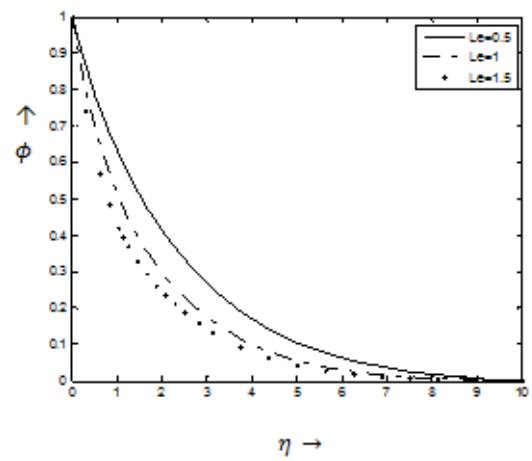


Fig. 7:Variation of concentration across the boundary layer for, N=1,n=2, D_f=0.5 ,S_r=0.5 ,M=1,γ=0.5

It is observed from Fig.1 to Fig.7 that concentration of the rarer and lighter component of the binary fluid mixture decreases exponentially from its maximum value at the plate to its minimum value at the end of boundary layer. It is seen that due to decrease in the values of parameters S_r and M, and also of the order of n, the concentration decreases sharply within the boundary layer. For increase in the values of parameters γ , N, D_f and L_e the concentration decreases sharply within the boundary layer .Hence we conclude that the separation of the binary fluid mixture is reduced by increasing the magnetic parameter M and also the order of chemical reaction.

REFERENCES

[1]Abo-Eldahad, E. M.,and Salem, A. M.(2005),"MHD flow and heat transfer of non- Newtonian power- law fluid with diffusion and chemical reaction on a moving cylinder ." Heat Mass Transf , 41, 703-708. | [2]Afifi,A. (2004), " MHD free convective flow and mass transfer over a stretching sheet with chemical reaction." Heat Mass Transf, 40, 495-500. | [3]Afifi, A.(2006), " Effects of thermal-diffusion and diffusion-thermo on non Darcy MHD free convective flow and mass transfer past a vertical isothermal surface embedded in a porous medium with thermal dispersion and temperature dependent viscosity."Appl Math Model(in press). | [4]Anjalidevi, S. P. and Kandasamy,R. (1999), "Effect of chemical reaction,heat and mass transfer on laminar flow along a semi-infinite horizontal plate."Heat Mass Transf , 35 , 465-472. | [5]Benano-Melly,L.B., Caltagirone, J.P., Faissat, B., Montel,F. andCostesque, P. (2001), "ModellingSoret coefficient measurement experiments in porous media considering thermal and solutal convection." Int J Heat Mass Transf, 44, 1285-1297. | [6]Chamka, A.J. (2003), "MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction."Int. Comm Heat Mass Transf, 30,413-422. | [7]Ibrahim, S.Y., and Makinde, O.D. (2011), "Radiation effect on chemically reacting MHD boundary layer flow of heat and mass transfer through a porous vertical flat plate."Int.J. PhysSci, 6(6), 1508-1516. | [8]Ingham, D.B., and Pop,I. (1998),"Transport phenomena in porous media I."Pergamon, Oxford. | [9]Ingham, D.B., and Pop, I. (2002), "Transport phenomena in porous media II."Pergamon, Oxford. | [10]Nield,D.A., and-Bejan, A. (1999), "Convection in porous media ."2nd edition, Springer , New York. | [11]Postelnicu, A. (2007), "Influence of chemical reaction on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects."Heat Mass Transf, 43, 595-602. | [12]Seddeek,M.A. (2005), "Finite-element method for the effects of chemical reaction, variable viscosity, thermophoresis and heat generation/absorption on a boundary-layer hydromagnetic flow with heat and mass transfer over a heat surface." ActaMech, 177, | 1-18. | [13]Sharma,B.R. (2011-2012), "Soret and Dufour effects on separation of a binary fluid mixture in MHD natural convection flow in porous media." Mathematical Forum ,Vol XXIV, 17-27. | |