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Impact of Chemical Reaction on MHD Free Convection Heat and Mass Transfer from Vertical Surfaces in Porous Media Considering Thermal Diffusion and Diffusion Thermo Effects

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ABSTRACT

Many researchers have been studied the influence of the heat and mass transfer by natural convection in porous medium due to its many applications, such as growth of modern technologies for nuclear waste organization, heating of ground water in hot dike complexes in volcanic regions, etc. In this paper, a two dimensional steady magneto hydrodynamics (MHD) free convection flow of heat and mass transfer from a vertical surface in porous media subjected to a chemical reaction has been analyzed numerically considering thermal-diffusion and diffusion-thermo effects. Here, we transformed the governing non linear partial differential equations into system of ordinary differential equations by a similar transformation to discuss the numerical solution of governing equations using implicit finite difference method. We displayed the dimensionless temperature profiles, velocity profiles and the concentration profiles graphically for the different values of the Lewis number, Soret number, Dufour number, Magnetic number, chemical reaction parameter.

Key words: Porous medium, MHD, Dufour effect, Soret effect and the Finite difference method

INTRODUCTION

Several studies have been found to analyze the influence of the combined heat and mass transfer process by normal convection in a thermal and/or mass stratified porous medium, due to its broad applications, such as development of modern technologies for nuclear waste management, hot ditch complexes in volcanic regions for heating of ground water, separation procedure in chemical engineering, etc.

When heat and mass transfer occur simultaneously in a moving fluid, the relation among the fluxes and the driving potentials are of more complex nature. It has been found that an energy flux can be generated by temperature gradients as well as composition gradients. The energy flux caused by a composition gradient is called the diffusion-thermo effect. On the other hand, mass fluxes can also be created by temperature gradient and this is the thermal–diffusion effect. These effects are considered as second-order phenomena on the basis that they are of lesser order of magnitude than the effects described by Fourier’s and Fick’s laws but they may become important in areas such as hydrology or geosciences.

The study of magneto hydrodynamics(MHD) flows have more concentration due to its significant applications in three diverse fields, such as an cosmological, geophysical and engineering problems. Free convection in electrically conducting fluids through an external magnetic field has been a subject of considerable research concern of a huge number of scholars for a long time due to its diverse applications in the areas such as nuclear reactors, geothermal engineering, fluid metals and plasma flows among the others. Fluid flow control under the magnetic force is also applicable in magneto hydrodynamics generators and a host of magnetic devices used in industries. Steady and transient free convection coupled heat and mass transfer by natural convection in a fluid-saturated porous medium has attracted significant attention in the previous years, due to several important engineering and geophysical applications.

Several researchers have discussed about Steady and transient free convection coupled heat and mass transfer by natural convection in a fluid-saturated porous medium, due to various applications in engineering. Nield and Bejan [1] and Ingham and Pop [2, 3] had presented a complete information in the above said field. Murthy et al[4] have studied effect of doubly stratification on free convection in Darcian porous medium . Lakshmi Narayana and Murthy [5] investigated the effects of Soret and Dufour on free convection heat and mass transfer from a vertical surface in a doubly stratified darcy porous medium. They have neglected the effect of MHD, (Viscous dissipation). Adrian postelnicu [6] studied the heat and mass transfer properties of natural convection about a vertical surface embedded in a saturated porous medium subjected to a chemical reaction by considering the dufour and soret effects.

Madhusudhana Reddy and Prasada Rao[7] discussed the effect of radiation, diffusion and chemical reaction on the mixed convective heat and mass transfer flow of a viscous electrically conducting fluid through a porous medium. Shariful Alam and Shirazul Hoque Mollah [8] have studied the effect of *n*th order chemical reaction and heat generation or absorption on MHD free convective flow with heat and mass transfer over an inclined permeable stretching sheet under the influence of Dufour and Soret effects with variable wall concentration and temperature. Dulal Pal and Babulal Talukdar [9] studied thermal radiation and magnetohydrodynamic on mixed convection flow of a viscous incompressible electrically conducting fluid through a porous medium with variable permeability. Sarada and Shanker [10] have analyzed the chemical reaction effect on an unsteady MHD free convection flow through an infinite vertical plate by taking into consideration of variable suction.

The objective of this paper is to investigate simultaneous heat and mass transfer by natural convection from a vertical surface in darcian porous medium under the influence of the magnetic field including effects of chemical reaction, Soret and Dufour.

Notation we used:

S_r	Soret number	ψ	Stream function
T	Temperature	γ	Dimensionless chemical reaction parameter
$x, \ y$	Cartesian co-ordinates along the normal to the surface respectively	Ra_x	Local Rayleigh number
α_m	Thermal diffusivity	u, v	Darcian velocities in the x and y directions
β_T	Coefficient of thermal expansion	D_m	Mass diffusivity
β_C	Coefficient of concentration expansion	f	Dimensionless stream function
ϕ	Dimensionless concentration	K	Darcy permeability
η	Similarity variable	k_T	Thermal diffusion ratio
υ	Kinematic viscosity	C	Concentration
θ	Dimensionless temperature	C_p	Specific heat at constant pressure
C_s	Concentration susceptibility	ρ	Density

Problem Formulation:

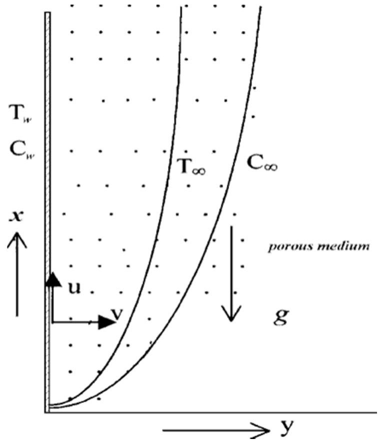

Figure a: Flow model

Consider the natural convection in a porous medium with a Newtonian fluid on a vertical flat plate. The x-coordinate is measured along the surface and the y-coordinate normal to it (see “Figure a”).The temperature of the ambient medium is T_∞ and the wall temperature is T_w. The flow along the vertical flat plate contains a species A slightly soluble in the fluid B, the concentration at the plate surface is C_w and the solubility of A in B far away from the plate is C_∞ .

The following assumptions are used throughout the present paper: (a) the fluid and the porous medium are in local thermodynamic equilibrium; (b) the flow is steady-state, laminar and two-dimensional; (c) the porous medium is homogeneous and isotropic; (d) the characteristics of the fluid and the porous medium are constant; (e) the Boussinesq approximation is valid and the boundary layer approximation is applicable; (f) the concentration of dissolved A is small enough. In-line with the above assumptions, the governing equations describing the conservation of mass, momentum, energy and concentration can be written as follows

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u=\frac{gK}{\upsilon}[\beta_T(T-T_\infty)+\beta_C(C-C_\infty)]-\frac{\sigma}{\rho}\left(B_0{}^2u\right) \tag{2}$$

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

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_m\frac{\partial^2 C}{\partial y^2}+\frac{D_m k_T}{T_m}\frac{\partial^2 T}{\partial y^2}-K_1C \tag{4}$$

Where all quantities are defined in the list of symbols.

The boundary conditions of the problem are

$$y=0: v=0, T=T_w, C=C_w \tag{5a}$$

$$y\to\infty: u\to 0, T\to T_\infty, C\to C_\infty \tag{5b}$$

Where T_w, T_∞ , C_w and C_∞ have constant values.

Equations 1, 2, 3, 4, 5 are now non dimensionalised using the following quantities:

$$\psi = \alpha_m Ra_x^{1/2} f(\eta), \quad \theta = (T - T_\infty)/(T_w - T_\infty),$$

$$\phi = (C - C_\infty)/(C_w - C_\infty), \eta = \frac{y}{x} Ra_x^{1/2}, \tag{6}$$

Where the stream function ψ is defined in the usual way

$$u = \frac{\partial \psi}{\partial y}, v = -\frac{\partial \psi}{\partial x} \tag{7}$$

and $Ra_x = gK\beta(T_w - T_\infty)x/(\upsilon\alpha_m)$ is the local Rayleigh number.

The governing equations become

$$f^{/}(1+M) = \theta + N\phi \tag{8}$$

$$\theta^{//} - f\theta^{/} + D_f\phi^{//} = 0 \tag{9}$$

$$\frac{1}{Le}\phi^{//} + f\phi^{/} - \gamma\phi + S_r\theta^{//} = 0 \tag{10}$$

Where Le, D_f, S_r and N are Lewis, Dufour. Soret numbers and sustentation parameter respectively

$$Le = \frac{\alpha_m}{D_m}, D_f = \frac{D_m k_T (C_w - C_\infty)}{C_s C_p \alpha_m (T_w - T_\infty)}, \; S_r = \frac{D_m k_T (T_w - T_\infty)}{C_s C_p \alpha_m (C_w - C_\infty)}, \; N = \frac{\beta_c (C_w - C_\infty)}{\beta_T (T_w - T_\infty)} \tag{11a}$$

We notice that N is positive for thermally assisting flows, negative for thermally opposing flows and zero for thermal-driven flows. Further, in order to get similarity solutions, the constant dimensionless chemical reaction parameter

$$\gamma = \frac{K_1}{\alpha_m} \cdot \frac{x^2}{Ra_x} \tag{11b}$$

Was introduced in Eq. 10.we notice to this end that primes denote with respect to η . The transformed boundary conditions are

$$f(0) = 0, \theta(0) = 1, \phi(0) = 1 \tag{12a}$$

$$\theta \to 0, \phi \to 0 \text{ as } y \to \infty \tag{12b}$$

Mathematical Solution:

The System of non-linear ordinary differential equations (8) - (10) with boundary conditions (12) have solved numerically, by using Crank Nicolson implicit finite difference method. A step size of $\Delta\eta = 0.01$ was selected to be satisfactory for a convergence criteria of 10^{-5} in all cases. The value of η_∞ was found to each iteration loop by the statement $\eta_\infty = \eta_\infty + \Delta\eta$. In order to see the effect of step size $\Delta\eta$ we ran the code for our model with two different step sizes $\Delta\eta = 0.01$, $\Delta\eta = 0.001$ and each case we found a very good agreement between them.

RESULTS AND DISCUSSION

Numerical Computations were carried out for non dimensional velocity profiles f', temperature profiles θ and concentration profiles ϕ with different values of D_f, S_r, M , γ and N . The velocity profile D_f, S_r, M

presented for fixed values of D_f , S_r , M in "Fig. 1". We observed that Non dimensional velocity f' increases with the increasing of N . "Fig. 2", explains velocity profile for different values of *M, N, Sr* and D_f. From "Fig. 2" we conclude that by increasing of Lewis number the velocity profile increases. From "Fig. 3", we observed that the velocity profile increases with increase of the magnetic parameter.

The temperature profiles for different parameters Lewis number *Le* and *M* have been discussed in "Fig. 4" and it shows that the Temperature profile increases by increasing of Soret number S_r. From "Fig. 5" we observed that by increase of the magnetic parameter, the temperature profile decreases. The concentration profile plotted for different Lewis number in fig.6 and we can observe that the concentration profile decreases with increase of Lewis number. From "Fig. 7-8" we observed that concentration profile increases by increasing of chemical reaction parameter for different values of *Le, M , N,* S_r and D_f .

Concluding Remarks:
In this paper, studied a two dimensional steady MHD free convection flow of heat and mass transfer from a vertical surface in porous media subjected to a chemical reaction and obtained numerical solution considering thermal-diffusion and diffusion-thermo effects. For this problem, velocity profiles, temper profiles and concentration profiles are studied with different parameters. Study reveals that , velocity profile increases with the increase of diverse parameters ,temperature profile decreases by increasing magnetic parameter and concentration profile increases with the increase of chemical reaction.

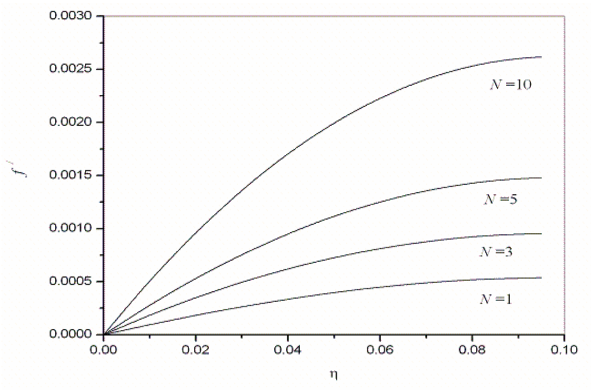

Figure 1: Velocity profile for different values of N **with** $S_r = 0.001, D_f = 10.0, M = 0$

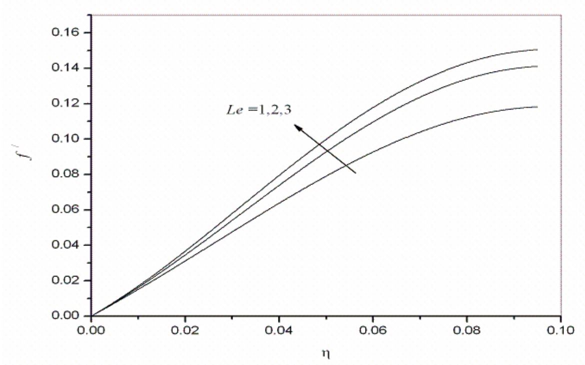

Figure 2: Velocity profile for different Le **with** $S_r = 0.001, D_f = 10.0, M = 0, N = 1$

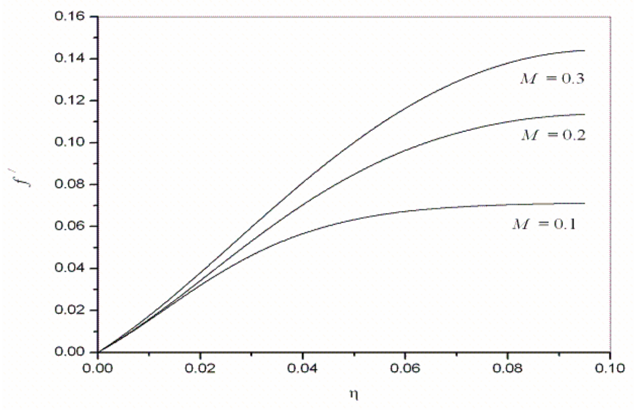

Figure 3: Velocity profile for different Magnetic parameters with $S_r = 0.001, D_f = 10.0$

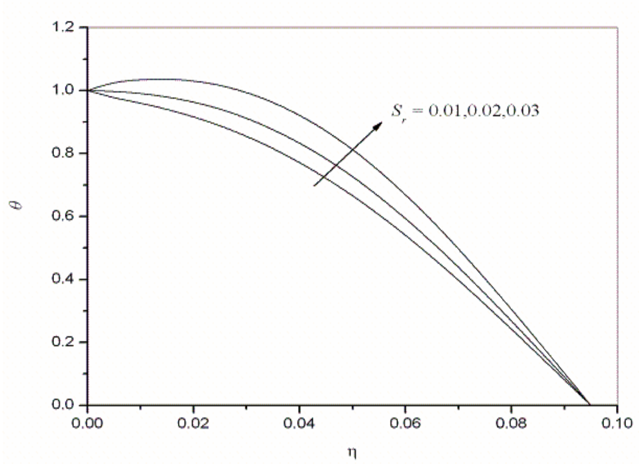

Figure 4: Temperature profiles for different soret parameters with $D_f = 10.0, M = 0, N = 1$

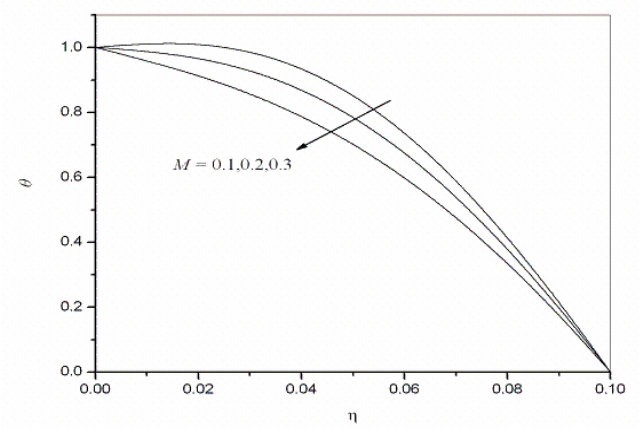

Figure 5: Temperature profiles for different magnetic parameter with $S_r = 0.001, D_f = 10.0$

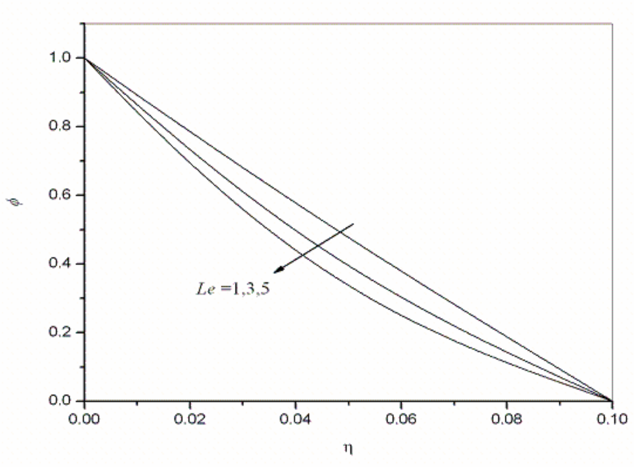

Figure 6: Concentration profiles for different Le **with** $D_f = 10.0, M = 0, S_r = 0.001$

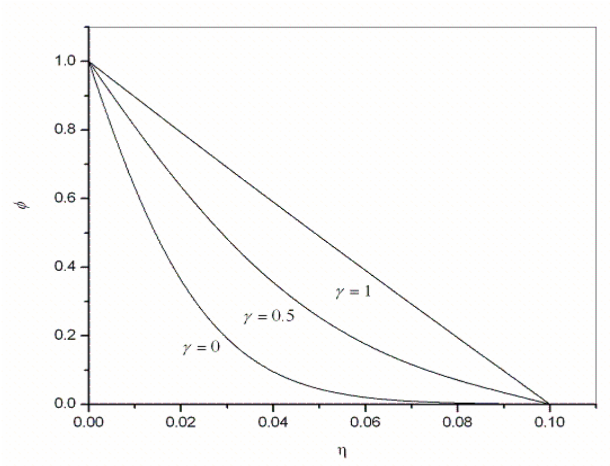

Figure 7: Concentration profile for different γ **with** $D_f = 10.0, S_r = 0.001, Le = 1, N = 1, M = 0$

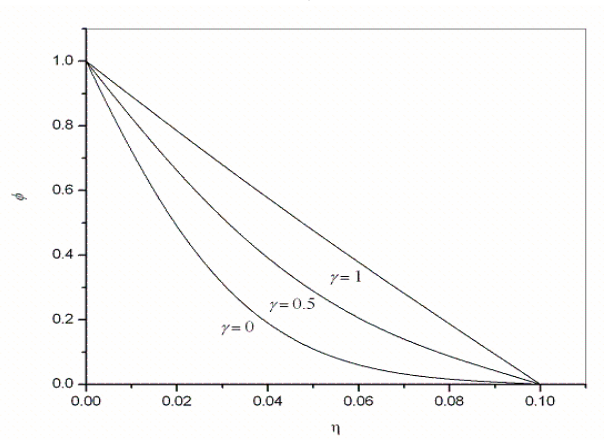

Figure 8: Concentration profile for different γ **with** $D_f = 0, S_r = 0, Le = 1.N = 1, M = 0$

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