Journal of Applied Fluid Mechanics, Vol. 8, No. 3, pp. 529- 537, 2015.
Available online at www.jafmonline.net, ISSN 1735-3572, EISSN 1735-3645.
DOI: 10.18869/acadpub.jafm.67.222.19344

Radiation and Mass Transfer Effects on MHD Oscillatory Flow in a Channel Filled with Porous Medium in the Presence of Chemical Reaction

S. Mohammed Ibrahim[1†], K. Gangadhar[2] and N. Bhaskar Reddy[3]

[1] *Dept. of Mathematics, Priyadarshini College of Engineering and Technology, Nellore – 524004, AndhraPradesh.*
[2] *ANU Ongole Campus, Ongole -523001, Prakasam district, AndraPradesh., India.*
[3] *S V University, Tirupati - 517501 Chittoor district, AndraPradesh., India.*

†*Corresponding Author Email: ibrahimsvu@gmail.com*

(Received July 16, 2011; accepted July 07, 2014)

ABSTRACT

The interaction of radiation and mass transfer in an electrically conducting fluid through a channel filled with porous medium has received little attention. Hence, an attempt is made to investigate the combined effects of a transverse magnetic field and radiation on an unsteady mass transfer flow with chemical reaction through a channel filled with saturated porous medium and non-uniform wall temperature. The equations of continuity, linear momentum, energy and diffusion, which govern the flow field, are solved by using an analytical method. The behaviour of the velocity, temperature, concentration, skin-friction, Nusselt number and Sherwood number has been discussed for variations in the governing parameters.

Keywords: Heat and mass transfer; Radiation; MHD; Porous medium; Chemical reaction

NOMENCLATURE

B_0 magnetic flux density
C dimensionless concentration
C_f skin friction coefficient
C_p specific heat at constant pressure
D mass diffusion coefficient
Da Darcy number
Gc solutal Grashof number
Gr Grashof number
g acceleration due to gravity
H Hartmann number
Kr chemical reaction parameter
k thermal conductivity
N Radiation parameter
Nu Nusselt number
n scalar constant
Pe Peclet number
p pressure
Q heat generation parameter
R Radiation parameter
Re_x local Reynolds number
Sc Schmidt number
Sh Sherwood number
s porous medium shape factor parameter

T temperature
t time
$u.v$ components of velocities along and perpendicular to the plate
U_p plate moving velocity
U_∞ scale of free stream velocity
V_o scale of suction velocity
x,y distances of along and perpendicular to the plate

α fluid thermal diffusivity.
β_c coefficient of volumetric concentration expansion of the working fluid
β_f coefficient of volumetric thermal expansion of the working fluid
ε scalar constant (<<1)
θ dimensionless temperature
μ fluid dynamic viscosity
ρ fluid density
λ constant
σ electrical conductivity.
υ fluid kinematic viscosity
τ friction coefficient

ω frequency of the oscillation

Subscripts

w wall condition

∞ free stream condition

Superscripts

( ) differentiation with respect to *y*

* dimensional properties

1. INTRODUCTION

The study of convective heat and mass transfer from a solid body with different geometries embedded in a fluid saturated porous medium has varied and wide applications in many areas of science and engineering such as geothermal reservoirs, drying of porous solids, chemical catalytic reactors, thermal insulators, nuclear waste repositories, heat exchanger devices, enhanced oil and gas recovery, underground energy transport etc. Ingham and Pop (1998) and Nield and Bejan (1998) presented a comprehensive account of the convective heat transfer and fluid flow through porous media. Bejan and Khair (1985) treated one of the most fundamental cases, namely buoyancy-induced heat and mass transfer from a vertical plate embedded in a saturated porous medium. Lai and Kulacki (1991) investigated coupled heat and mass transfer by mixed convection from an isothermal vertical plate in a porous medium. Yih (1997) analyzed the effect of transpiration on coupled heat and mass transfer in mixed convection over a vertical plate embedded in a saturated porous medium. Singh and Mathew (2012) proposed an oscillatory free convective flow through a porous medium in a rotating vertical porous channel.

There has been a renewed interest in studying magneto hydrodynamic (MHD) flow and heat transfer in porous and non–porous media due to the effect of magnetic fields on the boundary layer flow control and on the performance of many systems using electrically conducting fluids. In addition, this type of flow has attracted the interest of many investigators, in the view of its applications in many engineering problems such as MHD generators, plasma studies, nuclear reactors, and geothermal energy extractions. Engineers are continuously taking the task to improve the efficiency of the MHD energy systems (Aluwalia and Doss (1980). Raptis *et al.*(1982) analyzed hydromagnetic free convection flow through a porous medium between two parallel plates. Aldoss *et al. (*1995) studied mixed convection flow from a vertical plate embedded in a porous medium in the presence of a magnetic field. Chamkha (2000) considered MHD free convection flow from a vertical plate embedded in a thermally stratified porous medium with Hall effects. Kim (2000) presented an analysis of an unsteady MHD convection flow past a vertical moving plate embedded in a porous medium in the presence of transverse magnetic field. Kumar and Prasad (2014) analyzed the solution for MHD pulsatile flow driven by an unsteady pressure gradient between permeable beds of viscous incompressible Newtonian fluid saturated porous medium.

The role of thermal radiation on the flow and heat transfer process is of major importance in the design of many advanced energy conversion systems operating at higher temperatures. Thermal radiation within these systems is usually the result of emission by hot walls and the working fluid. Bakier and Gorla (1996) studied thermal radiation effect on mixed convection from horizontal surfaces in porous media. Bakier (2001) reported the effect of radiation on mixed convection flow on an isothermal vertical surface in a saturated porous medium and has obtained self-similar solution. Hossain and Takhar (1996) analyzed the effect of radiation on mixed convection along a vertical plate with uniform surface temperature. Kim *etal* (2003) studied transient mixed radiative convection flow of a micro polar fluid past a moving, semi-infinite vertical porous plate. Makinde and Mhone (2005) studied radiation effect on MHD oscillatory flow in a channel filled with porous medium. Chauhan *et al*. (2010) investigated the radiation effects on MHD flow in a rotating vertical porous channel in presence of porous medium. Srinivas and Muthuraj (2010) proposed the effects of radiation and space porosity on MHD convection flow through a vertical channel.

Combined heat and mass transfer problems with chemical reaction are of importance in many processes and have, therefore, received a considerable amount of attention in recent years. In processes such as drying, evaporation at the surface of a water body, energy transfer in a wet cooling tower and the flow in a desert cooler, heat and mass transfer occur simultaneously. Dekha *et al*. (1994) investigated the effect of the first order homogeneous chemical reaction on the process of an unsteady flow past a vertical plate with constant heat and mass transfer. Muthucumaraswamy and Ganesan (2001) studied the effect of the chemical reaction and injection on the flow characteristics in an unsteady upward motion of an isothermal plate. Uwanta *et al* (2011) studied the chemical reaction and thermal radiation effects on free convection flow through a porous medium. Sivaraj and Rushi Kumar (2011) found that the chemically reacting unsteady MHD oscillory slip, flow in a planer channel, in the presence of varying concentration. Raja Sekhar *et al.* (2012) studied the chemical reacting on MHD flow of oscillatory slip, flow in a planer channel, with varying temperature and concentration. Senapati and Dhal (2013) studied magnetic effect on mass and heat transfer of hydrodynamic flow, past a vertical oscillating plate in the presence of chemical reaction. Muthucumaraswamy *et al*. (2013) studied the radiation effects on unsteady flow past an accelerated isothermal vertical plate in presence of first order chemical reaction.

However the interaction of radiation and mass transfer in an electrically conducting fluid through a channel filled with porous medium has received little attention. Hence, an attempt is made to investigate the combined effects of a transverse magnetic field and radiation on an unsteady mass transfer flow with chemical reaction through a channel filled with saturated porous medium and non-uniform wall temperature. The equations of continuity, linear momentum, energy and diffusion, which govern the flow field is solved by using an analytical method. The behavior of the velocity, temperature, concentration, skin-friction, Nusselt number and Sherwood number has been discussed for variations in the governing parameters.

2. MATHEMATICAL ANALYSIS

An unsteady two dimensional convective heat and mass transfer flow of a viscous, incompressible, electrically conducting optically thin fluid in a channel filled with saturated porous medium with chemical reaction is considered. A uniform applied homogeneous magnetic field is considered in the transverse direction. It is assumed that the fluid has small electrical conductivity and the electromagnetic force produced is very small. A homogeneous first order chemical reaction between fluid and the species concentration is considered, in which the rate of chemical reaction is directly proportional to the species concentration. A Cartesian coordinate system (x', y') is assumed, where x'-axis lies along the center of the channel and y'- axis in the normal direction. Then, under the usual Boussinesq's approximation, the equations governing flow field under consideration are,

Momentum equation:

$$\frac{\partial u'}{\partial t'} = -\frac{1}{\rho}\frac{\partial P'}{\partial x'} + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\nu}{K'}u' - \frac{\sigma_e B_0^2}{\rho}u' + g\beta\left(T'-T_0'\right) + g\beta^*\left(C'-C_0'\right) \quad (1)$$

Energy equation:

$$\frac{\partial T'}{\partial t'} = \frac{\kappa}{\rho c_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial y'} \quad (2)$$

Species equation:

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} - K_r'\,(C'-C_0') \quad (3)$$

The boundary conditions for the velocity, temperature and concentration fields are:

$$u' = 0, T' = T_w', C' = C_w' \quad \text{on} \quad y' = 1$$

$$u' = 0, T' = T_0', C' = C_0' \quad \text{on} \quad y' = 0 \quad (4)$$

where u' is the axial velocity, t'- the time, T'- the fluid temperature, P'- the pressure, g- the gravitational force, q_r - the radiative heat flux , β and β^*- the coefficient of volume expansion due to temperature and concentration , c_p - the specific heat at constant pressure, κ the thermal conductivity, K' - the porous medium permeability coefficient,

Bo = $(\mu_e H_0)$ - the electromagnetic induction, μ_e - the magnetic permeability, *Ho*- the intensity of magnetic field, σ_e - the conductivity of the fluid, ρ - the fluid density and ν - the kinematic viscosity coefficient.

It is assumed that the temperature of the walls T_0', T_w' are high enough to induce radiative heat transfer. Following Cogley *et al*. (1968), it is assumed that the fluid is optically thin with a relatively low density and the radiative heat flux is given by:

$$\frac{\partial q_r}{\partial y'} = 4\alpha^2(T_0' - T'), \quad (5)$$

where α- is the mean radiation absorption coefficient.

In order to write the governing equations and the boundary conditions in dimensionless form, the following non-dimensional quantities are introduced.

$$x = \frac{x'}{a},\; y = \frac{y'}{a},\; u = \frac{u'}{a},\; t = \frac{t'U}{a},\; \mathrm{Re} = \frac{Ua}{\nu},\; \theta = \frac{T'-T_0'}{T_w'-T_0'},\; \phi = \frac{C'-C_0'}{C_w'-C_0'},\; P = \frac{aP'}{\rho\nu U},\; Da = \frac{K'}{a^2},\; H^2 = \frac{a^2\sigma_e B_0^2}{\rho\nu},\; Gr = \frac{g\beta(T_w'-T_0')a^2}{\nu U},$$
$$N^2 = \frac{4\alpha^2 a^2}{\kappa},\; Gc = \frac{g\beta^*(C_w'-C_0')a^2}{\nu U},\; Pe = \frac{Ua\rho c_p}{\kappa},\; Sc = \frac{\nu}{D},\; Kr = \frac{Kr'\,a}{U} \quad (6)$$

Where, *U* is the flow mean velocity and a being the width of the channel.

In view of the Eq. (6), the equations (1) – (3) reduce to the following dimensionless form:

$$\mathrm{Re}\frac{\partial u}{\partial t} = -\frac{\partial P}{\partial x} + \frac{\partial^2 u}{\partial y^2} - (s^2 + H^2)u + Gr\theta + Gc\phi \quad (7)$$

$$Pe\frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\partial y^2} + N^2\theta \quad (8)$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc\,\mathrm{Re}}\frac{\partial^2 \phi}{\partial y^2} - Kr^2\phi \quad (9)$$

The corresponding boundary conditions are:

$$u = 0,\; \theta = 1,\; \phi = 1 \quad \text{on} \quad y = 1$$

$$u = 0,\; \theta = 0,\; \phi = 0 \quad \text{on} \quad y = 0 \quad (10)$$

where *Gr, Gc, H, N, Pe, Re, Da, s*= (*1/Da*), *Sc, Kr* are thermal Grashoff number,solutal Grashof number, Hartmann number, Radiation parameter, Peclet number, Reynolds number, Darcy number, porous medium shape factor parameter, Schmidth number and chemical reaction parameter respectively.

3. SOLUTION OF THE PROBLEM

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

$$-\frac{\partial P}{\partial x}=\lambda e^{i\omega t}, u(y,t)=u_0(y)e^{i\omega t},$$

$$\theta(y,t)=\theta_0(y)e^{i\omega t},\ \phi(y,t)=\phi_0(y)e^{i\omega t} \qquad (11)$$

where λ is a constant and ω is the frequency of the oscillation.

Substituting the above expressions in Eq. (11) into Eqs. (7) -(10), we obtain,

$$\frac{d^2u_0}{dy^2}-m_3^2u_0=-\lambda-Gr\theta_0-Gc\phi_0 \qquad (12)$$

$$\frac{d^2\theta_0}{dy^2}+m_1^2\theta_0=0 \qquad (13)$$

$$\frac{d^2\phi_0}{dy^2}-m_2^2\phi_0=0 \qquad (14)$$

The corresponding boundary conditions are:

$u_0=0$, $\theta_0=1$, $\phi_0=1$ on y= 1,

$u_0=0$, $\theta_0=0$, $\phi_0=0$ on y= 0 (15)

where

$m_1=\sqrt{N^2-i\omega Pe}$, $m_2=\sqrt{Kr^2Sc\,\mathrm{Re}+i\omega Sc\,\mathrm{Re}}$ and $m_3=\sqrt{s^2+H^2+i\omega Re}$.

Solving the Eqs. (12)- (14) subject to boundary conditions (15), we obtain the fluid velocity, temperature and concentration as follows:

$$\theta(y,t)=\frac{\sin(m_1y)}{\sin m_1}e^{iwt} \qquad (16)$$

$$\phi(y,t)=\frac{\sinh(m_2y)}{\sinh m_2}e^{iwt} \qquad (17)$$

$$u(y,t)=u_0(y,t)e^{iwt} \qquad (18)$$

Where

$$u_0(y,t)=\frac{Gr}{m_1^2+m_3^2}\left(\frac{\sin(m_1y)}{\sin m_1}-\frac{\sinh(m_3y)}{\sinh m_3}\right)$$
$$+\frac{Gc}{m_2{}^2-m_3^2}\left(\frac{\sinh(m_3y)}{\sinh m_3}-\frac{\sinh(m_2y)}{\sinh m_2}\right)$$
$$+\frac{\lambda\sinh(m_3y)}{m_3^2\sinh m_3}\left(\cosh m_3-1\right)+\frac{\lambda}{m_3^2}\left(1-\cosh m_3y\right)$$

The skin-friction, Nusselt number and Sherwood number are important physical parameters for this type of boundary layer flow.

Knowing the velocity field, the skin-friction at both the walls of the channel can be obtained, which in non-dimensional form is given by:

$$\tau=-\mu\left(\frac{\partial u}{\partial y}\right)_{y=0,1}=$$
$$-\left(\frac{Gr}{m_1^2+m_3^2}\left(\frac{m_1\cos(m_1y)}{\sin m_1}-\frac{m_3\cosh(m_3y)}{\sinh m_3}\right)+\right.$$
$$\frac{Gc}{m_2^2-m_3^2}\left(\frac{m_3\cosh(m_3y)}{\sinh m_3}-\frac{m_2\cosh(m_2y)}{\sinh m_2}\right)e^{iwt}$$
$$+\frac{Gc}{m_2^2-m_3^2}\left(\frac{\lambda\cosh(m_3y)}{m_3\sinh m_3}\left(\cosh m_3-1\right)\right)e^{iwt}$$
$$-\frac{Gc}{m_2^2-m_3^2}\left(\frac{\lambda}{m_3}\sinh m_3y\right)e^{iwt} \qquad (19)$$

Knowing the temperature field, 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:

$$Nu=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0,1}=-\left(\frac{m_1\cos m_1y}{\sin m_1}\right)e^{i\omega t} \qquad (20)$$

Knowing the concentration field, 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:

$$Sh=-\left(\frac{\partial\phi}{\partial y}\right)_{y=0,1}=-\left(\frac{m_2\cosh m_2y}{\sinh m_2}\right)e^{i\omega t} \qquad (21)$$

4. RESULTS AND DISCUSSION

Numerical evaluation of analytical results reported in the previous section was performed and representative set of results is reported graphically. These results are obtained to illustrate the influence of various parameters on the velocity, temperature and concentration. For numerical validation of the analytical results, we have taken the real part of the results obtained in equations. The velocity, temperature, concentration, skin-friction, Nusselt number and Sherwood number are evaluated computationally for different sets of governing parameters viz., thermal Grashof number *Gr*, solutal Grashof number *Gc*, Hartmann number *H*, radiation parameter *N*, Peclet number *Pe*, Reynolds number *Re*, porous medium shape factor parameter*s*, Schmidt number *Sc* and chemical reaction parameter *Kr*. In the present study we adopted the following default parametric values: *Gr* = 1.0, *Gc = 0.5, Pe = 0.71, H = 1.0, N = 1.0, s = 1.0, Sc = 0.6,* K_r *= 0.5, Re = 1.0, t = 0.0,* λ *= 1.0 and* ω *= 1.0*. All the graphs therefore correspond to these values unless specifically indicated on the appropriate graph.

It can be observed that the fluid velocity profile is parabolic with maximum magnitude along the channel centerline and minimum at the walls. Here θ correspond to the profiles of the non-dimensional temperature, θ is positive or negative according as the temperature in the flow field is greater than or less than the temperature on the boundary, *y* = 0 (lower temperature plate). It is observed that in general the temperature θ is continuously positive for variations of the governing parameters. Thus the temperature in the flow field is always higher than the temperature on the plate y = 0, and less than the temperature on the plate y =1. For any given set of parameters, the profiles indicate that the temperature gradually enhances from its lowest value on the boundary y = 0 to attain its highest prescribed value on the boundary y =1.

Here ϕ correspond to the profiles of the non-dimensional concentration, ϕ is positive or negative according as the concentration in the flow field is greater than or less than the concentration on the boundary, y = 0 (lower concentration plate). It is observed that in general the concentration ϕ is continuously positive for variations of the governing parameters. Thus the concentration in the flow field is always higher than the concentration on the plate y = 0, and less than the concentration on the plate y =1. For any given set of parameters, the profiles indicate that the concentration gradually enhances from its lowest value on the boundary y = 0 to attain its highest prescribed value on the boundary y =1.

For the case of different values of thermal Grashof number *Gr*, the velocity profiles are shown in Fig.1. The thermal Grashof number *Gr* signifies the relative effect of the thermal buoyancy force to the viscous hydrodynamic force in the boundary layer. As expected, it is observed that magnitude of fluid velocity increases with an increase in the Grashof number *Gr*. For the case of different values of solutal Grashof number*Gc*, the velocity profiles are shown in Fig.2. The solutal Grashof number *Gc,* defines the ratio of the species buoyancy force to the viscous hydrodynamic force. As expected, it is observed that magnitude of fluid velocity increases with an increase in the solutal Grashof number *Gc*.

Figure 3 presents the typical velocity profiles in the boundary layer for various values of the magnetic field intensity *H* (Hartmann number), while all other parameters are kept at some fixed values. As expected, it is observed that the magnitude of fluid velocity decreases with an increase in the Hartmann number *H.*

The effect of the porous medium shape factor parameter *s* on the velocity field is shown in Fig.4. An increase in *s* will therefore increase the resistance of the porous medium which will tend to decelerate the flow and reduce the velocity. This behavior is evident from Fig.4.

Figures 5(a) and 5(b) illustrate the velocity and temperature profiles for different values of the radiation parameter *N*. The radiation parameter *N* defines the relative contribution of the heat transfer to thermal radiation transfer. The numerical results show that the effect of increasing values of radiation parameter *N* results in a rise in the velocity (Fig.5(a)). From Fig.5(b), it is observed that an increase in the radiation parameter results in an increase in the temperature.

The influence of the Peclet number *Pe* on the velocity and temperature profiles is plotted in Figs. 6 (a) and 6 (b) respectively. The Peclet number defines the ratio of momentum diffusivity to thermal diffusivity. The numerical results show that the effect of increasing values of Peclet number results in a decrease in the velocity (Fig.6 (a)). From Fig.6 (b), it is observed that an increase in the Peclet number results in a decrease in the temperature. The reason is that smaller values of *Pe* are equivalent to increase in the thermal conductivity of the fluid and therefore heat is able to diffuse away from the heated surface more rapidly for higher values of *Pe*. Hence, in the case of smaller Peclet numbers, the rate of heat transfer is reduced.

Figures 7(a) and 7(b) depict the velocity and concentration profiles for different values of the Reynolds number *Re*. It is noticed that an increase in the Reynolds number Re results in a decrease in the velocity and concentration.

The effect of the Schmidt number *Sc* on the velocity and concentration profiles are plotted in Figs.8(a) and 8(b) respectively. The Schmidt number embodies the ratio of the momentum to the mass diffusivity. The Schmidt number therefore quantifies the relative effectiveness of momentum and masstransport by diffusion in the hydrodynamic (velocity) and concentration (species) boundary layers. As the Schmidt number increases the concentration decreases. This causes the concentration buoyancy effects to decrease, yielding a reduction in the fluid velocity. This behaviors clear from Figs.8(a) and 8(b).

The influence of chemical reaction parameter *Kr* on the velocity and concentration are shown in Figs.9(a) and 9(b) respectively. It is noticed that an increase in the chemical reaction parameter *Kr* results in a decrease in the velocity and concentration.

The effects of various governing parameters on the wall shear stress τ, Nusselt number *Nu* and the Sherwood number *Sh* at lower wall y = 0 and upper wall y = 1 of the channel are shown in Tables 1, 2 and 3. From Table 1, it is observed that as *Gr* or *Gc* increases, there is a rise in the wall shear stress at both the walls. It is seen that as magnetic field intensity *H* increases, there is a fall in the wall shear stress at both the walls. From Table 2, it is observed that as the Peclet number *Pe*increases both the wall shear stress and Nusselt number decrease at the lower wall y = 0, but at the upper wall y = 1 wall shear stress decreases, while the Nusselt number increases. It is also noticed that as the radiation parameter *N*increases, both the wall shear stress and Nusselt number increase at both the walls. From Table 3, it is seen that as the Schimdt number *Sh* or chemical reaction parameter *Kr*increases both the wall shear stress and Sherwood number decreases at the lower wall y = 0, but at the upper wall y = 1, wall shear stress decreases while the Sherwood number increases. Furthermore, the negative values of the wall shear stress, Nusselt number and Sherwood number, for all values of the parameters, are indicative of the physical fact that the heat flows from the sheet surface to the ambient fluid.

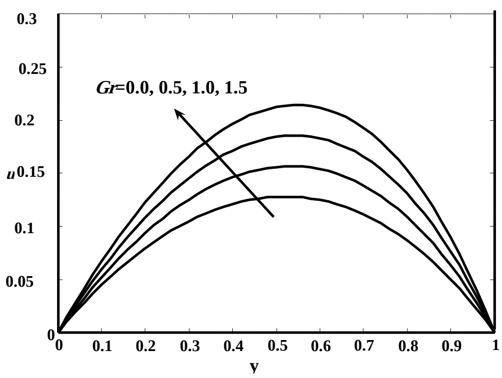


Fig. 1.Velocity profiles for different values of *Gr*

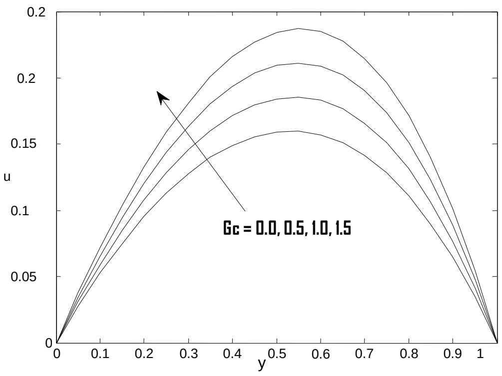


Fig. 2. Velocity profiles for different values of *Gc*

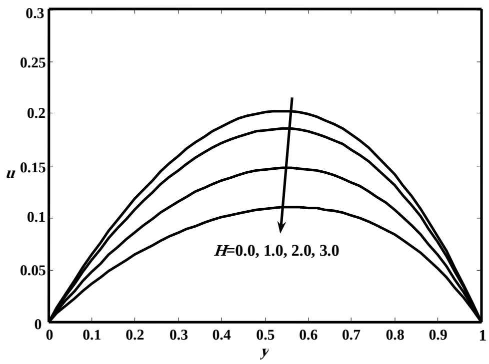


Fig. 3. Velocity profiles for different values of *H*

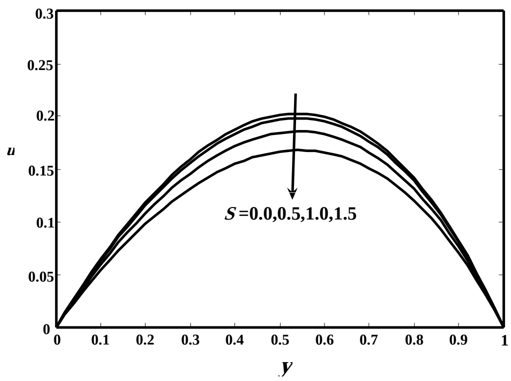
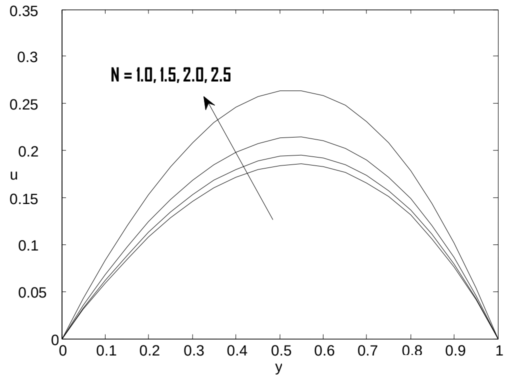
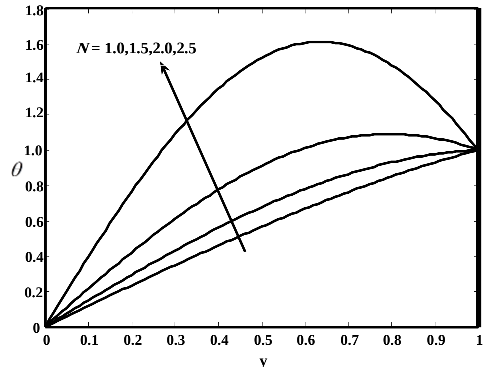


Fig. 4. Velocity profiles for different values of *s*

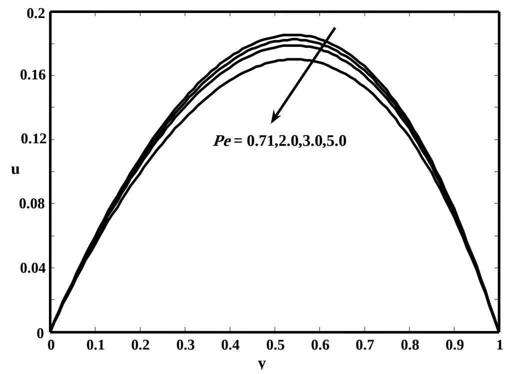


(a)

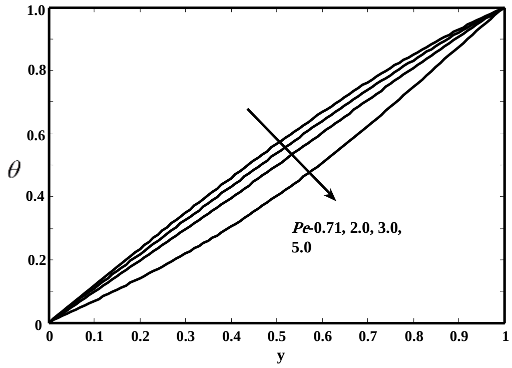


(b)

Fig. 5. (a) Velocity profiles for different values of *N;* (b) Temperature profiles for different values of *N*

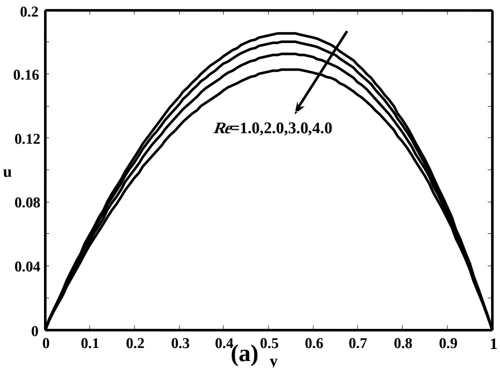


(a)

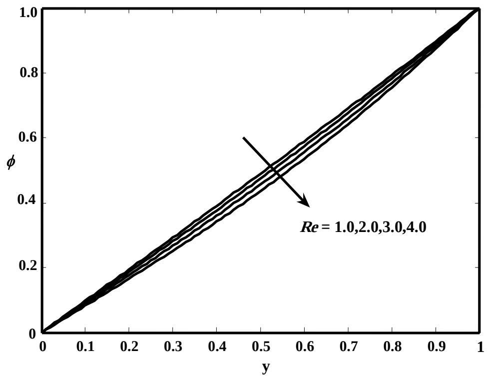


(b)

Fig. 6. (a) Velocity profiles for different values of *Pe;* (b) Temperature profiles for different values of *Pe*

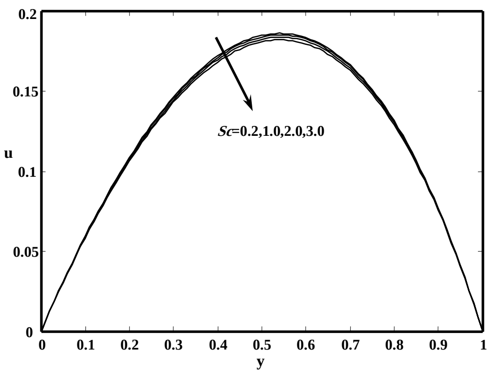


(a)

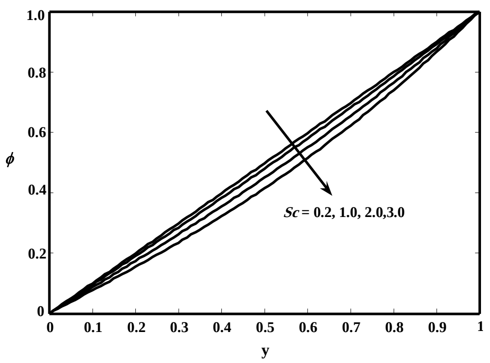


(b)

Fig. 7. (a) Velocity profiles for different values of *Re;* (b) Concentration profiles for different values of *Re*

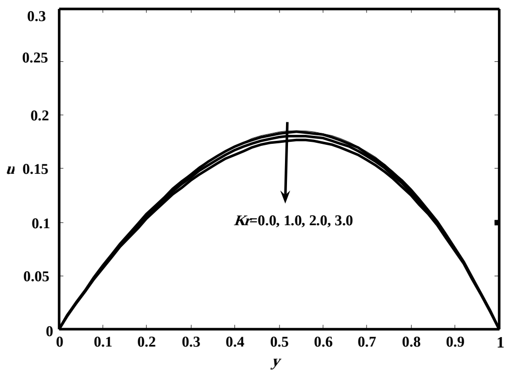


(a)

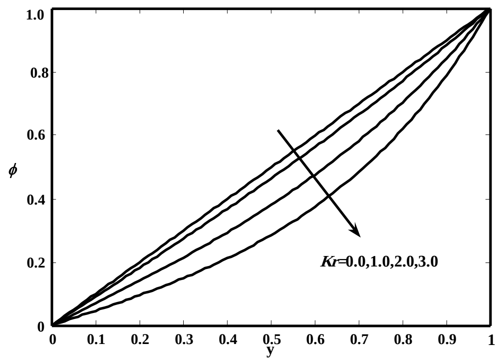


(b)

Fig. 8. (a) velocity profiles for different values of *Sc;* (b) Concentration profiles for different values of *Sc*



(a)



(b)

Fig. 9. (a) Velocity profiles for different values of *Kr*; (b) Concentration profiles for different values of *Kr*

Table 1 Numerical *values* of the shear stress of the channel for *Pe = 0.71, N = 1.0,* λ *= 1.0, t = 0.0, s = 1.0, Re = 1.0, w = 1.0, Kr = 0.5, Sc = 0.6*

Gr	*Gc*	*H*	$\tau(0)$	$\tau(1)$
1.0	0.5	1.0	-0.6418	0.8862
2.0	0.5	1.0	-0.7906	1.1990
1.0	1.0	1.0	-0.7067	1.00314
1.0	0.5	2.0	-0.5247	0.7583

Table 2 Numerical values of the shear stress and the rate of heat transfer i.e. Nusselt number of the channel for *Gr = 1.0, Gc = 0.5 = 1.0, H = 1.0,* λ *= 1.0, t = 0.0, s = 1.0, Re = 1.0, w = 1.0, Sc = 0.6, Kr = 0.5*

Pe	*N*	$\tau(0)$	$\tau(1)$	*N(0)*	*Nu(1)*
0.71	1.0	-0.6418	0.8862	-1.1748	-0.6572
1.0	1.0	-0.6402	0.8845	-1.1616	-0.6718
0.71	2.0	-0.7290	0.9823	-2.1518	0.8657

Table 3 Numerical values of the shear stress and the rate of mass transfer i.e. Sherwood number of the channel for *Gr = 1.0, Gc = 0.5 = 1.0, H = 1.0, λ = 1.0, t = 1.0, s = 1.0, Re = 1.0, w = 1.0, Pe = 0.71, N = 1.0*

Sc	*Kr*	$\tau(0)$	$\tau(1)$	*Sh(0)*	*Sh(1)*
0.6	0.5	-0.6418	0.8862	-0.9688	-1.0571
1.0	0.5	-0.6403	0.8845	-0.9417	-1.1025
0.6	1.0	-0.6386	0.8824	-0.9008	-1.1992

5. CONCLUSION

This paper investigates the heat and mass transfer effects on MHD oscillatory flow in a channel filled with a porous medium in the presence of thermal radiation and chemical reaction. The velocity, temperature and concentration profiles are obtained analytically and used to compute the wall shear stress, rate of heat transfer and rate of mass transfer at the channel walls. The study concludes that the velocity increases with decreasing magnetic field parameter or Porous medium. It is also observed that the velocity and concentration increases with decreasing Schmidt number or chemical reaction parameter. The temperature profiles increase under the effect of radiation parameter and decrease under the effects of Peclet number. It is found that an increase in Reynolds number results in a decrease in the velocity and concentration. It is noticed that as the radiation parameter increases, both the wall shear stress and Nusselt number increase at both the walls.

REFERENCES

Aldoss, T. K., M. A. Al-Nimr, M. A. Jarrah, and B. Al-Shaer (1995). Mixed convection flow from a vertical plate embedded in porous medium with magnetic field. *Heat Transfer* 28A, 635-645.

Aluwalia, R. K. and E. D. Doss (1980). Convective heat transfer in MHD channels and its influence on channel performance. *AIAA J. Energy*. 4(3), 126-134.

Bakier, A. Y. and R. S. R. Gorla (1996). Thermal radiation effects on horizontal surfaces in saturated porous media. *Transport in porous media* 23,357-361.

Bakier, A. Y. (2001). Thermal radiation effect on mixed convection from vertical surfaces in saturated porous media. *Int. Commun Heat Mass Transfer* 28,119-126.

Bejan, A. and K. R. Khair (1985). Heat and mass transfer by natural convection in porous medium, *Int. J. Heat Mass Transfer*. 28, 909-919.

Chamkha, A. J. (2000). MHD free convection flow from a vertical plate embedded in thermally stratified porous medium with Hall effects. *Int. J. Numer, Meth. Heat Fluid Flow* 10, 142-162.

Chauhan, Ch., S. Dileep, and R. Priyanka (2010). Radiation effects on Natural; convection MHD flow in a rotating vertical porous channel partially filled with a porous Medium. *Applied Mathematical Science* 4(13), 648 – 655.

Cogley, A. C. L., W. G. Vinvent, and E. S. Giles (1968). Differential approximation for radiative transfer in a non-gray near equilibrium. *American Institute of Aeronautics and Astronautics* 6, 551-553.

Dekha, R., U. N. Das, and V. M. Soundalgekar (1994). Effects on mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction. *Forschungim Ingenieurwesen* 60,284-289.

Hossain, M. A. and H. S. Takhar (1996). Radiation effect on mixed convection along a vertical plate with uniform surface temperature.*Heat Mass Transfer* 31, 243-248.

Ingham, D. B. and I. Pop (1998). *Transport phenomenon in porous media*. Pergamon Press, Oxford.

Kim, Y. J. (2000). Unsteady MHD convective heat transfer past semi-infinite vertical porous moving plate with variable suction. *Int. J. Eng. Sci*. 38, 833-845.

Kim, Y. J., G. Andrei, and M. Fedorov (2003). Trasient mixed radiative convection flow of a micropolar fluid past a moving, semi-infinite vertical porous plate. *Int. J. Heat Mass Transfer* 46, 1751-1758.

Kumar, R. and B. G. Prasad (2014). MHD pulsatile flow through a porous medium. Journal of Applied Fluid Mechanics 7(1), 63-74.

Lai, F. C. and F. A. Kulacki (1991). Coupled heat and mass transfer by natural convection from vertical surfaces in a porous medium. *Int. J. Heat Mass Transfer* 34, 1189-1194.

Makinde, O. D. and P. Y. Mhone (2005). Heat transfer to MHD oscillatory flow in a channel filled with porous medium. *Rom. Journ. Phys*. 50(9), 931-938.

Muthucumaraswamy, R. and P. Ganesan (2001). Effect of the chemical reaction and injection on the flow characteristics in an unsteady upward motion of an isothermal plate. *J Appl. Mech.Tech.Phys*. 42, 665-671.

Muthucumaraswamy, R., N. Dhanasekar, and G. E Prasad (2013). Radiation effects on unsteady flow past an accelerated isothermal vertical plate with variable mass transfer in presence of chemical reaction of first order, Journal of Applied Fluid Mechanics 6(4), 485-490.

Nield, D. A. and A. Bejan (1998). *Convection in porous media*, Second Edition, Springer, New York.

Raja Sekhar, K., G. V. Ramana Reddy, and B. D. C. N. Prasad (2012). Chemically reacting on MHD oscillatory slip flow in a planer channel with varying temperature and concentration. *Advances in Applied Science Research* 3(5), 2652-2659.

Raptis, A., C. Massias, and G. Tzivanidis (1982). Hydromagnetic free convection flow through a porous medium between two parallel plates, *Phys. Lett*. 90A, 288-289.

Senapati, N. and R. K. Dhal. (2013). Effect of slip condition on unsteady MHD oscillatory flow in a channel filled with porous medium with heat radiation and mass transfer. *International Journal of Applied Mathematics and Statistical Sciences* 2, 11-20.

Singh, K. D. and A. Mathew (2012). An oscillatory free convective flow through a porous medium in a rotating vertical porous channel. *Global Journal of Science Frontier Research* 12(3), 51-64.

Sivaraj, R and B Rushi Kumar (2011). Chemically reacting unsteady MHD oscillatory slip flow in a planer channel with varying concentration. *International Journal of Mathematics and Scientific Computing* 1(1), 35-42.

Srinivas, S, and R. Muthuraj (2010). Effects of thermal radiation and space porosity on MHD mixed convection flow in a vertical channel using homotopy analysis method. *Commun. Nonlinear Sci. Numer. Simulat*. 15, 2098–2108.

Uwanta, I. J., M. M. Hamza, and M. O. Ibrahim (2011). Radiation-convection flow in porous medium with chemical reaction, *Int Jour. of Comp. Applications* 36(2), 12-16.

Yih, K. A. (1997). The effect of transpiration on coupled heat and mass transfer in mixed convectionover a vertical plate embedded in a saturated porous medium. *International Communications Heat and Mass Transfer* 24(2), 265-275.