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Thermal Diffusion and Thermal Radiation effects on a MHD oscillatory free convective flow past a vertical plate in slip-flow regime with variable suction and periodic plate temperature

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Abstract- An attempt is made to study the effects of thermal diffusion and thermal radiation on a transient MHD free convection flow with mass transfer past a vertical plate in slip-flow regime with variable suction and periodic plate temperature. Assuming the medium to be non-scattered and fluid to be non-gray having emitting-absorbing and optically thick radiation properties. The governing equations are solved by regular perturbation technique with Eckert number E (<1) as perturbation parameter. The expressions for velocity, temperature and concentration fields, the rate of heat transfer from the plate to the fluid, the rate of mass transfer at the plate are obtained in non-dimensional form and the effects of different physical parameters involved in the problem on these fields are discussed graphically and the results are interpreted physically. It is observed that thermal diffusion accelerates the fluid motion whereas temperature falls due to the effect of thermal diffusion. Also concentration level and heat flux rises up under the effect of thermal diffusion. Further the rate of mass transfer falls from the plate to the fluid under the effect of thermal diffusion.

2010 Mathematics subject classification: 76R10, 76W05, 80A20

Key words: Thermal Diffusion, Thermal Radiation, Free convection, Viscous, Incompressible, Slip-flow regime, Mass Transfer.

1. Introduction

In recent years the study of the problems of the MHD (Magnetohydrodynamics) free convection flow with heat and mass transfer have attracted the attention of a number of scholars due to the importance of such problems in many branches of science and technology. MHD finds applications in electromagnetic pumps, MHD couples and bearings, MHD power generators, fusion reactors, chemical synthesis, plasma jets etc. The phenomena of heat and mass transfer are also very common in chemical process industries such as polymer production and food processing. There are many situations where convection heat transfer phenomena are accompanised by mass transfer. When mass transfer takes place in a fluid at rest, the mass is transferred purely by molecular diffusion, resulting from concentration gradient. For low transfer rates in fluid, the convection heat and mass transfer process are similar. Numerous investigations have already been made with combined heat and mass transfer under the assumption of different physical situations.

The natural flow arises in fluid when the temperature change causes density, variation leading to boundary force acting on the fluid. Free convection is a process of heat transfer in natural flow. The heating of rooms and buildings by use of radiator is an example of heat transfer by free convection. Radiation is another process of heat transfer through electromagnetic waves. Radiative heat and mass transfer play an important role in manufacturing industries for the design of reliable equipment. Nuclear power plants, gas turbines and various propulsion devices for aircraft, missiles, satellites and space vehicles are examples of such engineering applications. If the temperature of the surrounding fluid is rather high, radiation effects play an important role and this situation does exist in space technology. Due to importance of the above physical aspects several authors have carried out model studies on the problems of free convection flow. Some of them are Takhar et. al. (1996), Sattar and Kalim (1996), Raptish and Perdikis (1999) and Mansour (1990). Free convection flow with thermal radiation and mass transfer past a moving vertical porous plate was studied by Makinde (2005). The joint effect of free convection and thermal radiation on MHD unsteady flow of a viscous incompressible fluid past an impulsively started vertical plate with uniform heat and mass flux was analysed by Prasad et. al. (2006). Recently Ahmed and Sarmah (2009) have studied the thermal radiation effect on a transient MHD flow with mass transfer past an impulsively fixed infinite vertical plate.

However in the above mentioned works, the thermal diffusion (Soret) effect was not taken into account. This assumption is justified when the concentration level is very low. The flux of mass caused due to temperature gradient is known as the Soret effect or thermal diffusion effect. The experimental investigation of the thermal diffusion effect on mass transfer related to problems was first done by Charles Soret in 1879. There after this thermal diffusion is termed as the Soret effect in honour of Charles Soret. Soret effect is applied for isotop separation in mixture between gases with very light molecular weight (H_2, H_e) and medium molecular weight (N_2, air). In view of the importance of the diffusion thermo effect several investigators have studied the free convection and mass transfer flow with different boundary conditions taking into account the Soret effect. The name of whom Sattar and Alam (1994), Raju et. al. (2008) and Alam et. al. (2006). Ahmed et. al. (2011) investigated the effect of thermal diffusion as well as magnetic field on three dimensional free-convection from a vertical porous plate. Recently Ahmed (2012) has studied the combined effects of Soret and radiation on transient MHD free convection from an impulsively started vertical plate.

In view of the importance of combined effects of the magnetic field, thermal diffusion and thermal radiation, it is proposed to study a problem of two dimensional MHD oscillatory free convective flow past a vertical plate in slip flow regime with variable suction and periodic plate temperature taking into account the radiation and Soret effect. The present work is an extension to the work of Ahmed and Kalita (2008) to consider the effect of thermal diffusion and thermal radiation.

2. Mathematical Formulation

We consider the unsteady oscillatory free convective flow of an electrically conducting, viscous and incompressible fluid past a vertical plate in slip-flow regime with variable suction and periodic plate temperature under the influence of uniform transverse magnetic field. We introduce a coordinate system $\left(\bar{x},\bar{y},\bar{z}\right)$ with *x*-axis is taken along the upward vertical plate and *y*-axis perpendicular to it directed to the fluid region and *z*-axis along the width of the plate. Since the plate is of infinite length therefore all the physical quantities except the pressure p are independent of x. Let $\bar{q}\left(\bar{u},0,0\right)$ denote the fluid velocity and $\bar{B}\left(0,B,0\right)$ be the applied magnetic field at the point $\left(\bar{x},\bar{y},\bar{z},\bar{t}\right)$ in the fluid.

Our investigation is restricted to the following assumption

(1) All fluid properties are considered constant except the influence of the variation in density in the buoyancy force term.

(2) The viscous and ohmic dissipation of energy are negligible.

(3) The magnetic Reynolds Number is so small that the induced magnetic field can be neglected in comparison to the applied magnetic field.

(4) The plate is electrically non-conducting.

(5) The radiation heat flux in the direction of the plate velocity is considered negligible in comparison to that in normal direction.

(6) No external electric field is applied for which the polarization voltage is negligible leading to $\vec{E}=0$

The equations governing the flow are

Equation of continuity

$$\frac{\partial\bar{v}}{\partial\bar{y}}=0\Rightarrow\bar{v}=-v_0\left(1+\varepsilon Ae^{i\bar{\omega}\bar{t}}\right), \text{ where } v_0 \text{ and A being constants.} \qquad (2.1)$$

Momentum equation

$$\frac{\partial\bar{u}}{\partial\bar{t}}-v_0\left(1+\varepsilon Ae^{i\bar{\omega}\bar{t}}\right)\frac{\partial\bar{u}}{\partial\bar{y}}=g\beta(\bar{T}-\bar{T}_\infty)+g\bar{\beta}\left(\bar{C}-\bar{C}_\infty\right)+\upsilon\frac{\partial^2\bar{u}}{\partial\bar{y}^2}-\frac{\sigma B_0^{\,2}}{\rho}\bar{u} \qquad (2.2)$$

Energy equation

$$\rho c_p\left[\frac{\partial\bar{T}}{\partial\bar{t}}-v_0\left(1+\varepsilon Ae^{i\bar{\omega}\bar{t}}\right)\frac{\partial\bar{T}}{\partial\bar{y}}\right]=k\frac{\partial^2\bar{T}}{\partial\bar{y}^2}+\upsilon\rho\left(\frac{\partial\bar{u}}{\partial\bar{y}}\right)^2-\frac{\partial\bar{q_r}}{\partial\bar{y}} \qquad (2.3)$$ (Neglecting the higher powers of $\bar{u}$)

Species continuty equation

$$\frac{\partial\bar{C}}{\partial\bar{t}}+-v_0\left(1+\varepsilon Ae^{i\bar{\omega}\bar{t}}\right)\frac{\partial\bar{C}}{\partial\bar{y}}=D_M\frac{\partial^2\bar{C}}{\partial\bar{y}^2}+D_T\frac{\partial^2\bar{C}}{\partial\bar{y}^2} \qquad (2.4)$$

The boundary conditions are

at $\bar{y}=0$; $\bar{u}=\bar{h}\left(\frac{\partial \bar{u}}{\partial \bar{y}}\right)$, $\bar{T}=\bar{T}_w+\varepsilon\left(\bar{T}_w-\bar{T}_\infty\right)e^{i\bar{\omega}\bar{t}}$, $\bar{C}=\bar{C}_w+\varepsilon\left(\bar{C}_w-\bar{C}_\infty\right)e^{i\bar{\omega}\bar{t}}$

at $\bar{y}\to\infty$, $\bar{u}\to 0, \bar{T}\to\bar{T}_\infty$, $\bar{C}\to\bar{C}_\infty$ (2.5)

We assume that the medium is optically thin with relatively low density. Following the Cogly-Vincentine-Gilles equilibrium model, we have

$$\frac{\partial \bar{q}_r}{\partial \bar{y}}=4(\bar{T}-\bar{T}_\infty)\int_0^\infty K_w\left(\frac{\partial e_b}{\partial \bar{T}}\right)_w d\lambda=4\bar{I}\ (\bar{T}-\bar{T}_\infty) \quad (2.6)$$

Thus with the help of equation (2.6), equation (2.3) can be rewritten as

$$\rho c_p\left[\frac{\partial \bar{T}}{\partial \bar{t}}-v_0\left(1+\varepsilon A e^{i\bar{\omega}\bar{t}}\right)\frac{\partial \bar{T}}{\partial \bar{y}}\right]=k\frac{\partial^2 \bar{T}}{\partial \bar{y}^2}+\upsilon\rho\left(\frac{\partial \bar{u}}{\partial \bar{y}}\right)^2-4\bar{I}\,(\bar{T}-\bar{T}_\infty) \quad (2.7)$$

We introduce the following non-dimensional variables and similarity parameters to normalized the flow model

$$y=\frac{\bar{y}\,v_0}{\upsilon},\ t=\frac{\bar{t}v_0^{\,2}}{\upsilon},\ \omega=\frac{\upsilon\bar{\omega}}{v_0^{\,2}},\ u=\frac{\bar{u}}{v_0},\ P=\frac{\mu c_p}{\lambda},\ F=\frac{4I\upsilon^2}{k\,v_0^{\,2}},$$

$$\theta=\frac{\bar{T}-\bar{T}_\infty}{\bar{T}_w-\bar{T}_\infty},\ E=\frac{v_0^{\,2}}{c_p\left(\bar{T}_w-\bar{T}_\infty\right)},\ G_r=\frac{g\beta\upsilon(\bar{T}_w-\bar{T}_\infty)}{v_0^{\,3}},$$

$$G_m=\frac{g\beta\upsilon(\bar{C}_w-\bar{C}_\infty)}{v_0^{\,3}},\ M=\frac{\sigma B_0^{\,2}\upsilon}{\rho v_0^{\,2}},\ S_c=\frac{\nu}{D_M},\ S_0=\frac{D_T\left(\bar{T}_w-\bar{T}_\infty\right)}{D_T\left(\bar{C}_w-\bar{C}_\infty\right)},\ h=\frac{v_0\bar{h}}{\upsilon}.$$

All the physical quantities are defined in Nomenclature

The non-dimensional equations with boundary conditions are

$$\frac{\partial u}{\partial t}-\left(1+\varepsilon A e^{i\omega t}\right)\frac{\partial u}{\partial y}=G_r\theta+G_m\varphi+\frac{\partial^2 u}{\partial y^2}-Mu \quad (2.8)$$

$$P\frac{\partial \theta}{\partial t}-P\left(1+\varepsilon A e^{i\omega t}\right)\frac{\partial \theta}{\partial y}=\frac{\partial^2 \theta}{\partial y^2}+EP\left(\frac{\partial u}{\partial y}\right)^2-F\theta \quad (2.9)$$

$$S_c\frac{\partial \varphi}{\partial t}-S_c\left(1+\varepsilon A e^{i\omega t}\right)\frac{\partial \varphi}{\partial y}=\frac{\partial^2 \varphi}{\partial y^2}+S_cS_0\frac{\partial^2 \theta}{\partial y^2} \quad (2.10)$$

subject to boundary conditions

$$\left.\begin{array}{l} y=0; u=h\dfrac{\partial u}{\partial y}, \theta=1+\varepsilon A e^{i\omega t}, \varphi=1+\varepsilon A e^{i\omega t} \\ y\to\infty; u\to 0,\ \theta\to 0,\ \varphi\to 0 \end{array}\right\} \quad (2.11)$$

3. Method of solution

Assuming the small amplitude oscillation (ε <<1), we represent the velocity u, temperature θ and species concentration φ near the plate as

$$\left.\begin{array}{l} u=u_0(y)+\varepsilon e^{i\omega t}u_1(y)+O(\varepsilon^2) \\ \theta=\theta_0(y)+\varepsilon e^{i\omega t}\theta_1(y)+O(\varepsilon^2) \\ \varphi=\varphi_0(y)+\varepsilon e^{i\omega t}\varphi_1(y)+O(\varepsilon^2) \end{array}\right\} \quad (3.1)$$

Substituting from (3.1) in (2.8), (2.9) and (2.10) and by equating the harmonic terms and neglecting the higher powers of ε, the following equations are obtained

$$u_0''+u_0'-Mu_0=-G_r\theta_0-G_m\varphi_0 \quad (3.2)$$

$$u_1''+u_1'-\left(i\omega+M\right)u_1=-G_r\theta_1-G_m\varphi_1-Au_0' \quad (3.3)$$

$$\theta_0''+P\theta_0'-F\theta_0=-EPu_0'^2 \quad (3.4)$$

$$\theta_1'' + P\theta_1' - (F + i\omega P)\theta_1 = -AP\theta_0' - 2EPu_0'u_1' \quad (3.5)$$

$$\varphi_0'' + S_c\varphi_0' = -S_cS_0\theta_0'' \quad (3.6)$$

$$\varphi_1'' + S_c\varphi_0' - i\omega S_c\varphi_1 = -S_cA\varphi_0' - S_cS_0\theta_1'' \quad (3.7)$$

The corresponding boundary conditions are

$$\left.\begin{array}{l} y = 0; u_0 = h\dfrac{\partial u_0}{\partial y}, u_1 = h\dfrac{\partial u_1}{\partial y}, \theta_0 = 1, \theta_1 = 1, \varphi_0 = 1, \varphi_1 = 1 \\ y \to \infty; u_0 \to 0, u_1 \to 0, \theta_0 \to 0, \theta_1 \to 0, \varphi_0 \to 0, \varphi_1 \to 0 \end{array}\right\} \quad (3.8)$$

where, dashes denote differentiation with respect to y.

The equations (3.2) to (3.7) are still coupled for the variables u_0, u_1, θ_0, θ_1, φ_0 and φ_1. To solve them we note that E < 1 for all incompressible fluids and assume that

$$\left.\begin{array}{l} u_0 = u_{00} + Eu_{01} + O(E^2); u_1 = u_{10} + Eu_{11} + O(E^2) \\ \theta_0 = \theta_{00} + E\theta_{01} + O(E^2); \theta_1 = \theta_{10} + E\theta_{11} + O(E^2) \\ \varphi_0 = \varphi_{00} + E\varphi_{01} + O(E^2); \varphi_1 = \varphi_{10} + E\varphi_{11} + O(E^2) \end{array}\right\} \quad (3.9)$$

Substituting from (3.9) in the equations (3.2) to (3.7) and equating the terms independent of E and coefficient of E in each equation and neglecting higher powers of E the following equations are obtained

$$u_{00}'' + u_{00}' - Mu_{00} = -G_r\theta_{00} - G_m\varphi_{00} \quad (3.10)$$

$$u_{01}'' + u_{01}' - Mu_{01} = -G_r\theta_{01} - G_m\varphi_{01} \quad (3.11)$$

$$u_{10}'' + u_{10}' - (i\omega + M)u_{10} = -Au_{00}' - G_r\theta_{10} - G_m\varphi_{10} \quad (3.12)$$

$$u_{11}'' + u_{11}' - (i\omega + M)u_{11} = -G_r\theta_{11} - G_m\varphi_{11} - Au_{01}' \quad (3.13)$$

$$\theta_{00}'' + P\theta_{00}' - F\theta_{00} - = 0 \quad (3.14)$$

$$\theta_{01}'' + P\theta_{01}' - F\theta_{01} = -Pu_{00}'^2 \quad (3.15)$$

$$\theta_{10}'' + P\theta_{10}' - P(F + i\omega)\theta_{10} = -AP\theta_{00}' \quad (3.16)$$

$$\theta_{11}'' + P\theta_{11}' - (F + i\omega)\theta_{11} = -AP\theta_{01}' - 2Pu_{00}'u_{10}' \quad (3.17)$$

$$\varphi_{00}'' + S_c\varphi_{00}' = -S_cS_0\theta_{00}'' \quad (3.18)$$

$$\varphi_{01}'' + S_c\varphi_{01}' = -S_cS_0\theta_{01}'' \quad (3.19)$$

$$\varphi_{10}'' + S_c\varphi_{10}' - i\omega S_c\varphi_{10} = -S_cA\varphi_{00}' - S_cS_0\theta_{10}'' \quad (3.20)$$

$$\varphi_{11}'' + S_c\varphi_{11}' - i\omega S_c\varphi_{11} = -S_cA\varphi_{01}' - S_cS_0\theta_{11}'' \quad (3.21)$$

subject to boundary conditions

at y = 0, $$\left\{\begin{array}{l} u_{00} = h\dfrac{\partial u_{00}}{\partial y}, u_{01} = h\dfrac{\partial u_{01}}{\partial y}, u_{10} = h\dfrac{\partial u_{10}}{\partial y}, u_{11} = h\dfrac{\partial u_{11}}{\partial y} \\ \theta_{00} = 1, \theta_{01} = 0, \theta_{10} = 1, \theta_{11} = 0 \\ \varphi_{00} = 1, \varphi_{01} = 0, \varphi_{10} = 1, \varphi_{11} = 0 \end{array}\right\} \quad (3.22) \quad y \to \infty, \quad \left\{\begin{array}{l} u_{00} \to 0, u_{01} \to 0, u_{10} \to 0, u_{11} \to 0 \\ \theta_{00} \to 0, \theta_{01} \to 0, \theta_{10} \to 0, \theta_{11} \to 0 \\ \varphi_{00} \to 0, \varphi_{01} \to 0, \varphi_{10} \to 0, \varphi_{11} \to 0 \end{array}\right\}$$

(3.23)

Equations (3.10) to (3.21) are solve with the help of boundary conditions (3.22) and (3.33) but not shown here for the sake of brevity.

The final expression for the velocity, temperature and species concentration profiles in the following form

$$u(y,t) = u_{00}(y) + Eu_{01}(y) + \varepsilon\left\{\left(u_{10}{}^{R} + Eu_{11}{}^{R}\right)\cos\omega t - \left(u_{10}{}^{I} + Eu_{11}{}^{I}\right)\sin\omega t\right\}$$

$$\theta(y,t) = \theta_{00}(y) + E\theta_{01}(y) + \varepsilon\left\{\left(\theta_{10}{}^{R} + E\theta_{11}{}^{R}\right)\cos\omega t - \left(\theta_{10}{}^{I} + E\theta_{11}{}^{I}\right)\sin\omega t\right\}$$

$$\varphi(y,t) = \varphi_{00}(y) + \varphi_{01}(y) + \varepsilon\left\{\left(\varphi_{10}{}^{R} + E\varphi_{11}{}^{R}\right)\cos\omega t - \left(\varphi_{10}{}^{I} + E\varphi_{11}{}^{I}\right)\sin\omega t\right\}$$

where, superscripts R and I respectively represent the real and imaginary parts.

3. Rate of Heat Transfer

The rate of heat transfer in terms of Nusselt Number between the fluid and the plate is given by

$$N_u = \left.\frac{\partial\theta}{\partial y}\right]_{y=0} = \left.\frac{\partial\theta_0}{\partial y} + \varepsilon e^{i\omega t}\frac{\partial\theta_1}{\partial y}\right]_{y=0} = \left[\frac{\partial}{\partial y}\{\theta_{00} + E\theta_{01}\}\right]_{y=0}$$

$$+\varepsilon(\cos\omega t + i\sin\omega t)\left[\frac{\partial}{\partial y}\{\theta_{10} + E\theta_{11}\}\right]_{y=0}$$

5. Rate of Mass Transfer

The rate of mass transfer in terms of Sherwood number between the fluid and the plate is given by

$$Sh = \left.\frac{\partial\varphi}{\partial y}\right]_{y=0} = \left.\frac{\partial\varphi_0}{\partial y} + \varepsilon e^{i\omega t}\frac{\partial\varphi_1}{\partial y}\right]_{y=0} = \left[\frac{\partial}{\partial y}\{\varphi_{00} + E\varphi_{01}\}\right]_{y=0}$$

$$+\varepsilon(\cos\omega t + i\sin\omega t)\left[\frac{\partial}{\partial y}\{\varphi_{10} + E\varphi_{11}\}\right]_{y=0}$$

6. Results and Discussion

In order to get physical insight into the problem the numerical values of velocity distribution, temperature distribution, rate of heat transfer in terms of Nusselt number, rate of mass transfer in terms of Sherwood number have been obtained and they are demonstrated graphically.

For the purpose of discussing the effects of various parameters on the flow behaviour near the plate, numerical calculations have been carried out for different values of M, F, So, Sc and for fixed values of P, E, Gr, Gm, A, ω, ωt, h and ε. Throughout our investigation the Prandtl number P is taken to be equal to 0.71 which corresponds to the air at 20^0 C. The values of Eckert number E is assumed to be 0.01. The values of small reference parameter ε, frequency ω, phase angle ωt and suction parameter A are taken 0.001, 3, π/6, 0.4 respectively. In our investigation, Grashof number for heat transfer Gr > 0 corresponds to externally cooled plate. The value of Gr has been chosen as 5 whereas the Grashof number Gm for mass transfer has been chosen to be 2.

Figures 1-4 depict the change of behavior of velocity profile u against y under the effects of Hartman number M, radiation parameter F, Soret number So and Schmidt number Sc. From these figures we observe that fluid motion is accelerated due to the effects of magnetic field and thermal diffusion. But due to radiation effect fluid velocity decreases. From these figures we also observed that due to high molar diffusivity fluid velocity is decreased.

Figures 5-8 exhibit the variation of temperature field θ versus y under the influence of Hartmann number M, radiation parameter F, Soret number So and Schmidt number Sc. Figure 6 and 7 indicate that there is a fall in temperature due to increase in radiation effect as well as thermal diffusion effect. It is also seen from the figure 5 and 8 that temperature rises due to increase values of m and Sc. In other words we can say that due to magnetic force temperature increases whereas it falls due to high molar diffusivity.

The variation of species concentration φ versus y are shown in figures 9-12 for various values of M, F, So and Sc. It is marked in the figure 9 that species concentration falls due to magnetic force near the plate whereas it shows reverse effect far away from the plate. From these figures (10-12) it is cleared that concentration rise due to thermal diffusion effect whereas it falls for radiation effect and high molar diffusivity.

Figures 13-15 demonstrate how the Nusselt number Nu at the plate y=0 is affected by the parameters M, F, Sc, So. These figures clearly establish the fact that Nu rises under the effects of radiation and thermal diffusion whereas it falls due to high molar diffusivity. Further it is also clear from these figures that the imposition of magnetic field decrease the rate of heat transfer from the plate to the fluid.

The coefficient of rate of mass transfer in terms of Sherwood number Sh at the plate against M are presented in figure 16-18. It is observed from these figures that an increase in M, F or So results in a decrease in Sh whilst an increase in Sc causes Sh to increase. This means that due to magnetic force, radiation effect, thermal diffusion effect and molar diffusivity the rate of mass transfer from the plate to the fluid is decreased.

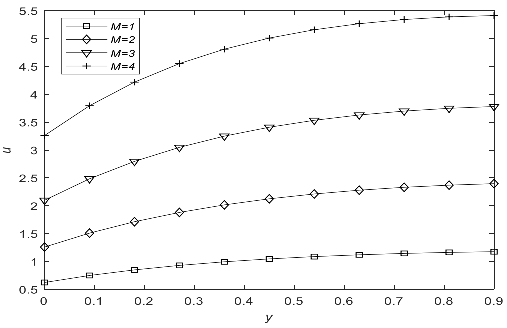

Figure 1: Velocity profile u versus y for various values of M when Sc=0.22, So=2.5 and F=9

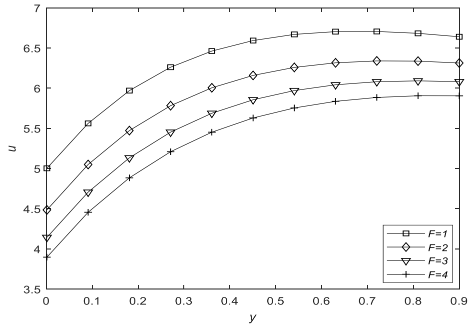

Figure 2: Velocity profile u versus y for various values of F when Sc=0.22, So=2.5 and M=4

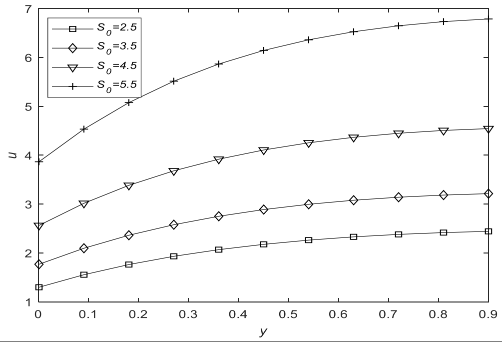

Figure 3: Velocity profile u versus y for various values of So when Sc=0.22, M=2 and F=5

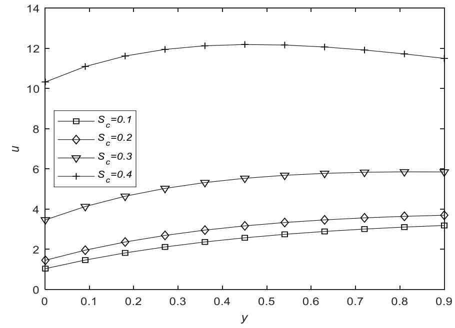

Figure 4: Velocity profile u versus y for various values of Sc when M=3, So=2.5 and F=4

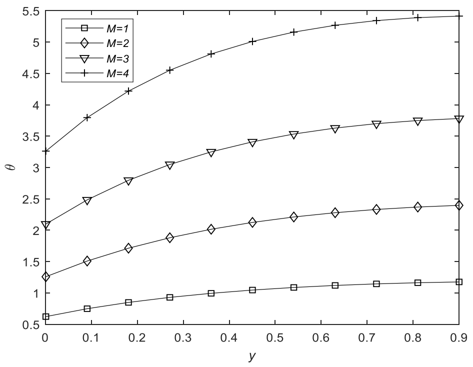

Figure 5: Temperature profile θ versus y for various values of M when Sc=0.22, So=2.5 and F=9

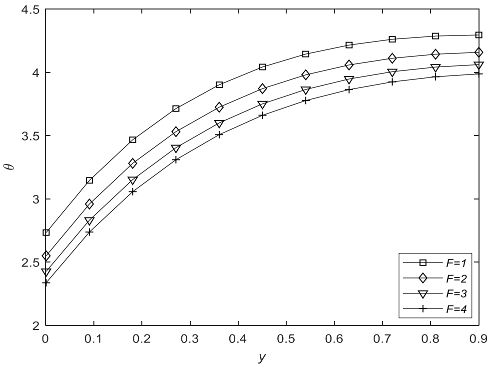

Figure 6: Temperature profile θ versus y for various values of F when Sc=0.22, So=2.5 and M=3

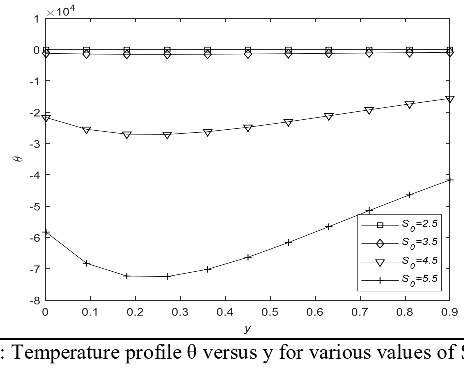

Figure 7: Temperature profile θ versus y for various values of So when Sc=0.22, M=3 and F=5

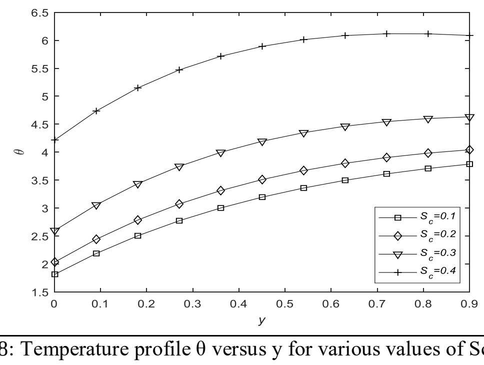

Figure 8: Temperature profile θ versus y for various values of Sc when So=3.5, M=3 and F=5

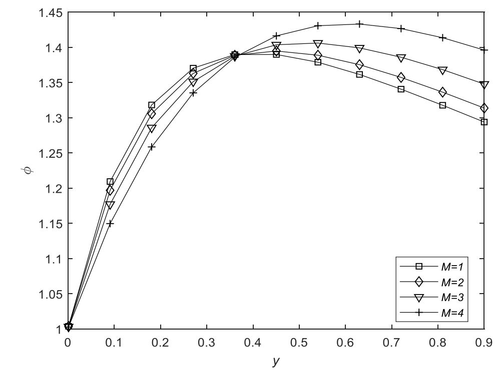

Figure 9: Species concentration φ versus y for various values of M when Sc=0.22, So=2.5 and F=7

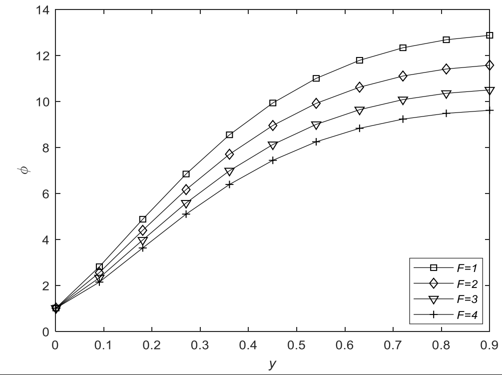

Figure 10: Species concentration φ versus y for various values of F when Sc=0.22, So=3.5 and M=5

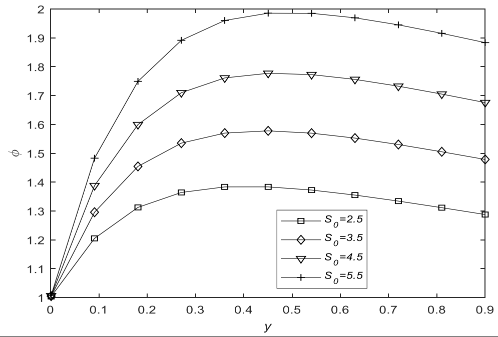

Figure 11: Species concentration φ versus y for various values of So when Sc=0.22, M=1 and F=5

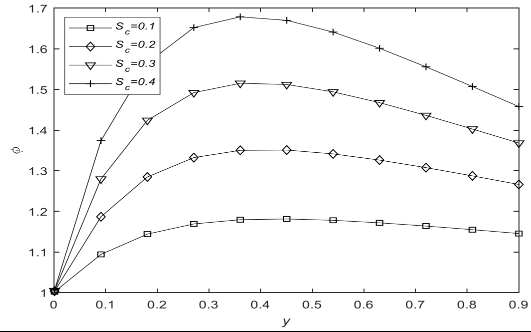

Figure 12: Species concentration φ versus y for various values of Sc when M=1, So=2.5 and F=5

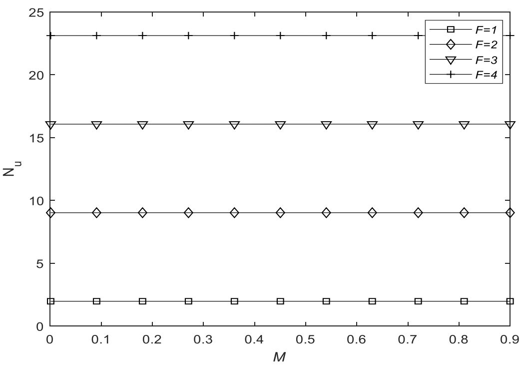

Figure 13: Nusselt number Nu versus M for various values of F when Sc=0.22 and So=2.5

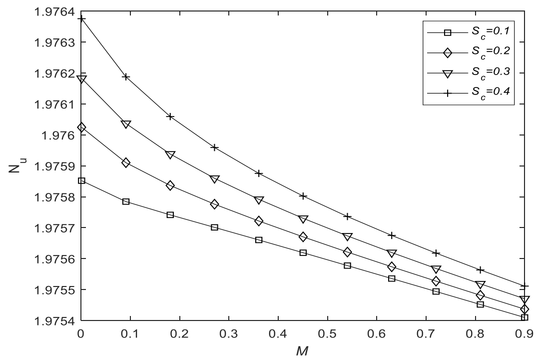

Figure 14: Nusselt number Nu versus M for various values of Sc when F=1 and So=2.5

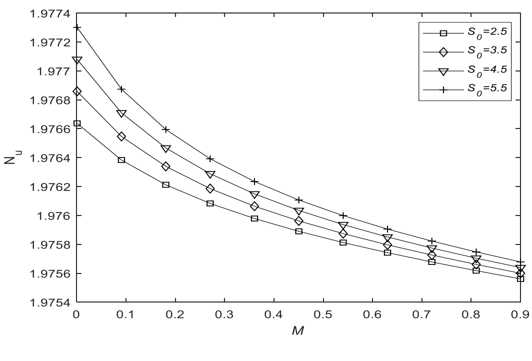

Figure 15: Nusselt number Nu versus M for various values of So when F=1 and Sc=0.5

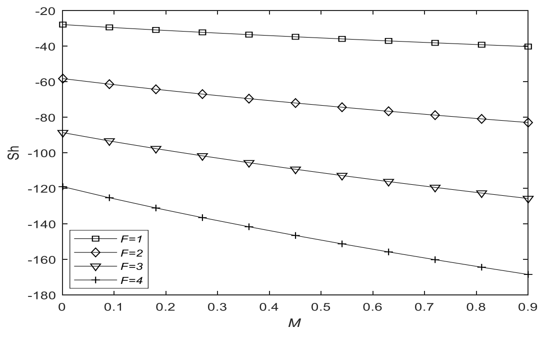

Figure 16: Sherwood number Sh versus M for various values of F when So=2.5 and Sc=0.5

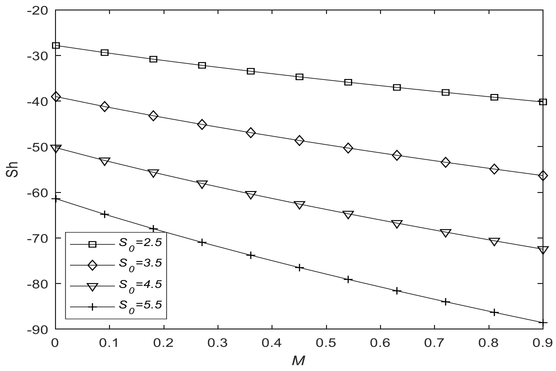

Figure 17: Sherwood number Sh versus M for various values of Sc when F=1 and Sc=0.5

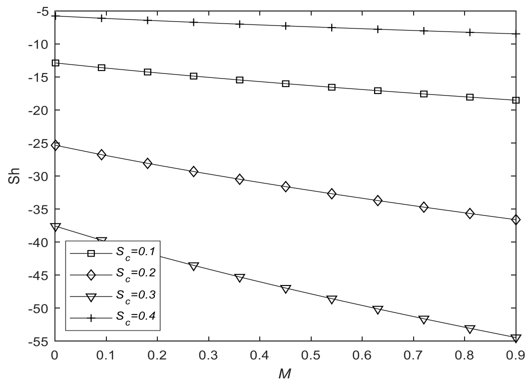

Figure 18: Sherwood number Sh versus M for various values of Sc when F=1 and So=2.5

7. Conclusions

Our investigation leads to the following conclusions

1. Magnetic field and thermal diffusion accelerate the fluid motion although radiation effect and high molar diffusivity retards the fluid flow.

2. The temperature falls due to effects of radiation and thermal diffusion whereas it rises up due to effect of magnetic field.

3. The concentration level of the fluid rises up under the effect of thermal diffusion whereas it falls due to radiation effect and high molar diffusivity.

4. Heat flux rises due to effects of radiation, thermal diffusion and high molar diffusivity.

5. Due to the effects of magnetic force, radiation, molar diffusivity and thermal diffusion the rate of mass transfer from the plate to the fluid falls.

8. Nomenclature

A Suction parameter, B_0 Applied magnetic field, Cp Specific heat at constant pressure, E Eckert number, Gr Grashof number for heat transfer, Gm Grashof number for mass transfer, So Soret number, Sc Schimdt number , g Acceleration due to gravity, h Rarefaction parameter, K_w Absorption coefficient, q_r Radiative heat flux, P Prandtl number, M Hartman number, F Thermal radiation parameter, k thermal conductivity, u dimensionless velocity, x Dimensionless coordinate along the plate, y Dimensionless coordinate normal to the plate, t time (dimensionless), $\overline{T}$ Temperature of the fluid near the plate, $\overline{T}_w$ Temperature of the plate, $\overline{T}_\infty$ Temperature at main stream fluid, $\bar{t}$ time, $\overline{u}$ velocity component in x-direction, $\overline{x}$ Coordinate along the plate.

***Greek Symbols*:**

β coefficient of thermal expansion, ρ fluid density, υ kinematics viscosity, ω frequency parameter, τ Dimensionless skin friction.

9. References

1. Takhar H. S., Gorla R. S. R. and Sundalgekar V. M.: Radition effects on MHD free convection flow of a radiating gas past a semi infinite vertical plate. Internatioal Journal of Numerical Methods Heat Fluid Flow 6, 1996, 77-83.

2. Sattar M. A. and Kalim H.: Unsteady free convection interaction with thermal radiation in a boundary layer flow past a vertical porous plate, Journal of Mathematical Physics 30, 1996, 25-37.

3. Raptis A. and Perdikis O.: Radiation and free convection flow past a moving plate, Applied Mechanics and Engineering 4(4), 1999, 817-821.

4. Mansour M. A.: Radiation and free convection effects on the oscillatory flow past a vertical plate, Astrophysics and Science, 166((2), 1990, 269-275.

5. Makinde O. D.: Free convection Flow with thermal radiation and mass transfer past a moving vertical porous plate, International comm.. in Heat and Mass Transfer; 32(10), 2005, 1411-1419.

6. Prasad V. R., Reddy Bhaskar N., Muthucumaraswamy R.: Transient radiative hydro magnetic free convection flow past an impulsively started vertical plate with uniform heat and mass flux, Theoretical Applied Mechanics, 33(1), 2006, 31-36.

7. Ahmed N., Sarmah H.K.: Thermal radiation effect on a transient MHD flow with mass transfer past an impulsively fixed infinite vertical plate, International Journal of Applied Mathematics and Mechanics; 5(5), pp 49-58, 2009.

8. Sattar M. A. and Alam M. M.: Thermal diffusion as well as transpiration effects on MHD free convection and mass transfer flow past an accelerated vertical porous plate, Indian Journal of Pure and Applied Mathematics 25(6), 1994, 679-688.

9. Raju M. C., Varma S. V. K., Reddy P. V. and Saha S.: Soret effect due to natural convection between heated inclined plates with magnetic field, Journal of Mechanical Engineering 39, 2008, 65-70.

10. Alam S., Rahman M. M., Maleque A. and Ferdows M.: Dofour and Soret effects on steady MHD combinedfree-forced convective and mass transfer flow past a semi-infinite vertical plate, Thammasat International journal of Science Technology II, 1-12, 2006.

11. Ahmed N., Sarmah H.K and Kalita D.: Thermal diffusion effect on a three dimensional MHD free convection with mass transfer flow from a porous vertical plate, Latin American Applied Research 41, 2011, 165-176.

12. Ahmed N.: Soret and radiation effects on transient MHD free convection from an impulsively started infinite vertical plate, Journal of Heat Transfer (ASME) 134/062701-1-9 (2012).

13. Ahmed N., Kalita D.: MHD oscillatory free convective flow past a vertical plate in slip-flow regime with variable suction and periodic plate temperature, International Journal of Heat and Technology, 21(3), 2008, pp 353-368.