Analytical Solution of MHD Free Convective Heat and Mass Transfer Flow in a Porous Medium.

Akindele Michael Okedoye Ph.D.

Department of Mathematics, Covenant University Km. 10, Idiroko Road, PMB 1023, Ota, Nigeria.

E-mail: dele.okedoye@covenantuniversity.edu.ng
micindex@yahoo.com

ABSTRACT

Analytical analysis of steady MHD free convective heat and mass transfer flow past a semi-infinite vertical porous plate in a porous medium has been studied including the Dufour and Soret effects. The resulting non-linear momentum equation is solved using asymptotic expansion in order of epsilon. The solutions for velocity, energy and species concentration fields are obtained for various control parameters. The effect of various parameters on skin friction coefficient, Nusselt number and Sherwood number are shown in tabular form.

(Keywords: MHD, free convection, vertical plate, steady flow, porous medium, Dufour effect, Soret effect, Grashof numbers, asymptotic expansion)

(AMS Subject Classification: 76W05)

INTRODUCTION

The study of flow and heat and mass transfer in the boundary layer induced by a surface moving with a uniform or non-uniform velocity in a quiescent ambient fluid is important in several manufacturing processes in industry which include the boundary layer along material handling conveyors, the cooling of an infinite metallic plate in a cooling bath, glass blowing, continuous casting, and spinning of fibers.

There has been a renewed interest in studying magnetohydrodynamics (MHD) flow and heat transfer aspects in various geometries due to the effect of magnetic field on the flow control and on the performance of many system using electrically conducting fluids such as liquid metals, water mixed with little acid and others hence a lot of work has been reported in the literature. Okedoye and Lamidi [2] presented a good review of some of these works.

In recent years, the problems of free convective and heat transfer flows through a porous medium under the influence of a magnetic field have been attracted the attention of a number of researchers because of their possible applications in many branches of science and technology, such as its applications in transportation, cooling of re-entry vehicles and rocket boosters, cross-hatching on ablative surfaces, and film vaporization in combustion chambers. On the other hand, flow through a porous medium have numerous engineering and geophysical applications, for example, in chemical engineering for filtration and purification process; in agriculture engineering to study the underground water resources; in petroleum technology to study the movement of natural gas, oil and water through the oil reservoirs.

In view of these applications, many researchers have studied MHD free convective heat and mass transfer flow in a porous medium; some of them are Raptis and Kafoussias [2], they studied free convection and mass transfer flow through a porous medium in the presence of transverse magnetic field, due to the importance of mass transfer and that of applied magnetic field in the study of star and planets.

Sattar, Rahman, and Samad [3] obtained similar solutions of a steady MHD free convection and mass transfer flow with viscous dissipation. They have used the perturbation method to solve the problem.

However, in all the above studies, Dufour and Soret effects were neglected, on the basis that they are of a smaller order of magnitude than the effects described by Fourier's and Fick's laws. There are, however, exceptions. The Soret effect, for instance, has been utilized for isotope separation and in mixture between gases and with very light molecular weight (H_2 , He),and for medium molecular weight (H_2 , air) the Dufour effect was found to be of considerable magnitude such that it cannot be neglected [2].

Recently, Postelnicu [3] studied the influence of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects. Anghel et al [4] investigate boundary layer over a vertical surface embedded in a porous medium.

Recently, Alam and Rahman [5] report convection flow past a vertical porous flat plate with variable suction. Hence the objective of the present paper is to obtain an analytical solution of Dufour and Soret effects on steady free convection and mass transfer flow past a continuously moving semi-infinite vertical porous flat plate embedded in a porous medium.

The proposed solution is based on asymptotic expansion of flow equation applicable to free/forced convection. Consequently the transformed momentum equation (Eq. 2) in the original text) is expand in order of epsilon, where $0<\varepsilon<<1$.

MATHEMATICAL FORMULATION

Consider the steady free convection and mass transfer flow of a viscous, incompressible and electrically conducting fluid past a continuously moving semi-infinite vertical porous plate embedded in a porous medium under the influence of a transversely applied magnetic field.

The flow is assumed to be in the x-direction, which is taken along the vertical plate in the upward direction, and the y-axis is taken to be normal to the plate. The surface of the plate is maintained at a uniform constant temperature Tw and a uniform constant concentration Cw, of a foreign fluid. It is also assumed that the free stream velocity u_w , parallel to the vertical plate, is constant. The flow configuration and the coordinates system are shown in Figure 1.

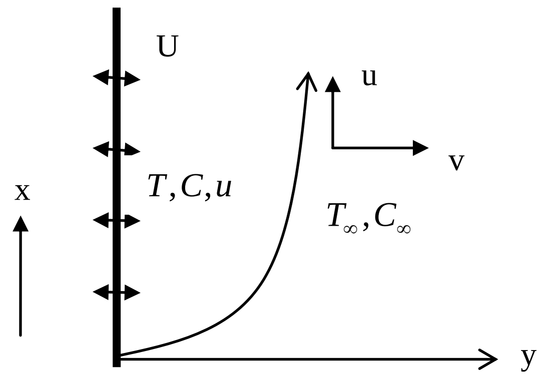

Figure 1: Flow Configuration and Coordinate System.

The induced magnetic field is assumed to be negligible, such that $B=(0,B_0,0)$. The equation of conservation of electric charge $\nabla\cdot J=0$ gives $J_y=$ constant, where $J=(J_x,J_y,J_z)$. Since the plate is electrically non-conducting, this constant is zero and hence $J_y=0$ everywhere in the flow. Under the boundary-layer and Darcy-Boussinesq approximations, the basic boundary-layer equations are given by:

Continuity equation, $$\frac{\partial v}{\partial y}=0 \qquad \textbf{(1)}$$

Momentum equation,

$$v\frac{\partial u}{\partial y} = \upsilon\frac{\partial^2 u}{\partial y^2} + g\beta_\tau\,(T-T_\infty) + g\beta_c\,(C-C_\infty) - \frac{\sigma B_0^2\,u}{\sigma} - \frac{\upsilon}{K}u - \frac{b}{K}u^2 \qquad \textbf{(2)}$$

Energy equation,

$$\rho c_p\, v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} + \frac{D_m K_T}{c_s c_P}\frac{\partial^2 C}{\partial y^2} \qquad \textbf{(3)}$$

Concentration equation,

$$v\frac{\partial C}{\partial y} = D_m\frac{\partial^2 C}{\partial y^2} + \frac{D_m K_T}{T_m}\frac{\partial^2 T}{\partial y^2} \qquad \textbf{(4)}$$

where the variables and related quantities are defined in the Nomenclature.

The boundary conditions for the model are given by:

$$\left.\begin{aligned} & u(0)=u_w, v(0)=-v_w, T(0)=T_w, C(0)=C_w \\ & as\ y\to\infty, u\to\infty, T\to\infty, C\to\infty, \end{aligned}\right\} \quad (5)$$

where u_w is the uniform velocity and v_w is the velocity of suction at the plate.

METHOD OF SOLUTION

We use the non – dimensional variables:

$$\begin{aligned} & y^1 = yv_w/\upsilon,\ u^1 = \frac{u}{u_w}, \\ & \theta = \frac{T-T_\infty}{T_w-T_\infty},\ \phi=\frac{C-C_\infty}{C_w-C_\infty} \end{aligned} \quad (6)$$

From Equation (1) i.e $\frac{dv}{dy}=0$

We have v = constant, but $v(0)=-v_w$ constant

$$v(y)=-v_w \quad (7)$$

Substituting Equations 6 and 7 into Equations 2 – 5 and dropping (‘), we have:

$$\begin{aligned} & \frac{d^2u}{dy^2}+\frac{du}{dy}+G_{r\mathrm{T}}\,\theta+G_{rc}\phi \\ & \quad -\left(M+\frac{1}{\mathrm{Re}\,Da}\right)u-\varepsilon\frac{Fs}{Da}u^2=0 \end{aligned} \quad (8)$$

$$\frac{d^2\theta}{dy^2}+\Pr\frac{d\theta}{dy}+\Pr Du\frac{d^2\phi}{dy^2}=0 \quad (9)$$

$$\frac{d^2\phi}{dy^2}+Sc\frac{d\phi}{dy}+Sr\frac{d^2\theta}{dy^2}=0 \quad (10)$$

The dimensionless boundary conditions are,

$$\left.\begin{aligned} & u(0)=1,\ \theta(0)=1,\ \phi(0)=1 \\ & y\to\infty\ u\to 0,\ \theta\to 0,\ \phi\to 0 \end{aligned}\right\} \quad (11)$$

where,

$$G_{r\mathrm{T}}=\frac{g\beta_{\mathrm{T}}\,v(T_w-T_\infty)}{u_w v^2\upsilon},\ G_{rc}=\frac{g\beta_c\,v(C_w-C_\infty)}{u_w v^2\upsilon}$$

$$Sr=\frac{K_T}{Tm}\left(\frac{c_w-c_\infty}{T_w-T_\infty}\right),\ Da=\frac{K}{\varepsilon_1 x^2},\ \Pr=\frac{\mu c_p}{\alpha}$$

$$Du=\frac{DmK_T}{\mu c_p c_s}\left(\frac{c_w-c_\infty}{T_w-T_\infty}\right),\ Fs=\frac{b}{x},$$

$$\varepsilon=\frac{u_w}{\varepsilon_1\upsilon x},\ M=\frac{\sigma\beta_0^2 v}{\rho v_w^2},\ Sc=\frac{v_w}{Dm}$$

Equations (9) and (10) are solved simultaneously subject to (11) to obtain:

$$\left.\begin{aligned} & \theta(y)=a_0e^{-my}+a_1e^{-ny} \\ & \phi(y)=a_2e^{-my}+a_3e^{-ny} \end{aligned}\right\} \quad (12)$$

$$m=\frac{1}{2}\frac{\Pr+Sc+\sqrt{(\Pr-Sc)^2+4\Pr^2 DuScSr}}{1-\Pr DuSr},$$

$$n=\frac{1}{2}\frac{\Pr+Sc-\sqrt{(\Pr-Sc)^2+4\Pr^2 DuScSr}}{1-\Pr DuSr},$$

where $a_0=\frac{a_2(Sc-m)}{mSr}$, $a_1=\frac{a_3(Sc-n)}{nSr}$,

$a_2=\frac{-m(nSr+n-Sc)}{Sc(m-n)}$ and

$$a_3=\frac{n(mSr+m-Sc)}{Sc(m-n)}$$

Now expanding asymptotically using the following asymptotic variables:

$$u=u_0+\varepsilon u_1+\varepsilon^2u_2+\cdots \quad (13)$$

and equate the powers of ε we have :

$$\varepsilon^0:\frac{d^2u_0}{dy^2}+\frac{du_0}{dy}-a_4u_0+Grc\phi+Grt\theta=0 \quad (14)$$

$$u_0(0)=1,\ u_0(y)\to 0,\ as\ y\to\infty$$

$$\varepsilon^1: \quad \frac{d^2u_1}{dy^2}+\frac{du_1}{dy}-a_4u_1=\frac{Fs}{Da}u_o^2$$

$$u_1(0)=0,\ u_1(y)\to 0,\ as\ y\to\infty \qquad \textbf{(15)}$$

$$\varepsilon^2: \quad \frac{d^2u_2}{dy^2}+\frac{du_2}{dy}-a_4u_2=\frac{2Fs}{Da}u_0u_1$$

$$u_2(0)=1,\ u_2(y)\to 0,\ as\ y\to\infty \qquad \textbf{(16)}$$

Now the solution to Equations (14) and (16) are obtained using the method of undetermined coefficient, we have:

$$\left.\begin{aligned}
u_0(y)&=a_9e^{-n_1y}+a_8e^{-ny}+a_7e^{-my}\\
u_1(y)&=a_{11}e^{-n_1y}+a_{12}e^{-2n_1y}+a_{13}e^{-2ny}\\
&\quad+a_{14}e^{-2my}+a_{15}e^{-(n_1+n)y}\\
&\quad+a_{16}e^{-(n_1+m)y}+a_{17}e^{-(n+m)y}\\
u_2(y)&=a_{18}e^{-2n_1y}+a_{19}e^{-3n_1y}+a_{20}e^{-3ny}\\
&\quad+a_{21}e^{-3my}+a_{22}e^{-(2n+m)y}\\
&\quad+a_{23}e^{-(n_1+2m)y}+a_{24}e^{-(2n_1+m)y}\\
&\quad+a_{25}e^{-(2n_1+m)y}+a_{26}e^{-(2n+m)y}\\
&\quad+a_{27}e^{-(n+2m)y}+a_{28}e^{-(n_1+n)y}\\
&\quad+a_{29}e^{-(n_1+m)y}+a_{30}e^{-(n+n_1+m)y}\\
&\quad+a_{31}e^{-(n_1)y}
\end{aligned}\right\} \textbf{(17)}$$

On substituting (17) into (13), we obtain the solution $u(y)$ for the momentum equation, that is,

$$u(y)\approx u_0(y)+\varepsilon u_1(y)+\varepsilon^2u_2(y)$$

where,

$$n_1=\frac{1}{2}\left(1+\sqrt{1+4a_4}\right),$$

$$a_7=-\frac{(a_0Grt+a_2Grc)}{m^2-m-a_4},\quad a_8=-\frac{(a_1Grt+a_3Grc)}{n^2-n-a_4},$$

$$a_9=1-a_7-a_8$$

$$a_{12}=\frac{a_9^2Fs}{(4m^2-2m-a_4)Da},$$

$$a_{13}=\frac{a_8^2Fs}{(4n^2-2n-a_4)Da},$$

$$a_{14}=\frac{a_7^2Fs}{(4m^2-2m-a_4)Da},$$

$$a_{15}=\frac{2a_9a_8Fs}{((n_1+n)^2-2(n_1+n)-a_4)Da},$$

$$a_{16}=\frac{2a_9a_7Fs}{((n_1+m)^2-2(n_1+m)-a_4)Da},$$

$$a_{17}=\frac{2a_7a_8Fs}{((n+m)^2-2(n+m)-a_4)Da},$$

$$a_{11}=-(a_{12}+a_{13}+a_{14}+a_{15}+a_{16}+a_{17})$$

$$a_{18}=\frac{2a_9a_{11}Fs}{(4n_1^2-2n_1-a_4)Da},$$

$$a_{19}=\frac{2a_9a_{12}Fs}{(9n_1^2-3n_1-a_4)Da},$$

$$a_{20}=\frac{2a_8a_{12}Fs}{(9n^2-2n_1-a_4)Da}$$

$$a_{21}=\frac{2a_7a_{14}Fs}{(9m^2-3m-a_4)Da},$$

$$a_{22}=\frac{2Fs(a_9a_{13}+a_8a_{15})}{(2(n+m)^2-2(n+m)-a_4)Da},$$

$$a_{23}=\frac{2Fs(a_9a_{14}+a_7a_{16})}{((n_1+2m)^2-(n_1+2m)-a_4)Da},$$

$$a_{24}=\frac{2Fs(a_8a_{12}+a_9a_{15})}{((2n_1+n)^2-(2n_1+n)-a_4)Da},$$

$$a_{25}=\frac{2Fs(a_9a_{16}+a_{17}a_{12})}{((2n_1+m)^2-(2n_1+m)-a_4)Da},$$

$$a_{26}=\frac{2Fs(a_8a_{17}+a_7a_{13})}{((2n+m)^2-(2n+m)-a_4)Da},$$

$$a_{27}=\frac{2Fs(a_8a_{14}+a_7a_{17})}{((n+2m)^2-(n+2m)-a_4)Da},$$

$$a_{28}=\frac{2a_8a_{11}Fs}{((n_1+n)^2-(n_1+n)-a_4)Da},$$

$$a_{29} = \frac{2a_7 a_{11} Fs}{\left((n_1+m)^2 - (n_1+m) - a_4\right)Da},$$

$$a_{29} = \frac{2a_7 a_{11} Fs}{\left((n_1+m)^2 - (n_1+m) - a_4\right)Da},$$

$$a_{30} = \frac{2(a_9 a_{17} + a_7 a_{15} + a_8 a_{16})Fs}{\left((n_1+n+m)^2 - (n_1+n+m) - a_4\right)Da},$$

$$a_{31} = -(a_{18} + a_{19} + a_{21} + a_{21} + a_{22} + a_{23} + a_{24} + a_{25} + a_{26} + a_{27} + a_{28} + a_{29} + a_{30})$$

The parameters of engineering interest for the present problem are the local skin-friction coefficient (c_f), the local Nusselt number (Nu) and the local Sherwood number (Sh), which are defined respectively by the following expressions:

Skin-Friction

We now study skin-friction from velocity field. It is given by:

$$c_f = \frac{T_f}{\rho u_\omega v_\omega} = \frac{d^2}{dy^2} u(y,t)\Big|_{y=0}, \quad \tau_f = \mu \frac{du}{dy}\Big|_{y=0}$$

which reduces to:

$$c_f = \left(\frac{du}{dy}\right)_{y=0}$$

Nusselt Number

In non-dimensional form, the rate of heat transfer at the wall is computed from Fourier's law and is given by

$$Nu = \frac{q_\omega v}{(T_\omega - T_\infty)K v_\omega} = \frac{-d}{dy}\theta(y\,t)\Big|_{y=0},$$

$$q_\omega = -K \frac{dT}{dy}\Big|_{y=0},$$

Sherwood Number

The rate of mass transfer at the wall which is the ratio of length scale to the diffusive boundary layer thickness is given by:

$$Sh = \frac{J_\omega\ v}{(c_\omega - c_\infty) D v_\omega} = -\frac{d}{dy}\phi(y,t)\Big|_{y=0},$$

$$J_\omega = -D \frac{d\phi}{dy}\Big|_{y=0}$$

RESULTS AND DISCUSSION

In order to point out the effects of various parameters on the flow characteristic, the following considerations are made:

To be realistic, the values of Schmidt number (Sc) are chosen for hydrogen (Sc = 0.22), water vapor (Sc = 0.62) and ammonia (Sc = 0.78) at temperature 25^{o}C and one atmospheric pressure. The values of Prandtl number is chosen to be Pr = 0.71 which represents air and Pr=0.015 for mercury at temperature 25^{o}C and one atmospheric pressure. Attention is focused on positive values of the buoyancy parameters i.e. thermal Grashof number $Gr\tau > 0$ (which corresponds to the cooling problem) and solutal Grashof number $Grc > 0$ (which indicate that the chemical species concentration in the free stream region is less than the concentration at the boundary surface).

The cooling problem is often encountered in engineering applications; for example in the cooling of electronic components and nuclear reactors. It is should be mentioned here that *Da* > 0 indicates an increase in the chemical reaction rate.

The values of Dufour number *Du* and Soret number *Sr* are chosen in such a way that their product $\Pr DuSr < 1$ provided that the mean temperature *Tm* is kept constant as well. All parameters are primarily chosen as follows: $Gr\tau = 3,\ Grc = 2,\ Fs = 1,\ \mathrm{Re} = 200,$ $Da = 0.5$, and $M = 0.5$ unless otherwise stated.

The effect of each flow parameters on the concentration, temperature and velocity distribution of the flow field are presented with the help of concentration profile (Figures 2 – 4), temperature profile (Figures 5 and 6), and velocity profiles (Figures 7 - 13).

Concentration Distribution

The concentration distribution of the flow field in presence of foreign species, such as water vapor (*Sc* = 0.62) is shown in Figures 2 – 4. It is characterized by Shroudal number (Sr), Schmidt number (*Sc*), and Prandtl number (Pr).

Effect of Schmidt number (Sc): The effect of presence of foreign chemical species is shown in figure (3), it is shown that concentration distribution decreases as the density of the species increases, thus concentration distribution decreases as Schmidt number increases.

Effect of Shroudal number (Sr): We display in figure (3) the effect of Shroudal number on the concentration distribution of the flow field. It is observed that concentration distribution increases as Shroudal number increases.

Effect of Prandtl number (Pr): Figure (4) shows that concentration distribution of the flow field decreases faster in the case of Mercury as the species compare to water vapour. Thus concentration distribution increases as Prandtl number increases.

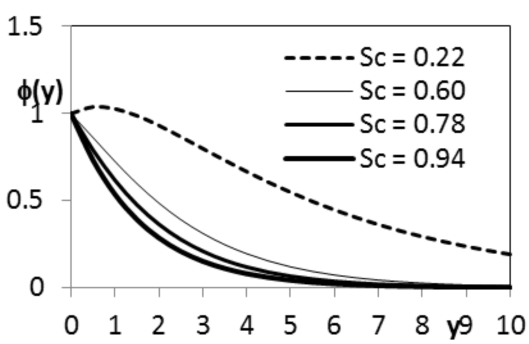

Figure 2: Concentration Profiles for various Schmidt Numbers.

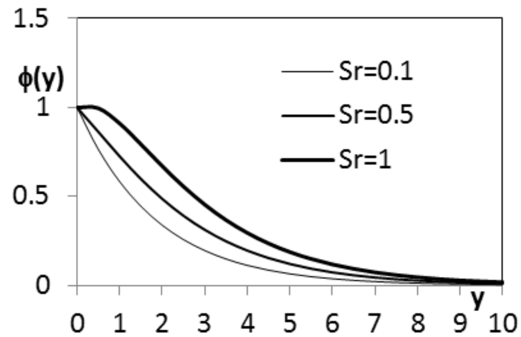

Figure 3: Concentration Profiles for various Sr.

Temperature Field

The temperature of the flow field is mainly affected by Prandtl number (Pr) and Dufour number (Du). The effects of these parameters on the temperature field are shown graphically in Figures 5 and 6 and the following discussion is set out.

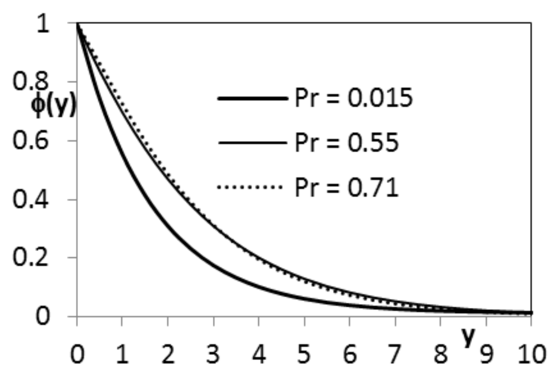

Figure 4: Concentration Profiles for different Prandtl Numbers.

Effect of Prandtl number (Pr): It is observed in figure (5) that temperature distribution decreases as the Prandtl number increases. Moreover, we observed that for lower values of Prandtl number corresponding to mercury, temperature distribution is higher which validate the assertion that mercury conduct heat better than other species, hence the temperature is highest.

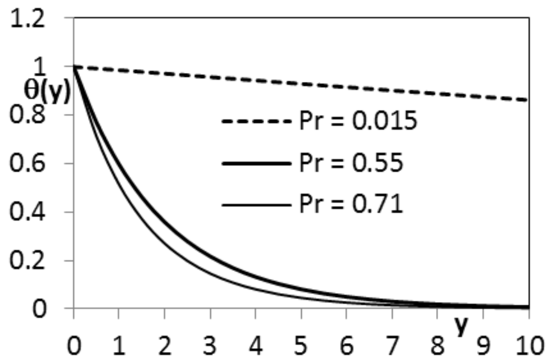

Figure 5: Temperature Profiles for different Prandtl Numbers.

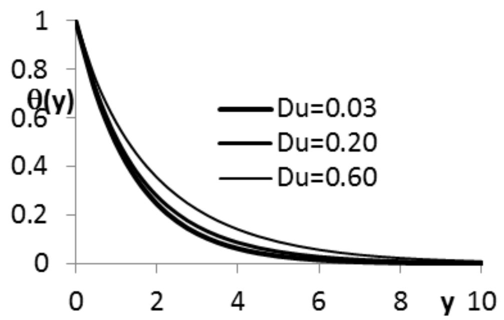

Figure 6: Temperature Profiles for various Dufour Numbers.

Effect of Dufour Number (Du): The effect of Dufour number on the temperature field is shown in Figure 6. We observe that temperature increases as the Dufour number increases. Also the thermal bopundary layer decreases faster for lower values of Dufour number.

Velocity Field

The velocity of the flow field is found to change more or less with the variation of the flow parameters. The effect of the flow parameters on the velocity field is analyzed with the help of Figures 7 - 13. Our attention is on the case of cooling of plate.

Effect of Dufour number (Du): Figure 7 depicts the effect of Dufour number Du on the velocity of the flow field. Here, we discovered that during cooling of the plate, velocity increases as the Dufour number increases. This is because the presence of foreign species has the tendency to increase mass buoyancy. The velocity boundary layer also increases with an increase in Dufour number.

Effect of Hartmann Number (M): Figure 8 brings out clearly the effect of the Hartmann number M on the velocity boundary layer thickness. We observe that increasing M decreases the velocity boundary layer. The effect of M on velocity is seen to stabilize the velocity as the maximum velocity can only occur at the surface for higher values of M .

Effect of Prandtl Number (Pr): In general, for our case here, *Pr<1* which means the conduction effects exceeds viscous diffusion the thermal boundary layer is thicker than the velocity boundary layer. It could be seen from Figure (9), increases in Prandtl number decreases the velocity layer of the flow field.

Effect of Shroudal Number (Sr): In Figure 10, we show the velocity distribution of the flow field for different Shroudal number. We observed that as in the case of Dufour number, velocity distribution increases as Shroudal number increases.

Effect of Schmidt Number (Sc): In Figure 11, we show the velocity distribution of the flow field for different Schmidt number. We discovered that Hydrogen as the chemical species has the highest velocity followed by water vapor. Thus velocity decreases as the density of the chemical species increases. Velocity boundary layer also increases as an increase in Schmidt number.

Effect of Thermal Grashof Number (Grt): The effects of Grashof numbers for heat transfer (*Grt*) on the velocity field is presented in Figure 12. A study of the curves of the Figure 12 shows that the Grashof number for thermal transfer accelerates the velocity of the flow field. Comparing the curves of Figure 12, it is observed that the reverse velocity occurs, and is more pronounced with higher thermal Grashof number close to the surface.

Effect of Grashof Number for Mass Transfer (Grc): The effect of mass Grashof number on the velocity of the flow field is presented in Figure 13. In the figure, we show that the Grashof number for mass transfer (*Grc*) accelerate the velocity of the flow field. Comparing the curves of Figure 13, it is further observed that the increase in velocity of the flow field is more significant in presence higher mass buoyancy. Thus, mass transfer has a dominant effect on the flow field. The presence of peak in the curves shows that maximum velocity occurs in the body of the fluid close to the surface.

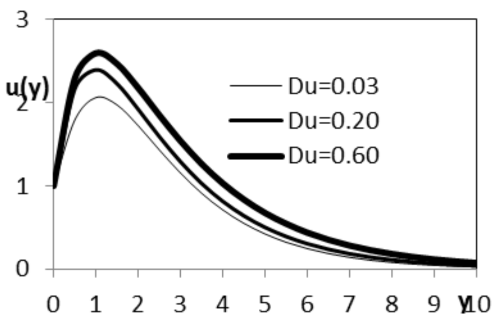

Figure 7: Velocity Profiles for various Dufour Numbers.

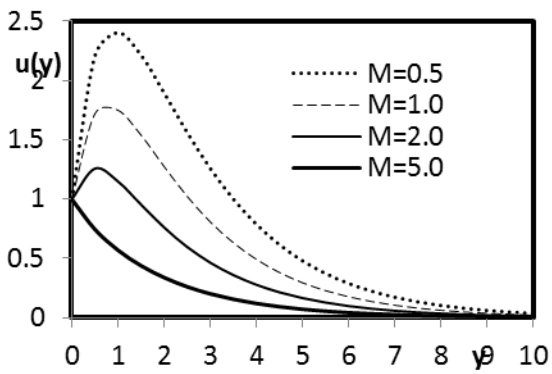

Figure 8: Variation of Velocity for various Values of Hartmann Numbers.

Finally, the effects of Soret and Dufour numbers on the skin-friction coefficient, Nusselt number and Sherwood number are shown in Table 1. The table also indicates that the magnitude of Nu and c_f decreases with increasing Sc and Sh increases with increasing Sc. The behavior of these parameters is self-evident from the Table 1 and hence they will not discuss any further due to brevity.

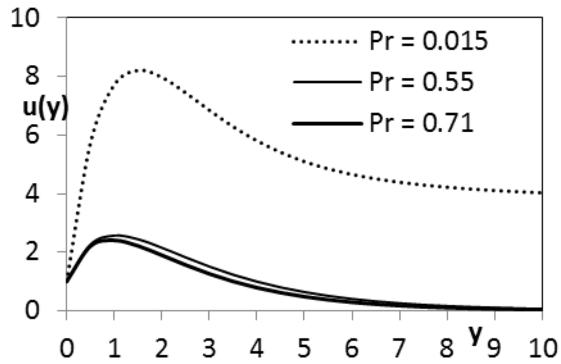

Figure 9: Variation of Velocity for various Values of Pr.

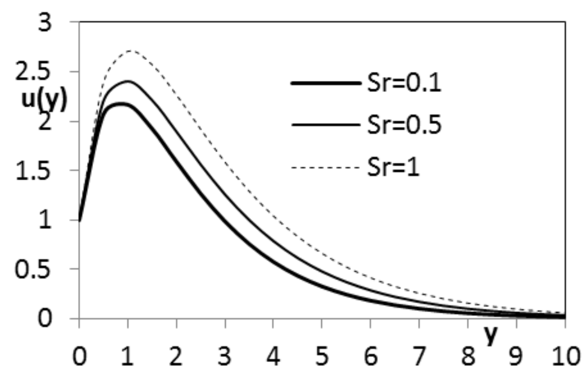

Figure 10: Variation of Velocity for various Values of Sr.

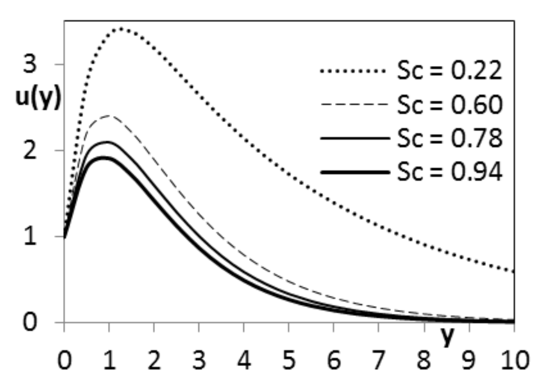

Figure 11: Variation of Velocity for various Values of Sc.

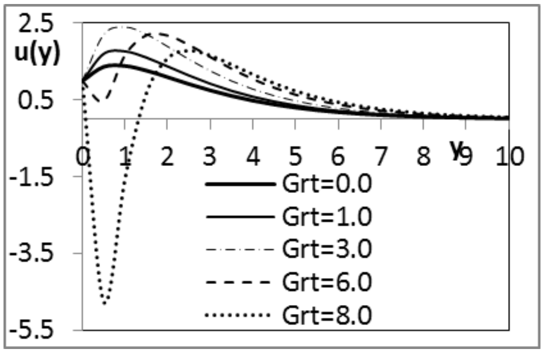

Figure 12: Variation of Velocity for various Values of Grt.

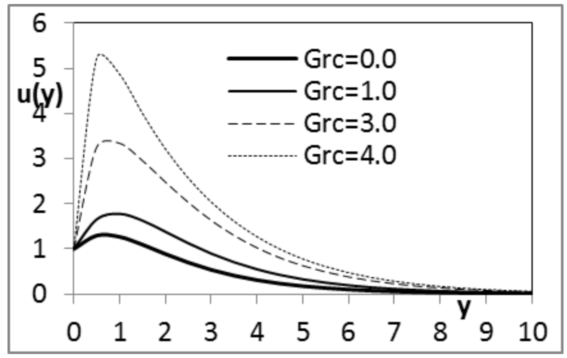

Figure 13: Variation of Velocity for various Values of Grc.

Table 1: Numerical Values of Skin-Friction Coefficient (*Cf*), Nusselt Number (*Nu*), and Sherwood Number (*Sh*).

Du	Sr	M	Grt	Grc	Fs	Pr	Sc	Nu	Sh	cf
0.03	0.5	0.5	3	2	1	0.71	0.6	0.704725	0.247637	-12.1814
0.2	0.5	0.5	3	2	1	0.71	0.6	0.672551	0.263724	12.96703
0.6	0.5	0.5	3	2	1	0.71	0.6	0.577382	0.311309	10.29801
0.15	0.1	0.5	3	2	1	0.71	0.6	0.653055	0.534694	14.3852
0.15	0.5	0.5	3	2	1	0.71	0.6	0.68244	0.25878	26.06247
0.15	1	0.5	3	2	1	0.71	0.6	0.723111	-0.12311	19.31645
0.15	0.5	0.2	3	2	1	0.71	0.6	0.68244	0.25878	30.85507
0.15	0.5	0.4	3	2	1	0.71	0.6	0.68244	0.25878	17.50322
0.15	0.5	0.8	3	2	1	0.71	0.6	0.68244	0.25878	7.673346
0.15	0.5	0.5	0	2	1	0.71	0.6	0.68244	0.25878	9.895589
0.15	0.5	0.5	2	2	1	0.71	0.6	0.68244	0.25878	20.41524
0.15	0.5	0.5	3	0	1	0.71	0.6	0.68244	0.25878	1.044178
0.15	0.5	0.5	3	1	1	0.71	0.6	0.68244	0.25878	5.017362
0.15	0.5	0.5	3	3	1	0.71	0.6	0.68244	0.25878	11.62471
0.15	0.5	0.5	3	2	2	0.71	0.6	0.68244	0.25878	143.0452
0.15	0.5	0.5	3	2	3	0.71	0.6	0.68244	0.25878	461.7641
0.15	0.5	0.5	3	2	1	0.015	0.6	0.013665	0.593167	19.63784
0.15	0.5	0.5	3	2	1	0.55	0.6	0.522034	0.338983	7.506385
0.15	0.5	0.5	3	2	1	0.71	0.22	0.725186	-0.14259	11.85326
0.15	0.5	0.5	3	2	1	0.71	0.6	0.68244	0.25878	24.9237
0.15	0.5	0.5	3	2	1	0.71	0.78	0.662192	0.448904	7.69816

CONCLUSIONS

In this paper we have studied the Dufour and Soret effects on a steady MHD free convention and mass transfer flow past a semi-infinite vertical plate embedded in a porous medium in a closed form. From the present study the following conclusions can be drawn:

- The velocity profiles decrease with an increase of magnetic field parameter.
- The velocity profiles increase whereas with an increase of free convection currents.
- For fluids with medium molecular weight (H_2, air), Dufour and Soret effects should not be neglected.
- Temperature and concentration profiles decrease with an increase in Prandtl and Schmidt numbers, respectively.
- Increase in Magnetic parameter and Prandtl number reduces velocity profiles.
- Increase in Magnetic, Dufour and Soret numbers increases velocity profiles.
- Temperature and concentration profiles increases with an increase in Dufour and Soret numbers, respectively.

REFERENCES

1. Anghel, M., H.S. Takhar, and I. Pop. 2000. "Dufour and Soret Effects on Free-Convection Boundary Layer over a Vertical Surface Embedded in a Porous Medium". *Studia Universitatis Babes-Bolyai, Mathematica*. XLV:11-21.

2. Eckert, E.R.G. and R.M. Drake. 1972. *Analysis of Heat and Mass Transfer.* McGraw-Hill: New York, NY.

3. Okedoye, A.M. and O.T. Lamidi. 2009. "Analytical Solution of Mass Transfer Effect on Unsteady Flow Past an Accelerated Vertical Porous Plate with Suction". *J. Nigerian Association of Mathematical Physics*. 15:501 – 512.

4. Postelnicu, A. 2004. "Influence of a Magnetic Field on Heat and Mass Transfer by Natural Convection from Vertical Surfaces in Porous Media Considering Soret and Dufour Effects". *Int. J. Heat Mass Transfer*. 47:1467-1472.

5. Raptis, A. and N.G. Kafoussias. 1982. "Magnetohydrodynamic Free Convection Flow and Mass Transfer through Porous Medium Bounded by an Infinite Vertical Porous Plate with Constant Heat Flux". *Can. J. Phys.* 60:1725-1729.

6. Sattar, M.A., M.M. Rahman, and M.A. Samad. 2001. "Similar Solutions of an MHD Free Convection and Mass Transfer Flow with Viscous Dissipation". *Dhaka Univ. J. Sci*. 49:67-78.

ABOUT THE AUTHOR

Dr. Akindele M. Okedoye is a Senior Lecturer in the Department of Mathematics, Covenant University, Nigeria. He holds a Ph.D. degree in Applied Mathematics and currently serves as the Postgraduate and Research Chair for CU Maths Units. His research interests are in the areas of computational fluid, differential equations, and mathematical modelling.

SUGGESTED CITATION

Okedoye, A.M. 2013. "Analytical Solution of MHD Free Convective Heat and Mass Transfer Flow in a Porous Medium". *Pacific Journal of Science and Technology*. 14(2):119-128.

Pacific Journal of Science and Technology