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THERMAL DIFFUSION EFFECT ON MHD OSCILLATORY CHANNEL FLOW WITH SLIP CONDITION AND MASS TRANSFER

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Abstract: An analysis is carried out to study the effect of thermal diffusion on an oscillatory channel with mass transfer in presence of uniform magnetic field. Fluid slip is applied at the lower wall and magnetic field is normal to the walls of the channel. The effect of thermal diffusion (Sr), solutal Grashof number (Gm), magnetic field (M) and radiation parameter (N) on the flow are studied through graphs . It is observed that with the increase in thermal diffusion (Sr), Schimdt number (Sc) velocity decreases whereas it shows a reverse nature for solutal Grashof number (Gm).

Keywords: MHD, Thermal diffusion, chemical reaction, permeability.

1. Introduction

MHD is the study of the magnetic properties of electrically conducting fluids. Examples of such magneto fluids include plasmas, liquid metals, salt water and electrolytes. The fundamental concept behind MHD is that magnetic fields can induce current in a moving conductive fluid . MHD is related to engineering problems such as plasma confinement, liquid metal cooling of nuclear reactors and electromagnetic casting. Chang and Yen [3], Raptis [11], Singh [12] have done significant works on MHD related various topics. Thermal diffusion is a relative motion of the components of the gaseous mixture or solution , which is established when there is a temperature gradient in a medium. Thermal diffusion in liquids has an alternative term, the Soret effect. The effect of thermal diffusion in MHD flows have been studied extensively by many scientist. Prakash et al. [10], Osalausi et.al [9], Afify [1] have done extensive work on various topics related to thermal diffusion. Thermal radiation is electromagnetic radiation generated by the thermal motion of charged particles in matter. Many scientists like Makinde and Mhone [7] have studied the effects of radiative heat transfer to MHD oscillatory flow in a channel filled with saturated porous medium. Ahmed and Shiekh [2] have also investigated in the same field.

The concept of oscillating flows of fluids in porous channels has become a fundamental interest for many biological and industrial process because of its applications in irrigation, drainage, soil mechanics, absorption and filtration process in chemical engineering. Khodadadi [6] have presented oscillatory fluid flow through a porous medium bounded by two impermeable parallel plates. Many researchers have also studied the effects of Navier slip condition because of its application in industrialization, modern science etc.. The effects of slip conditions on the hydromagnetic steady flow in a channel with permeable conditions was presented by Makinde and Oslausi [8]. Eegunjobi and Makinde [5] have established that the effect of Navier slip condition depends on the shear stress of both upper and lower walls of a channel. Srinivas and Kothandapani [15] have investigated the effects of heat and mass transfer on peristaltic transport in porous space with compliant walls. The effects of mass transfer on flow past an accelerated vertical plate has been studied by Soundelgekar [14] and Singh and Singh [13].

The present work aims to study the effect of thermal diffusion on the flow. It may be mentioned that the work is an extension work done by Ahmed and Shiekh [2].

2. Mathematical Analysis

An incompressible, viscous and electrically conducting fluid bounded by two parallel plates separated by a distance *a*, filled with saturated porous medium under the influence of a uniform magnetic field applied normal to the plates is considered. The magnetic Reynolds number is assumed to be very small so that the induced magnetic field is neglected in comparison to applied magnetic field.

We have considered a cartesian co-ordinates system ($\bar{X}$,$\bar{Y}$) where $\bar{X}$ - axis is taken along the lower plate and $\bar{Y}$ - axis along the upward normal to the plate.

Momentum equation :

$$\frac{\partial \bar{u}}{\partial \bar{t}} = -\frac{1}{\rho}\frac{\partial \bar{p}}{\partial \bar{x}} + \nu \frac{\partial^2 \bar{u}}{\partial \bar{y}^2} - \frac{\nu}{\bar{k}}\bar{u} - \frac{\sigma_e B_0^2}{\rho}\bar{u} + g\beta\left(\bar{T} - T_0\right) + g\bar{\beta}\left(\bar{C} - C_0\right) \tag{1}$$

Energy equation :

$$\frac{\partial \bar{T}}{\partial \bar{t}} = \frac{\kappa}{\rho C_p}\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial \bar{y}} \tag{2}$$

Species continuity equation :

$$\frac{\partial \bar{C}}{\partial \bar{t}} = D\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} + \overline{Cr}\left(C_0 - \bar{C}\right) + \frac{DK_T}{T_M}\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} \tag{3}$$

The relevant boundary conditions are

$$\bar{u}-\bar{h}\frac{\partial \bar{u}}{\partial \bar{y}}=0, \bar{T}=T_0, \bar{C}=C_0 \text{ at } \bar{y}=0$$
$$\bar{u}=0, \bar{T}=T_w, \bar{C}=C_w \text{ at } \bar{y}=a \tag{4}$$

We have assumed the walls temperature T_0 and T_w to be high so that it is enough to induce radiative heat transfer. The fluid is taken to be optically thin with a relatively low density. According to Coogley et al. [4] the radiative heat flux is given by

$$\frac{\partial q_r}{\partial \bar{y}}=4\alpha^2\left(T_0-\bar{T}\right) \tag{5}$$

To make the mathematical model normalized, the following non-dimensional quantities have been introduced.

$$Re=\frac{Ua}{\nu}, x=\frac{\bar{x}}{a}, y=\frac{\bar{y}}{a}, u=\frac{\bar{u}}{U}, \theta=\frac{\bar{T}-T_0}{T_w-T_0}, t=\frac{\bar{t}U}{a},$$

$$p=\frac{a\bar{p}}{\rho\nu U}, Da=\frac{\bar{K}}{a^2}, \varphi=\frac{\bar{C}-C_0}{C_w-C_0}, Cr=\frac{a\overline{Cr}}{U}, M^2=\frac{a^2\sigma_e B_0^2}{\rho\nu}$$

$$Gr=\frac{g\beta\left(T_w-T_0\right)}{\nu U}a^2, Pe=\frac{U\rho a C_p}{\kappa}, N^2=\frac{4\alpha^2 a^2}{\kappa}, Sc=\frac{\upsilon}{D}, Gm=\frac{g\bar{\beta}\left(C_w-C_0\right)a^2}{\nu U},$$

$$h=\frac{\bar{h}}{a}, Sr=\frac{K_T D}{T_M \nu}\frac{T_w-T_0}{C_w-C_0}.$$

The governing equations (1), (2) and (3) in non-dimensional form are :

$$Re\frac{\partial u}{\partial t}=-\frac{\partial p}{\partial x}+\frac{\partial^2 u}{\partial y^2}-\left(s^2+M^2\right)u+Gr\theta+Gm\varphi \tag{6}$$

$$Pe\frac{\partial \theta}{\partial t}=\frac{\partial^2 \theta}{\partial y^2}+N^2\theta \tag{7}$$

$$\frac{\partial \varphi}{\partial t}=\frac{1}{Re.Sc}\frac{\partial^2 \varphi}{\partial y^2}-Cr\varphi+\frac{Sr}{Re}\left(\frac{\partial^2 \theta}{\partial y^2}\right) \tag{8}$$

where

$$s = \left(\frac{1}{Da}\right)^{\frac{1}{2}}$$

The boundary conditions (4.1) and (4.2) in non-dimensional forms are

$$u - h\frac{\partial u}{\partial y} = 0, \theta = 0, \varphi = 0 \quad at \quad y = 0$$
$$u = 0, \theta = 1, \varphi = 1 \quad at \quad y = 1 \tag{9}$$

For the solutions of (6), (7) and (8) subject to the boundary conditions (9), we consider the following transformations

$$\left.\begin{aligned} -\frac{\partial p}{\partial x} &= \lambda e^{i\omega t} \\ u(y,t) &= u_0(y)e^{i\omega t} \\ \theta(y,t) &= \theta_0(y)e^{i\omega t} \\ \varphi(y,t) &= \varphi_0(y)e^{i\omega t} \end{aligned}\right\} \tag{10}$$

Subsituting the transformations (10) in (6), (7) and (8) we derive the following set of differential equations :

$$\frac{d^2u_0}{dy^2} - m_2^2 u_0 = -\lambda - Gr\theta_0 - Gm\varphi_0 \tag{11}$$

$$\frac{d^2\theta_0}{dy^2} + m_1^2\theta_0 = 0 \tag{12}$$

$$\frac{d^2\varphi_0}{dy^2} - m_3^2\varphi_0 + Sr.Sc\frac{d^2\theta_0}{dy^2} = 0 \tag{13}$$

where

$$m_1 = \sqrt{N^2 - i\omega Pe} \quad , m_2 = \sqrt{s^2 + M^2 + i\omega Re} \quad , m_3 = \sqrt{(Cr + i\omega)ScRe}$$

The boundary conditions of (11), (12) and (13) are

$$u_0 - h\frac{du_0}{dy} = 0, \; \theta_0 = 0, \; \varphi_0 = 0 \quad at \; y = 0$$
$$u_0 = 0, \; \theta_0 = 1, \; \varphi_0 = 1 \quad at \quad y = 1 \tag{14}$$

Equation (11), (12) and (13) are solved subject to boundary conditions (14.1) and (14.2)

$$u(y,t)=C_1e^{m_2y}+C_2e^{-m_2y}+\frac{\lambda}{m_2^2}+\frac{Gr}{\left(m_1^2+m_2^2\right)}\frac{\sin(m_1y)}{\sin(m_1)}-$$

$$\frac{Gm}{m_1^2+m_3^2}\left\{\frac{\left[m_1^2\left(1+Sr.Sc\right)+m_3^2\right]\sinh\left(m_3y\right)}{\left(m_3^2-m_2^2\right)\sinh\left(m_3\right)}+\frac{m_1^2Sr.Sc}{\left(m_1^2+m_2^2\right)}\frac{\sin(m_1y)}{\sin(m_1)}\right\}e^{i\omega t} \quad (15)$$

$$\theta(y,t)=\frac{\sin(m_1y)}{\sin(m_1)}e^{i\omega t} \quad (16)$$

$$\varphi(y,t)=\frac{1}{m_1^2+m_3^2}\left\{\frac{\sinh\left(m_3y\right)\left[m_1^2\left(1+Sr.Sc\right)+m_3^2\right]}{\sinh\left(m_3\right)}-\frac{m_1^2Sr.Sc\sin(m_1y)}{\sin(m_1)}\right\}e^{i\omega t} \quad (17)$$

where

$$C_1=-\frac{1}{2\sinh\left(m_2\right)\left(1+hm_2\right)+hm_2e^{-m_2}}\left\{\frac{\lambda\left(1+hm_2-e^{-m_2}\right)}{m_2^2}+\frac{Gr\left[\left(1+hm_2\right)\sin\left(m_1\right)+m_1he^{-m_2}\right]}{\left(m_1^2+m_2^2\right)\sin\left(m_1\right)}-\right.$$

$$\frac{Gm\left[m_1^2\left(1+Sr.Sc\right)+m_3^2\right]\left[\left(1+hm_2\right)\sinh\left(m_3\right)+m_3he^{-m_2}\right]}{\left(m_1^2+m_3^2\right)\left(m_3^2-m_2^2\right)\sinh\left(m_3\right)}$$

$$\left.-\frac{m_1^2GmSr.Sc\left[\left(1+hm_2\right)\sin\left(m_1\right)+m_1he^{-m_2}\right]}{\left(m_1^2+m_3^2\right)\left(m_1^2+m_2^2\right)\sin\left(m_1\right)}\right\}$$

$$C_2=\frac{1}{\left(1+hm_2\right)}\times$$

$$\left[-C_1-\frac{\lambda}{m_2^2}+h\left\{m_2C_1+\frac{m_1Gr}{\left(m_1^2+m_2^2\right)\sin(m_1)}-\frac{Gm}{\left(m_1^2+m_3^2\right)}\left(\frac{\left[m_1^2\left(1+Sr.Sc\right)+m_3^2\right]m_3}{\left(m_3^2-m_2^2\right)\sinh(m_3)}+\frac{m_1^3Sr.Sc}{\left(m_1^2+m_2^2\right)\sin(m_1)}\right)\right\}\right]$$

3. Skin Friction

By the Newton's law of viscosity the shear stress at any point in the fluid is given by

$$\bar{\tau}=-\mu\frac{\partial\bar{u}}{\partial\bar{y}}=\frac{\mu U}{a}\frac{\partial u}{\partial y}$$

$$\tau = \frac{\bar{\tau}}{\frac{\mu U}{a}} = -\frac{\partial u}{\partial y}$$

Skin friction coefficients τ_0 and τ_1 on the walls at *y=0* and *y=1* respectively is given by

$$\tau_0 = -\left[\frac{\partial u}{\partial y}\right]_{y=0}$$

$$= -e^{i\omega t}\left[m_2\left(C_1 - C_2\right) + \frac{m_1 Gr}{\left(m_1^2 + m_2^2\right)\sin\left(m_1\right)} - \frac{Gm}{\left(m_1^2 + m_3^2\right)}\left\{\frac{\left[m_1^2\left(1 + Sr.Sc\right) + m_3^2\right]m_3}{\left(m_3^2 - m_2^2\right)\sinh\left(m_3\right)} + \frac{m_1^3 Sr.Sc}{\left(m_1^2 + m_2^2\right)\sin\left(m_1\right)}\right\}\right] \tag{18}$$

and

$$\tau_1 = -\left[\frac{\partial u}{\partial y}\right]_{y=1}$$

$$= -e^{i\omega t}$$

$$\left[m_2\left(C_1 e^{m_2} - C_2 e^{-m_2}\right) + \frac{m_1 Gr}{\left(m_1^2 + m_2^2\right)}\cot\left(m_1\right) - \frac{Gm}{\left(m_1^2 + m_3^2\right)}\left\{\frac{\left[m_1^2\left(1 + Sr.Sc\right) + m_3^2\right]m_3}{\left(m_3^2 - m_2^2\right)}\coth(m_3) + \frac{m_1^3 Sr.Sc}{\left(m_1^2 + m_2^2\right)}\cot\left(m_1\right)\right\}\right]$$

4. Nusselt Number

The co-effiecient of the rate of heat transfer Nu_0 and Nu_1 on the walls *y=0* and *y=1* respectively in terms of Nusselt number are given by

$$Nu_0 = -\left[\frac{\partial \theta}{\partial y}\right]_{y=0} \qquad = -\frac{m_1 e^{i\omega t}}{\sin\left(m_1\right)}$$

$$Nu_1 = -\left[\frac{\partial \theta}{\partial y}\right]_{y=1} \qquad = -m_1 e^{i\omega t}\cot\left(m_1\right)$$

5. Results and Discussions

For the purpose of physical insights into the problem the effects of various parameters have been studied and are interpreted through graphs. These parameters are velocity slip (*h*), solutal Grashof number (*Gm*), Schimdt number (*Sc)*, chemical reaction parameter (*Cr)*, Hartmann number (*M*), radiation parameter (*N*), Soret effect (*Sr*) whose effects on the flow and heat and mass transfer characteristics have been considered.

In our study we have considered Pe =0.71, Re =1 and so Pr =0.71 because of the relation $Pe = Re\ Pr$. It is to be mentioned that Pr =0.71 refers to air. Figure 1, 2, 3, 4 and 5 shows that velocity decreases with increasing Hartmann number (M), Soret number (Sr), chemical reaction parameter (Cr), Schimdt number (Sc) and time (t) respectively. Thus it is seen that the increase in magnetic field (M) increases the frictional force which reduces the fluid motion. Also the increase in Soret number (Sr) decelerated the fluid motion. The increase in Schimdt number (Sc) means a decrease in mass diffusivity. It agrees with the physical fact that the fluid moves freely as it becomes less dense due to high mass diffusivity. From figure 6, 7, and 8 it is seen that with the increase in solutal Grashof number (Gm), Radiation parameter (N) and Slip parameter (h) velocity increases. The increase in Slip parameter (h) reduces the frictional forces thereby increasing the fluid velocity.

The effect of chemical reaction parameter (Cr), Schimdt number (Sc), Soret number (Sr) and Radiation parameter (N) on concentration (φ) have been depicted in figure 9, 10, 11 and 12. From the figures it is seen that the concentration (φ) decreases for increasing Cr, Sc,Sr and N. At y=0 the magnitude of skin friction (τ_0) increases for increasing slip parameter (h) and Soret number (Sr) which is shown in figure 13, 14 respectively whereas in figure 15,16 a reverse nature is seen for solutal Grashof number (Gm) and Radiation parameter (N) respectively. It is seen from figure 17,18, 19 that at the wall y=1 the magnitude of skin friction (τ_1) rises with the increase in solutal Grashof number (Gm), Slip parameter (h) and Soret number (Sr) respectively but it decreases for rise in Radiation parameter (N) which is shown in figure 20. Figure 21 and 22 shows how Radiation parameter (N) effects the fluid temperatures Nu_0 and Nu_1 at the walls y=0 and y=1 respectively. It is observed From figure 21 that Nu_0 decreases with increase in N whereas Nu_1 increases which is depicted in figure 22.

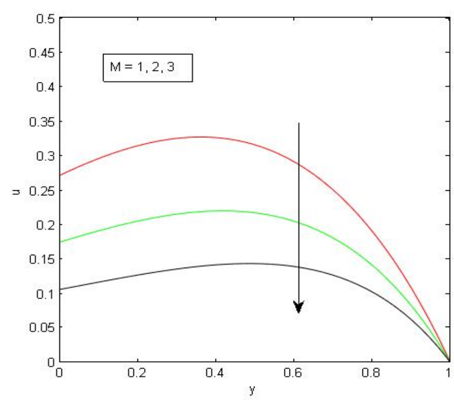

Figure1. Velocity u for variation in M when Re=1,N=1,Da=1,Gr=1,Gm=1,Cr=1,λ=1,h=1,Cr=1 ω=1,t =0.2, Sr =1,Sc=1

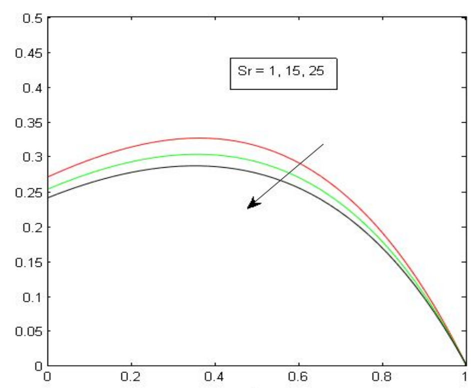

Figure2. Velocity u for variation in Sr when Re=1,N=1,Da=1,Gr=1,Gm=1,Cr=1,λ=1,h=1,Cr=1 ω=1,t =0.2,M=1,Sc=1

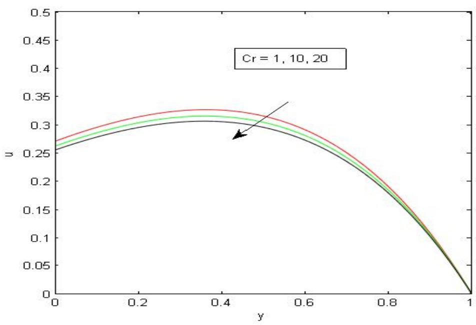

Figure3. Velocity u for variation in Cr when Re=1,N=1,Da=1,Gr=1,Gm=1,M=1,λ=1,h=1, ω=1,t =0.2,Sc=1,Sr =1

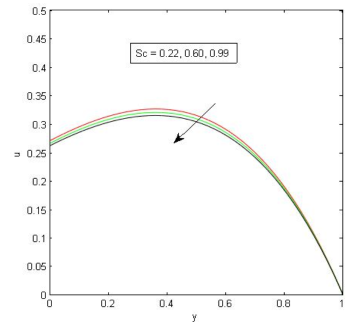

Figure4. Velocity u for variation in Sc when Re=1,N=1,Da=1,Gr=1,Gm=1,Cr=1,λ=1,h=1,Cr=1 ω=1,t =0.2 ,M=1, Sr =1

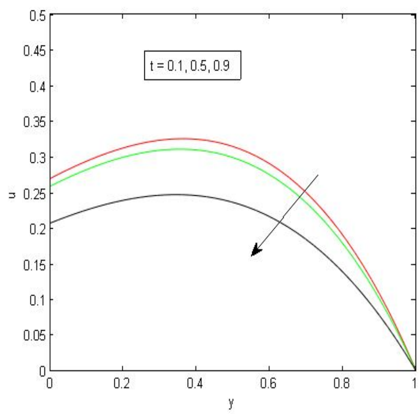

Figure5. Velocity u for variation in t when Re=1,N=1,Da=1,Gr=1,Gm=1,Cr=1,λ=1,h=1,Cr=1 ω=1, M=1, Sr =1, Sc=1

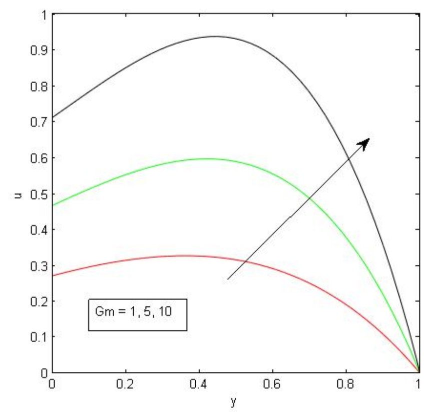

Figure6. Velocity u for variation in Gm when Re=1,N=1,Da=1,Gr=1,M=1,Cr=1,λ=1,h=1,Cr=1 , ω=1,t =0.2, Sr =1, Sc=1

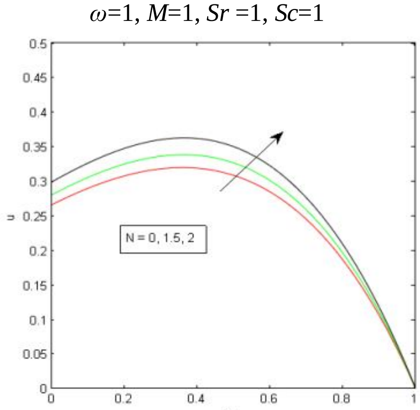

Figure7. Velocity u for variation in N when Re=1,N=1,Da=1,Gr=1,Gm=1,Cr=1,λ=1,h=1,Cr=1 ω=1,t =0.2

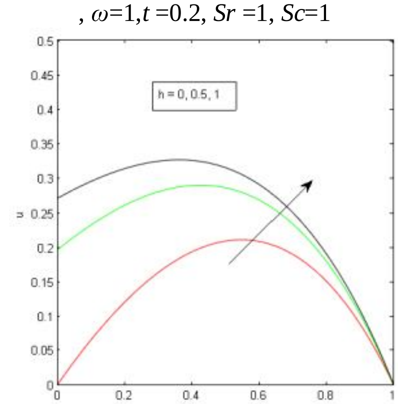

Figure8. Velocity u for variation in h when Re=1,N=1,Da=1,Gr=1,Gm=1,Cr=1,λ=1,ω=1, M=1, Sr =1, Sc=1, t =0.2

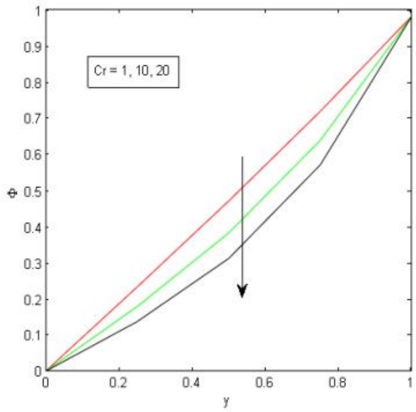

Figure9. Concentration φ for variation in *Cr* when *Re*=1,*N*=1,λ=1,ω=1, *M*=1, *Sr* =1, *Sc*=1, *t* =0.2

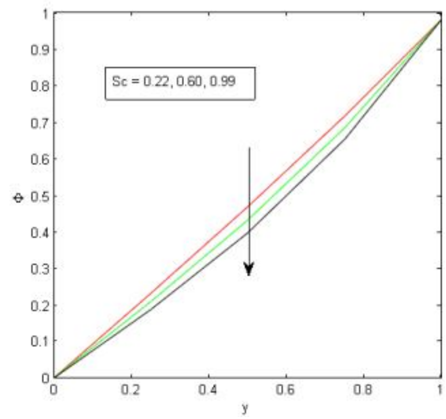

Figure10. Concentration φ for variation in *Sc* when *Re*=1,*N*=1,λ=1,ω=1, *M*=1, *Sr* =1, *Cr*=1, *t* =0.2

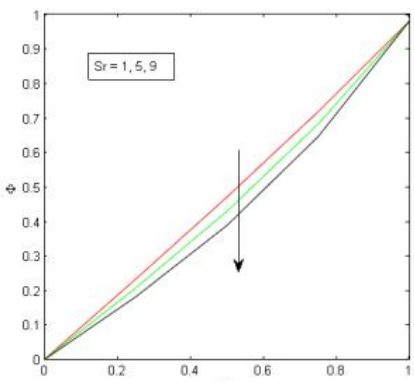

Figure11. Concentration φ for variation in *Sr* when *Re*=1,*N*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2

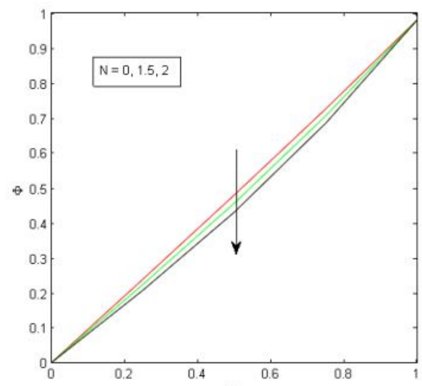

Figure12. Concentration φ for variation in *N* when *Re*=1,*Sr*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2

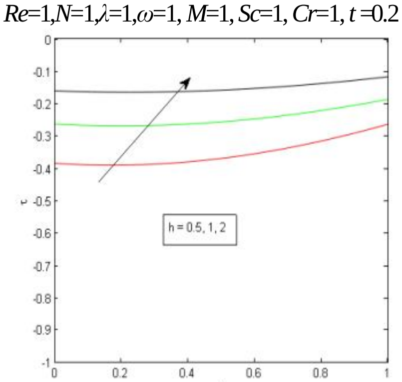

Figure13. Skin friction τ_0 for variation in *h* when *Re*=1,*Sr*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71, *Gm*=1, *N*=1

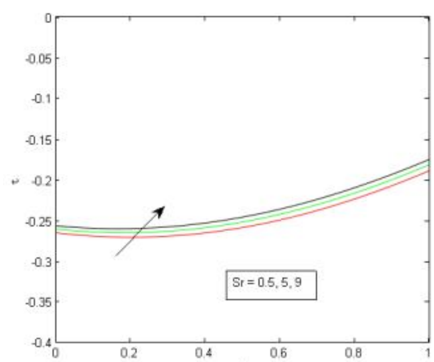

Figure14. Skin friction τ_0 for variation in *Sr* when *Re*=1,*h*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1,*t* =0.2,*Pe*=0.71, *Gm*=1, *N*=1

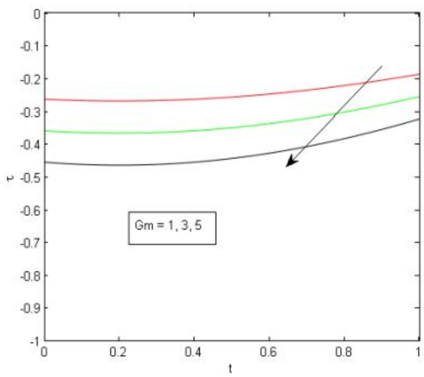

Figure15. Skin friction τ_0 for variation in *Gm* when *Re*=1,*h*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71,*Sr* =1,*N*=1

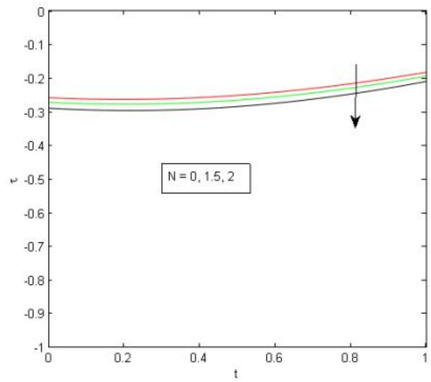

Figure16. Skin friction τ_0 for variation in *N* when *Re*=1,*h*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71,*Sr* =1,*Gm*=1

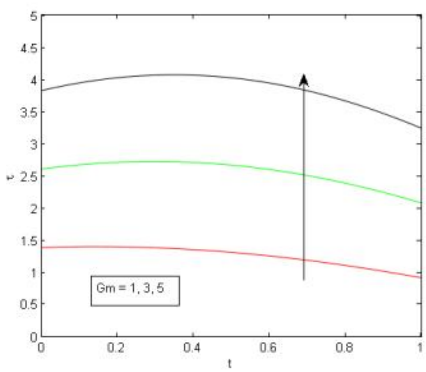

Figure17. Skin friction τ_1 for variation in *Gm* when *Re*=1,*h*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71,*Sr* =1,*N*=1

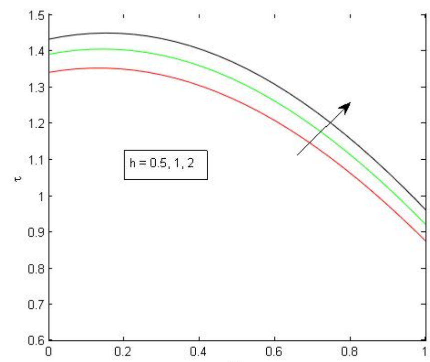

Figure18. Skin friction τ_1 for variation in *h* when *Re*=1,*Gm*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71,*Sr* =1,*N*=1

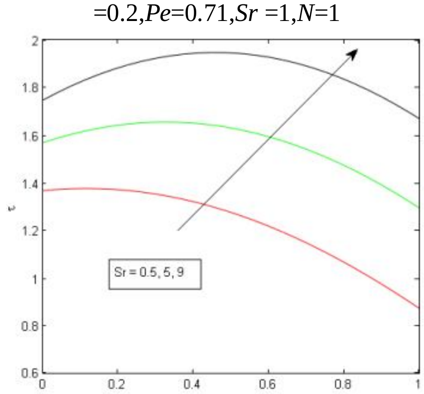

Figure19. Skin friction τ_1 for variation in *Sr* when *Re*=1,*Gm*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71,*h*=1,*N*=1

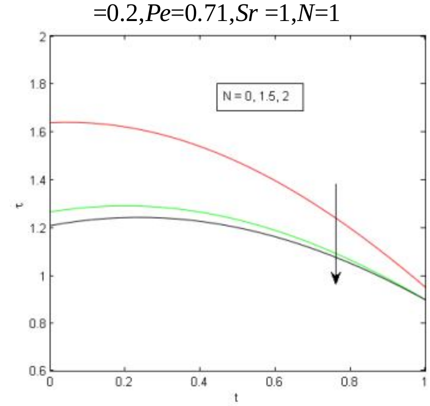

Figure20. Skin friction τ_1 for variation in *N* when *Re*=1,*Gm*=1,λ=1,ω=1, *M*=1, *Sc*=1, *Cr*=1, *t* =0.2,*Pe*=0.71,*h*=1,*Sr*=1

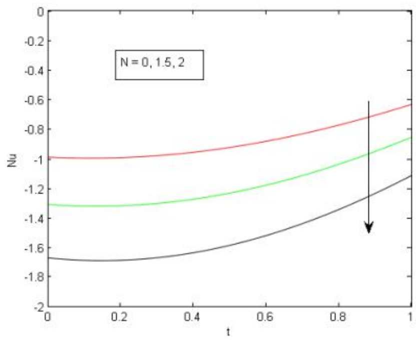

Figure21. Nusselt number Nu_0 for variation in N when Re=1,Gm=1,λ=1,ω=1, M=1, Sc=1, Cr=1, t =0.2,Pe=0.71,h=1,Sr=1

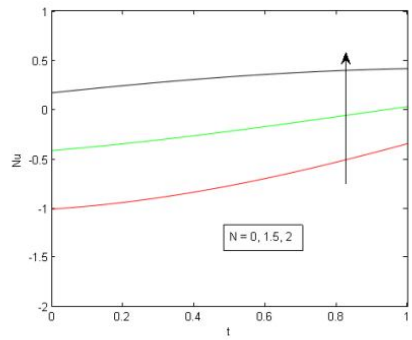

Figure22. Nusselt number Nu_1 for variation in N when Re=1,Gm=1,λ=1,ω=1, M=1, Sc=1, Cr=1, t =0.2,Pe=0.71,h=1,Sr=1

6. Conclusion

The following conclusions have been arrived under the investigation.

(i) The fluid velocity decreases for increasing Soret number (Sr)
(ii) The flow is accelerated with the increase in solutal Grashof number(Gm)
(iii) The concentration of the fluid decreases with increase in Cr, Sc, Sr and N .
(iv) The magnitude of the skin friction at the plate y=0 and y=1 increases with the increase in Soret number (Sr) .

7. Comparison

We have compared our present work for slip parameter h against velocity u when Sr=0 with the work of Ahmed and Sheikh [8] . It is found that both the graphs are almost identical. Hence our work is in agreement with Ahmed and Sheikh [8] .

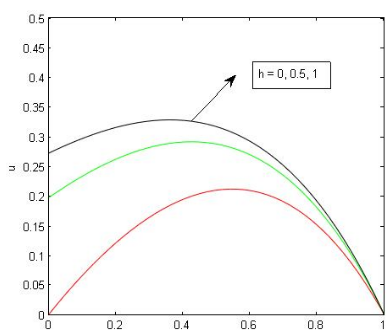

Figure23. Nusselt number Nu_1 for variation in N when Re=1,Gm=1,λ=1,ω=1, M=1, Sc=1, Cr=1, t=0.2,Pe=0.71,h=1,Sr=0

Nomenclature :

a	=	Distance between two walls.
B_0	=	Electromagnetic induction.
$\overline{C}$	=	Concentration
C_0	=	Concentration at y=0.
C_w	=	Concentration at y=1.
$\overline{Cr}$	=	Rate of first order homogeneous chemical reaction
Cr	=	Non-dimensional chemical reaction parameter.
C_p	=	Specific heat at constant pressure.
D	=	Mass diffusion coefficient.
Da	=	Darcy number .
g	=	Gravitional acceleration.
Gm	=	Solutal Grashof number.
Gr	=	Grashof number.
H_0	=	Intensity of magnetic field.
κ	=	*Thermal conductivity*
$\overline{K}$	=	Permeability of the medium
K	=	Permeability parameter.
M	=	Hartmann number.
N	=	Radiation parameter.
$\overline{p}$	=	Pressure
p	=	Non-dimensional pressure.
Pe	=	Peclet number.
q_r	=	Radiative heat flux.
Re	=	Reynolds number.
s	=	Porous medium shape factor.
Sc	=	Schimdt number.
$\overline{t}$	=	Time
t	=	Non-dimensional time.
$\overline{T}$	=	*Fluid temperature*
T	=	Dimensionless fluid temperature.
T_0	=	Temperature at y=0.
T_w	=	Temoerature at y=1.
$\overline{u}$	=	The axial velocity
u	=	Dimensionless axial velocity.
U	=	Reference velocity.
$(\overline{x}, \overline{y})$	=	Co-ordinate system
(x, y)	=	Non–dimensional co-ordinate system.

K_T = Thermal diffusion ratio.
T_M = Mean fluid temperature.
α = Mean radiation absorption coefficient.
β = Coefficient of volume expansion for heat transfer.
$\overline{\beta}$ = Coefficient of volume expansion
$\overline{h}$ = Slip parameter
h = Dimensionless slip parameter.
λ = Amplitude of the pressure gradient.
μ_e = magnetic permeability.
σ_e = Electrical conductivity.
ρ = Fluid density.
ω = Frequency parameter.
υ = Kinematic viscocity.
φ = Non-dimensional concentration.
θ = Non-dimensional temperature.

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