International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Heat and Mass Transfer in MHD Oscillatory Flow between Two Inclined Plates with Radiation Absorption and Chemical Reaction

Mamta Goyal[1], Kiran Kumari[2]

[1, 2]Department of Mathematics, University of Rajasthan, Jaipur-302004, India

Abstract: ***A study of free convection heat and mass transfer MHD oscillatory flow of visco-elastic fluid between two inclined plates in the presence of radiation absorption, chemical reaction and thermal radiation has been presented. Analytical solutions for velocity, temperature and concentration field are obtained by using perturbation technique and the effects of flow parameters on resulting non-dimensional velocity, temperature and concentration are analyzed graphically. Also the rate of heat transfer (Nusselt number) and rate of mass transfer (Sherwood number) are computed and presented in tabular form.***

Keywords: MHD, Chemical reaction, Radiation absorption, Thermal radiation, Heat source, Oscillatory flow

1. Introduction

The phenomenon of heat and mass transfer by MHD oscillatory flow of a visco-elastic fluid between two inclined plates has received great attention because of its wide applications in many engineering fields such as chemical process industries, food preservation, petroleum production, electro-static precipitation, polymer technology and power engineering. The MHD free convective heat and mass transfer flow past an inclined surface with heat generation have been analyzed by Alam and Rahman [1]. Chen [2] investigated the heat and mass transfer in MHD flow by natural convection from a permeable inclined surface with variable wall temperature and concentration. S Daniel and Daniel [3] discussed convective flow two immiscible fluids and heat transfer with along an inclined channel with pressure gradient. Ekambavannan et al. [4] studied finite difference analysis of unsteady natural convection along an inclined plate with variable surface temperature and mass diffusion. Ganesan and Palani [5] reported the results of a convective flow over an inclined plate with variable heat and mass flux. Hossain et al. [6] investigated free convection radiation interaction from an isothermal plate inclined at a small angle to the horizontal. Many researchers have studied the flows with chemical reaction and radiation absorption in different geometries and under various flow conditions. Ibrahim et al. [7] had presented the effect of chemical reaction and radiation absorption on the unsteady MHD free convection flow past semi infinite vertical permeable plate with heat source and suction. Kesavaiah et al. [8] had analyzed the effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a medium with heat source and suction. The use of non-Newtonian visco-elastic fluids has grown considerably because of more applications in chemical process industries, food preservation techniques, petroleum production and power engineering. In view of these applications, the study of boundary layer behavior has been channelized to visco-elastic fluids. Kumar [9] had introduced an analytical solution to the problem of radiative heat and mass transfer over an inclined plate at prescribed heat flux with chemical reaction. MHD flow and heat transfer in a visco-elastic fluid over a , flat surface with constant suction has been studied by A Kumar et al. [10]. Makinde et al. [11] have examined the heat transfer to MHD oscillatory flow in a channel filled with medium. Nandeppanavar et al. [12] examined the heat transfer in MHD visco-elastic boundary layer flow over a stretching sheet with thermal radiation and non-uniform heat source/sink. Effects of thermal diffusion and chemical reaction on MHD flow of dusty visco-elastic (Walter's liquid model-B) fluid have been studied by Prakash [13]. The study of heat and mass transfer with chemical reaction is of great practical importance to engineers and scientists because of its almost universal occurrence in many branches of science and engineering. Raju et al. [14] analyzed soret effects due to natural convection between heat inclined plates with magnetic field. Seddeek et al. [15] investigated Effects of chemical reaction and variable viscosity on hydromagnetic mixed convection heat and mass transfer for Hiemenz flow through media with radiation. Saritha at el. [16] analyzed thermal diffusion and chemical reaction effects on unsteady MHD free convection flow past a semi infinite vertical permeable moving plate.

In the present study we have investigated the effects of radiation absorption, heat absorption/ generation and chemical reaction on unsteady heat and mass MHD oscillatory flow of a visco-elastic fluid between two inclined plates. The equations of continuity, linear momentum, energy and diffusion, which govern the flow field, are solved by using a regular perturbation method. Numerical results and discussion are presented graphically and in tabular form. The behavior of velocity, temperature, concentration, Nusselt number and Sherwood number has been discussed for variations in the flow parameters.

2. Mathematical Formulation of the Problem

The unsteady, two-dimensional, MHD oscillatory flow of visco-elastic (rheological liquids) and incompressible viscous fluid through a channel and subjected to a transverse magnetic field in the presence of thermal radiation, chemical reaction, radiation absorption and concentration buoyancy effects. Let x-axis be along the lower plate and straight line perpendicular to that as the y-axis. The present visco-elastic fluid model introduces additional terms into the momentum equation. The transversely applied magnetic field and magnetic Reynolds number are assumed to be very small so that the induced magnetic field and the Hall effects are negligible. Under the above assumption with usual Boussinesq's approximation, the conservation equation of momentum, energy and diffusion that govern the flow field are

$$\frac{\partial u^*}{\partial t^*}=-\frac{1}{\rho}\frac{\partial P^*}{\partial x^*}+\upsilon_1\frac{\partial^2 u^*}{\partial y^{*2}}+\upsilon_2\frac{\partial^3 u^*}{\partial y^{*2}\partial t^*}-\frac{\upsilon_1}{K^*}u^*-\frac{\sigma_e B_0^2}{\rho}u^* + g\beta_T\left(T^*-T_0^*\right)\sin\phi+g\beta_c\left(C^*-C_0^*\right)\sin\phi \quad (1)$$

$$\rho c_p\frac{\partial T^*}{\partial t^*}=k\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{\partial q}{\partial y^*}-Q(T^*-T_0^*)+Q_c(C^*-C_0^*) \quad (2)$$

$$\frac{\partial C^*}{\partial t^*}=D\frac{\partial^2 C^*}{\partial y^{*2}}-K_r(C^*-C^*{}_0) \quad (3)$$

The boundary conditions of the problem are

$$u^*=0, T^*=T_w^*, C^*=C_w^* \quad at \quad y^*=1$$
$$u^*=0, T^*=T_0^*, C^*=C_0^* \quad at \quad y^*=0 \quad (4)$$

Following ref [11], it is assumed that the fluid is optically thin with a relativity low density radiative heat flux is given by

$$\frac{\partial q}{\partial y^*}=4\alpha^2(T_0^*-T^*) \quad (5)$$

where α is the mean radiation absorption coefficient.

Introducing the non-dimensional quantities,

$$x=\frac{x^*}{a},\ y=\frac{y^*}{a},\ u=\frac{u^*}{U},\ t=\frac{t^*U}{a},\ \mathrm{Re}=\frac{Ua}{\upsilon_1},\ \theta=\frac{T^*-T_0^*}{T_w^*-T_0^*},$$
$$C=\frac{C^*-C_0^*}{C_w-C_0^*},\ Gc=\frac{g\beta_c(C_w^*-C_0^*)a^2}{\upsilon_1 U},\ Gr=\frac{g\beta_T(T_w^*-T_0^*)a^2}{\upsilon_1 U},$$
$$P=\frac{aP^*}{\rho\upsilon_1 U},\ Da=\frac{K^*}{a^2},\ H^2=\frac{a^2\sigma_e B_0^2}{\rho\upsilon_1},\ Q_1=\frac{a^2 Q_c(C_w^*-C_0^*)}{k(T_w^*-T_0^*)},$$
$$Pe=\frac{Ua\rho c_p}{k}, R^2=\frac{4\alpha^2 a^2}{k}, Sc=\frac{D}{aU}, S^2=\frac{1}{Da}, E=\frac{Qa^2}{k}, J=\frac{K_r a}{U} \quad (6)$$

In view of the above non-dimensional variables, the system of the equations (1) - (3) reduce to the following dimension - less form

$$\mathrm{Re}\frac{\partial u}{\partial t}=-\frac{\partial P}{\partial x}+\frac{\partial^2 u}{\partial y^2}+\gamma\frac{\partial^3 u}{\partial y^2\partial t}-(s^2+H^2)u+Gr_1\theta+Gc_1 C \quad (7)$$

$$Pe\frac{\partial\theta}{\partial t}=\frac{\partial^2\theta}{\partial y^2}+(R^2-E)\theta+Q_1 C \quad (8)$$

$$\frac{\partial C}{\partial t}=Sc\frac{\partial^2 C}{\partial y^2}-JC \quad (9)$$

where $Gr_1=Gr\sin\phi$ and $Gc_1=Gc\sin\phi$

The corresponding boundary conditions in non-dimensional form are

$$u=0,\ \theta=1,\ C=1 \quad at \quad y=1$$
$$u=0,\ \theta=0,\ C=0 \quad at \quad y=0 \quad (10)$$

3. Solution of the problem

In order to solve equations (7) - (10) for purely oscillatory flow, let

$$-\frac{\partial P}{\partial x}=\lambda e^{i\omega t},\ u(y,t)=u_0(y)e^{i\omega t},\ \theta(y,t)=\theta_0(y)e^{i\omega t},\ C(y,t)=C_0(y)e^{i\omega t} \quad (11)$$

Substituting in equation (11) into equations (7) - (10), we obtain,

$$(1+i\gamma\omega)\frac{d^2u_0}{dy^2}-M_2^2u_0=-\lambda-Gr_1\theta_0-Gc_1C_0 \quad (12)$$

$$\frac{d^2\theta_0}{dy^2}+M_1^2\theta_0+Q_1C_0=0 \quad (13)$$

$$\frac{d^2C_0}{dy^2}-M_3^2C_0=0 \quad (14)$$

The corresponding boundary conditions are

$$u_0=0,\ \theta_0=1,\ C_0=1 \quad at \quad y=1$$
$$u_0=0,\ \theta_0=0,\ C_0=0 \quad at \quad y=0 \quad (15)$$

Solving equations (12) to (14) under the boundary condition (15), we get the solution of velocity, temperature and concentration distributions as follows

$$u(y,t)=\left[\begin{array}{c} Gr_1\left\{\begin{array}{l}\left(\dfrac{1+k_1}{M_1^2L^2+M_2^2}\right)\dfrac{\sin M_1 y}{\sin M_1}+\left(\dfrac{k_1}{M_3^2L^2-M_2^2}\right)\dfrac{\sinh M_3 y}{\sinh M_3}\\ -\left(\dfrac{1+k_1}{M_1^2L^2+M_2^2}+\dfrac{k_1}{M_3^2L^2-M_2^2}\right)\left(\dfrac{\sinh \frac{M_2}{L}y}{\sinh \frac{M_2}{L}}\right)\end{array}\right\}+\dfrac{Gc_1}{L^2M_3^2-M_2^2}\\ \left(\dfrac{\sinh\frac{M_2}{L}y}{\sinh\frac{M_2}{L}}-\dfrac{\sinh M_3 y}{\sinh M_3}\right)+\dfrac{\lambda}{M_2^2}\left(1-\cosh\dfrac{M_2}{L}y\right)\left(1-\dfrac{\sinh\frac{M_2}{L}y}{\sinh\frac{M_2}{L}}\right)\end{array}\right]e^{i\omega t}$$

$$\theta(y,t)=\left[\left(1+\frac{Q_1}{M_1^2+M_3^2}\right)\frac{\sin M_1 y}{\sin M_1}-\left(\frac{Q_1}{M_1^2+M_3^2}\right)\frac{\sinh M_3 y}{\sinh M_3}\right]e^{i\omega t}$$

$$C(y,t)=\left(\frac{\sinh M_3 y}{\sinh M_3}\right)e^{i\omega t}$$

The rate of heat transfer coefficient at both walls of the channel can be obtained, which in the terms of the Nusselt number, is given by

$$Nu_1=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0}\Rightarrow Nu_1=-\left[\begin{array}{l}\left(1+\dfrac{Q_1}{M_1^2+M_3^2}\right)\dfrac{M_1}{\sin M_1}-\\ \left(\dfrac{Q_1}{M_1^2+M_3^2}\right)\dfrac{M_3}{\sinh M_3}\end{array}\right]e^{i\omega t}$$

$$Nu_2=-\left(\frac{\partial\theta}{\partial y}\right)_{y=1}\Rightarrow Nu_2=-\left[\begin{array}{l}\left(1+\dfrac{Q_1}{M_1^2+M_3^2}\right)\dfrac{M_1\cos M_1}{\sin M_1}-\\ \left(\dfrac{Q_1}{M_1^2+M_3^2}\right)\dfrac{M_3\cosh M_3}{\sinh M_3}\end{array}\right]e^{i\omega t}$$

The rate of mass transfer coefficient at both walls of the channel can be obtained, which in the terms of the Sherwood number, is given by

$$Sh_1=-\left(\frac{\partial C}{\partial y}\right)_{y=0}\Rightarrow Sh_1=-\left(\frac{M_3}{\sinh M_3}\right)e^{i\omega t}$$

$$Sh_2=-\left(\frac{\partial C}{\partial y}\right)_{y=1}\Rightarrow Sh_2=-\left(\frac{M_3\cosh M_3}{\sinh M_3}\right)e^{i\omega t}$$

4. Results and Discussions

The solutions of the present problem are discussed graphically considering fixed values of different parameters: $R=1, E=2, Pe=0.71, J=2, Sc=0.60, Q_1=2, Gr=4, Gc=4,$ $S=1, H=1, Pe=0.71,\ t=0.1,\ \omega=0.1,\ \lambda=0.1, \gamma=0.1,$ $\phi=\pi/4, \mathrm{Re}=1$ for velocity profile and $Q_1=1, t=0.1,$ $R=1, E=1, Pe=0.71, J=2, Sc=0.60,\ \omega=0.1, \lambda=0.1$ for temperature distribution. Figs. 1-5 exhibit the variation of the velocity profile $u(y,t)$ with y under the influence of Grashof number Gr, Solutal Grashof number Gc, angle of inclination ϕ, radiation absorption parameter Q_1, heat source parameter E. Figs. 1-2 depict that the fluid velocity increase with increases the Grashof number and Solutal Grashof number. It is due to reason that increases in Gr give rise to buoyancy effects resulting in more induced flows. Fig. 3 shows the effects of angle of inclination ϕ on the velocity. The velocity increases as the ϕ increase because the magnitude of the buoyancy force increases with increase in the inclination angle. Figs. 4 and 10 illustrate the influence of the radiation absorption parameter Q_1 on the velocity and temperature profiles. As Q_1 increases, velocity and temperature distributions increase. This is physically true since an increase in radiation absorption leads to heat accumulation which increases the thermal boundary layer and temperature of the fluid. Fig. 5 demonstrates the effect of heat source parameter E against on the velocity. The velocity profile decreases with increasing heat source parameter. This is due to the fact that when heat is absorbed the buoyancy force decreases which retards the flow rate and by giving rise to decrease in the velocity profile. Fig. 6 elucidates that the velocity profiles notably decrease for the higher values of thermal radiation parameter because the increase of the radiation parameter R leads to decrease the boundary layer thickness and to enhance the heat transfer rate in the presence of thermal and solutal buoyancy force. Fig. 7 indicates that the fluid velocity decreases with the increase in Hartmann number H because the increasing value of Hartmann number tends to the increasing of Lorentz force, which produces more resistance to the transport phenomena. The influence of chemical reaction parameter on velocity profile across the boundary layer is presented in Fig. 8. It is found that the velocity profile decreases with increasing values of chemical reaction parameter J. The increase of the chemical reaction parameter leads to decrease the boundary layer thickness and to enhance the heat transfer rate in the presence of thermal and solutal buoyancy force. It is also observed that the peak value attains near the boundary surface. Figs. 9 and 11 reveal the temperature profile for increasing value of thermal radiation parameter R and heat source parameter E. It is seen from Fig. 9 that the fluid temperature increases with the increasing value of radiation parameter. Fig.11 illustrates that the temperature decrease with increases E because when heat is absorbed, the buoyancy force decreases the temperature profile. Fig. 12 indicates that there is marked effect of increasing the value of J on concentration distribution in the boundary layer. Further, it is observed that increasing value of the chemical reaction parameter decrease the concentration of species in the boundary layer, this is due to the fact that destructive chemical reduces the solutal boundary layer thickness and increases the mass transfer. Fig. 13 shows the concentration profiles C across the boundary layer for various values of Schmidt number Sc. The figure shows that an increasing in results in an increasing the concentration distribution C. Fig. 14 presents the velocity increases with increases Schmidt number. This causes the velocity buoyancy effects to decreases yielding a reduction in the fluid velocity.

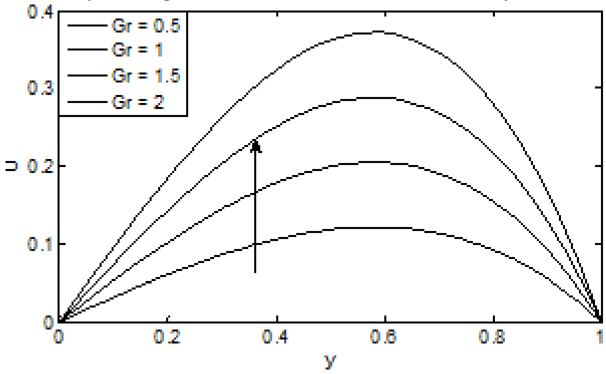

Figure 1: Variation of velocity with Gr

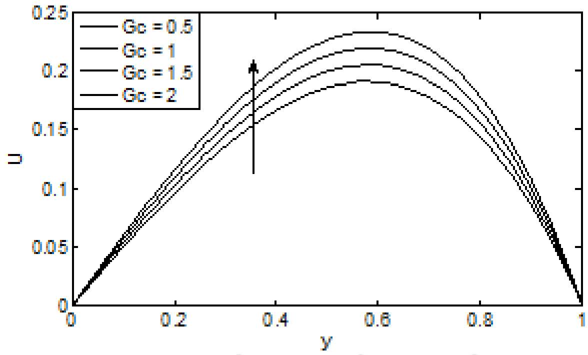

Figure 2: Variation of velocity with Gc

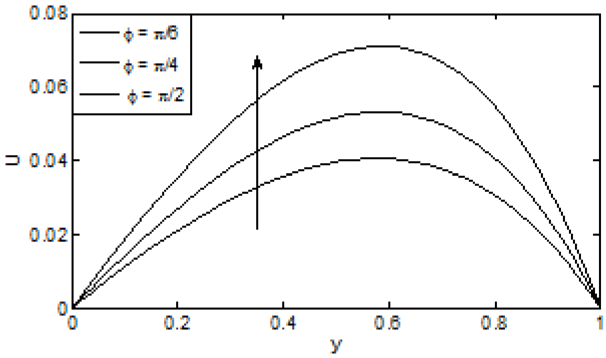

Figure 3: Variation of velocity with ϕ

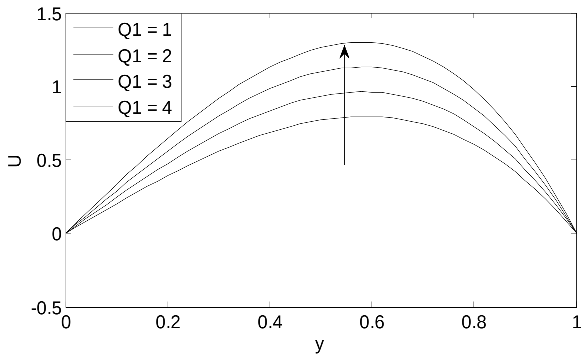

Figure 4: Variation of velocity with Q_1

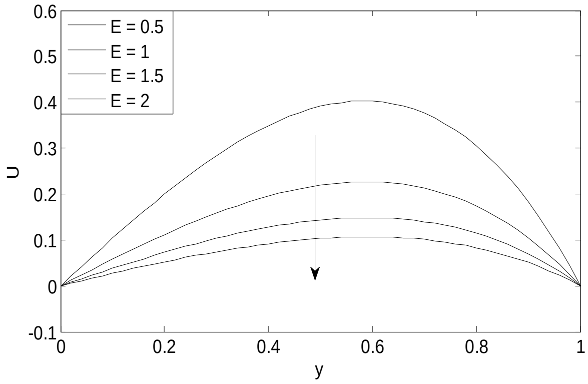

Figure 5: Variation of velocity with E

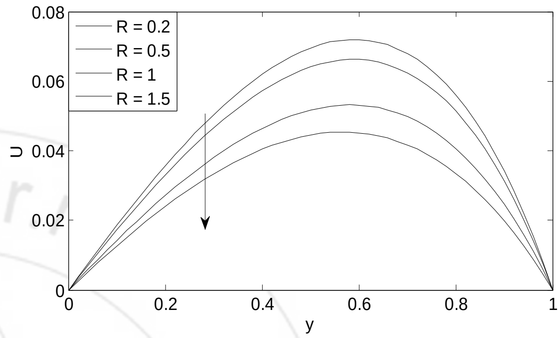

Figure 6: Variation of velocity with R

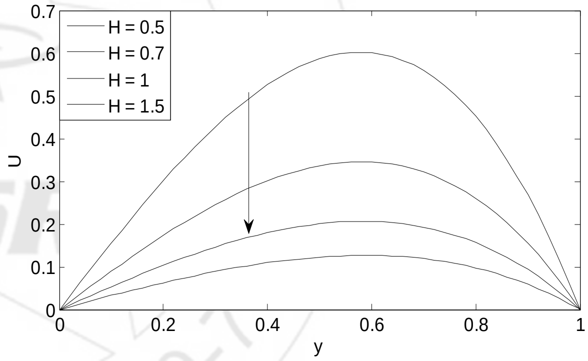

Figure 7: Variation of velocity with H

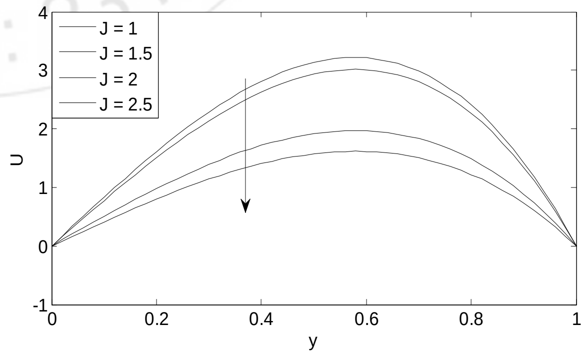

Figure 8: Variation of velocity with J

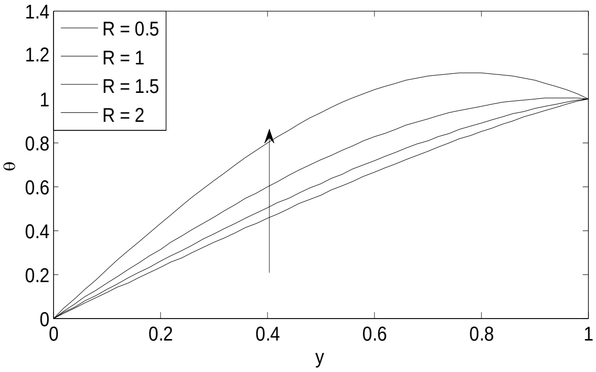

Figure 9: Variation of temperature with R

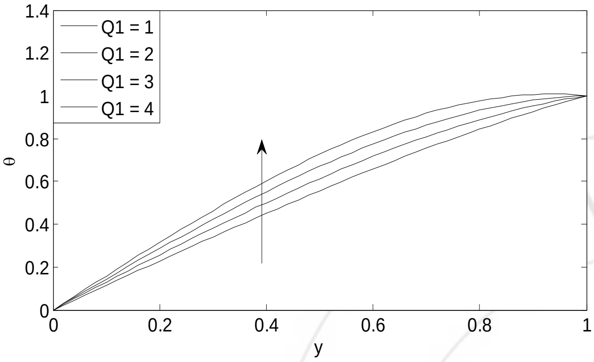

Figure 10: Variation of temperature with Q_1

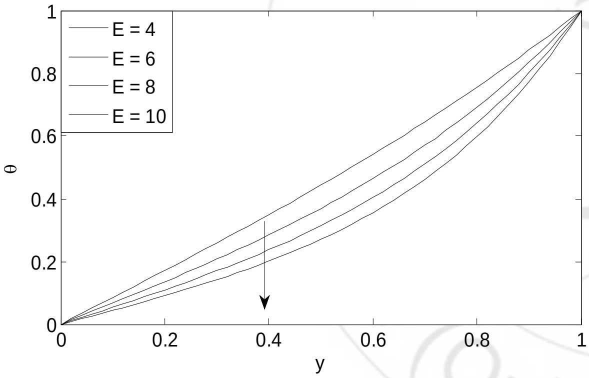

Figure 11: Variation of temperature with E

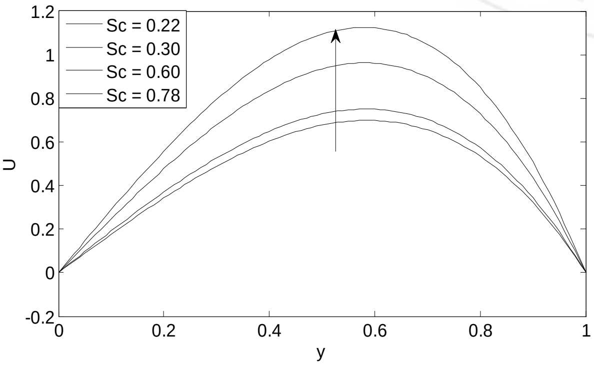

Figure 14: Variation of velocity with Sc

The numerical values of Nu_1, Nu_2, Sh_1 and Sh_2 are evaluated and these are listed in Table 1-2. From the Table 1, it is observed that the Nusselt number Nu_1 (lower plate at $y = 0$) increases with increasing radiation parameter R, heat source parameter E and radiation absorption parameter Q_1 but decreases with decreasing and increasing the value of the Schmidt number Sc and chemical reaction parameter J. Further, the Nusselt number Nu_2 (upper plate at $y = 1$) decreases with increasing R and Q_1 but increases with increasing E, J and decreasing Sc respectively. Now from the Table 2, it is shows that the Sherwood number Sh_1 and Sh_2 decreases and increases with increasing J and decreasing Sc respectively.

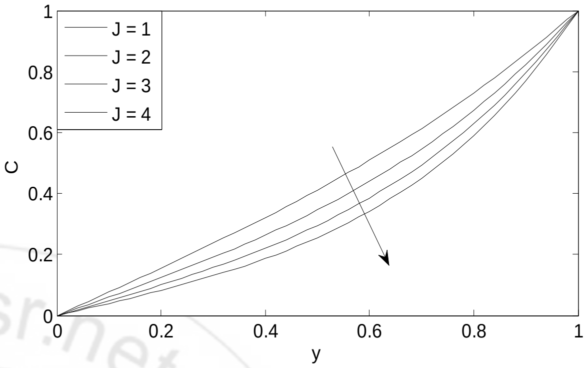

Figure 12: Variation of concentration with J

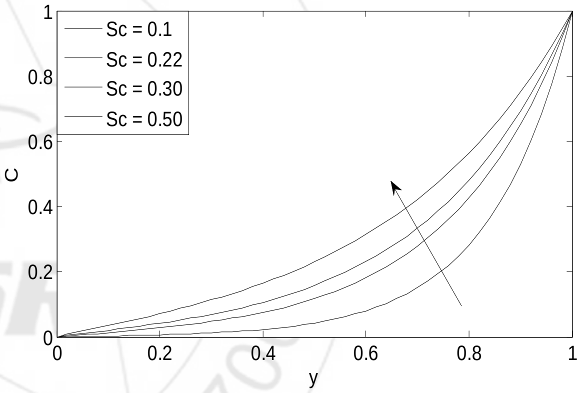

Figure 13: Variation of concentration with Sc

Table 1: Nusselt number Nu_1 and Nu_2 with different parameters at $Pe = 0.71, t = 0.1, \omega = 0.1, \lambda = 0.1, \gamma = 0.1$

R	E	Q_1	Sc	J	Nu_1	Nu_2
1	1	2	0.60	2	1.2376	0.4474
2	1	2	0.6	2	2.1181	0.9788
3	1	2	0.6	2	10.6868	10.6082
1	1.5	2	0.6	2	1.1452	0.6245
1	2	2	0.60	2	0.9882	0.9474
1	1	3	0.60	2	1.2572	0.3565
1	1	4	0.60	2	1.3692	0.0931
1	1	2	0.30	2	1.0926	0.6919
1	1	2	0.22	2	1.0666	0.7273
1	1	2	0.60	3	1.1158	0.6615
1	1	2	0.60	4	1.0927	0.6917

Table 2: Sherwood number Sh_1 and Sh_2 with different parameters at $t = 0.1, \omega = 0.1, \lambda = 0.1,$

J	Sc	Sh_1	Sh_2
2	0.60	0.6039	1.9237
3	0.60	0.4835	2.2882
3.5	0.60	0.4350	2.4545
2	0.30	0.3927	2.6130
2	0.22	0.2963	3.0314

5. Conclusion

In this paper the effects of radiation absorption, chemical reaction, heat and mass transfer on MHD free convection visco-elastic oscillatory fluid flow between two plates is analyzed.

The main conclusions of the present analysis are as follows:
- The velocity profiles enhance for increasing the value of Grashof number, Solutal Grashof number, angle of inclination and radiation absorption parameter but they decrease for increasing the value of heat source parameter, radiation parameter, Hartmann number and chemical reaction parameter.
- An increase in Schmidt number increases the velocity and concentration profiles.
- With the increasing effect of radiation parameter and radiation absorption parameter the temperature variation are increasing.
- An increasing value of heat source parameter leads to decrease in temperature distribution.
- For the increase of the chemical reaction parameter concentration profiles decreases.
- An increasing value of radiation parameter, heat source parameter and radiation absorption parameter increases Nusselt number Nu_1 while decreasing Schmidt number and increasing chemical reaction parameter decreases it.
- The Nusselt number Nu_2 decreases with increasing radiation parameter and radiation absorption parameter but increases with increasing heat source parameter, chemical reaction parameter and decreasing Schmidt number respectively.
- The Sherwood number Sh_1 decreases and Sh_2 increases with increasing chemical reaction parameter and decreasing Schmidt number.

Nomenclature

x^* dimensional coordinate along the channel
y^* dimensional coordinate perpendicular to the channel
U flow mean velocity
u^* axial velocity
T^* fluid temperature
C^* dimensional concentration of the fluid
g gravitational force
Re Reynolds number
P_e Peclet number
Sc Schmidt number
Gr Grashof number
Gc Solutal Grashof number
C_p specific heat at constant pressure
Q dimensional heat absorption coefficient
Q_c dimensional radiation absorption coefficient
B_0 Electromagnetic induction
P^* pressure
k Thermal conductivity
K^* permeability of the medium
q radiative heat flux
Nu Nusselt number
Sh Sherwood number
E Heat source parameter
R Radiation parameter
H Hartmann number
Q_1 radiation absorption parameter
J chemical reaction parameter
S medium shape factor
T_0, T_w walls of temperature

Greek Symbols
ρ fluid density
β_T thermal expansion coefficient
β_c concentration expansion coefficient
τ Skin friction
μ_e Magnetic permeability
θ Fluid temperature
υ Kinematics viscosity coefficient
λ Wave length
ω Frequency of the oscillation
σ_e Conductivity of the fluid

Appendix
$$L^2 = 1 + i\gamma\omega,$$
$$k_1 = \frac{Q_1}{M_1^2 + M_3^2},$$
$$M_1^2 = R^2 - E - i\omega Pe,$$
$$M_2^2 = S^2 + H^2 + i\omega \mathrm{Re},$$
$$M_3^2 = \frac{J + i\omega}{Sc},$$

References

[1] M. S. Alam and M. M. Rahman, "MHD Free Convective Heat and Mass Transfer Flow past an Inclined Surface with Heat Generation," Thammasat

International Journal of Science and Technology, 11 (4), pp. 1-8, 2006.

[2] C. H. Chen, "Heat and mass transfer in MHD flow by natural convection from a permeable inclined surface with variable wall temperature and concentration," Acta Mechanica, 172, pp. 219-235, 2004.

[3] S. Daniel and Y. S. Daniel, "Convective flow two immiscible fluids and heat transfer with along an inclined channel with pressure gradient," International Journal of Engineering and Science, 2, pp. 12-18, 2013.

[4] K. Ekambavannan and P. Ganesa, "Finite difference analysis of unsteady natural convection along an inclined plate with variable surface temperature and mass diffusion," Wearme Stoffubertrag, 31, pp. 17-24, 1995.

[5] P. Ganesan and G. Palan, "Convective flow over an inclined plate with variable heat and mass flux," Proceedings of the Fourth ISHMT/ASME Heat and Mass transfer Conference, pp. 323–329, 2000.

[6] M. A. Hossain, D. A. C Rees and I. Pop, "Free convection radiation interaction from an isothermal plate inclined at a small angle to the horizontal," Acta Mechanica, 127, pp. 63–73, 1998.

[7] F. S. Ibrahim, A. M. Elaiw and A. A. Bakr, "Effect of chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi infinite vertical permeable moving plate with heat source and suction," Communication in Nonlinear Science and Numerical Simulation, 13, pp. 1056-1066, 2008.

[8] D. C. Kesavaiah, P. V. Satyanarayana and S. Venkataramana, "Effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a medium with heat source and suction," International Journal of Applied Mathematics and Mechanics, 7, pp. 52-69, 2011.

[9] H. Kumar, "An analytical solution to the problem of radiative heat and mass transfer over an inclined plate at prescribed heat flux with chemical reaction," Journal of the Serbian Chemical Society, 77, pp. 1-14, 2012.

[10] A. Kumar, P. Ram and H. Singh, "MHD flow and heat transfer in a visco-elastic fluid over a , flat surface with constant suction," Journal of Computer and Mathematical Sciences; 1, pp. 552-565, 2010.

[11] O. D. Makinde and P. Y. Mhone, "Heat transfer to MHD oscillatory flow in a channel filled with medium," Romanian Journal of Physics," 50, pp. 931-938, 2005.

[12] M. M. Nandeppanavar, K. Vajravelu and M. S. Abel, "Heat transfer in MHD visco-elastic boundary layer flow over a stretching sheet with thermal radiation and non-uniform heat source/sink," Communication in Nonlinear Science and Numerical Simulation, 16, pp. 3578–90, 2011.

[13] O. Prakash, D. Kumar and Y. K. Dwivedi, "Effects of thermal diffusion and chemical reaction on MHD flow of dusty visco-elastic (Walter's liquid model-B) fluid," Journal of Electromagnetic Analysis and Application, 2, pp. 581–7, 2010.

[14] M. C. Raju, S. V. K Varma, P. V. Reddy and S. Suman, "Soret effects due to natural convection between heat inclined plates with Magnetic field," Journal of Mechanical Engineering, 39, pp. 43-48, 2008.

[15] M. A. Seddeek, A. A. Darwish and M. S. Abdelmeguid, "Effects of chemical reaction and variable viscosity on hydromagnetic mixed convection heat and mass transfer for Hiemenz flow through media with radiation," Communication in Nonlinear Science Numerical Simulation, 12, pp. 195–213, 2007.

[16] S. S. Saritha and P. V. Satya Narayana, "Thermal diffusion and chemical reaction effects on unsteady MHD free convection flow past a semi infinite vertical permeable moving plate," Asian Journal of Current Engineering and Maths, 1, pp. 131-138, 2012.

Author Profile

Mamta Goyal is currently working as Associate Professor, Department of Mathematics, University of Rajasthan, Jaipur. Her fields of research are Fluid Dynamics, Boundary Layer, MHD, Heat and Mass Transfer, Channels. She has published many research papers in national and international journals.

Kiran Kumari working as an Research Scholar, Department of Mathematics, University Rajasthan, Jaipur. She is pursuing research work under the supervision of Mamta Goyal. Her area of research is Fluid Dynamics, MHD, Heat Transfer, Mass transfer and Channels.