Influence of Chemical Process and Thermo-Diffusion Effects on Oscillatory MHD Flow in a Porous Medium with Absorption

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ABSTRACT:

The combined influence of chemical and thermo diffusion on oscillatory flow of electrically conducting incompressible fluid in a symmetric channel through porous medium in the occurrence of a magnetic field is investigated. The governing equations of the flow are formulated on the basis of certain assumptions. Dimensionless equation solutions are realised in closed form, followed by an analytical approach. The numerical computations of the physical parameters Grashof number, Peclet number, Hartmann number, Reynolds number and Soret number were presented graphically to highlight the key features.It has also been observed that velocity increases as flow parameters such as Grashof number and soret number increase. Temperature profiles oscillate as the radiation parameter N changes. It has also been discovered that as the heat source increases, so do the temperature profiles. Concentration profiles decrease as the chemical reaction parameters K_c and Sr increase, and the pattern reverses as the Schmidt number Sc increases.It is also observed that velocity is increasing when flow parameters like Grashof number and soret number increase.

Keywords: Thermal Radiation, Chemical Reaction, Heat Absorption, Mass Transfer, MHD Oscillatory Flow, Porous Medium

INTRODUCTION

In recent decades, there has been a great deal of curiosity in combined heat and mass transfer problems involving chemical reactions and soret.Drying process, evaporation of a water body at the surface,HMT occur simultaneously. This type of flow application is used in a variety of industries. Ogulu et al. [2] can investigate this further.Flows passing through porous media play an important role in many areas, including filtering gases and liquids, breathing in human body and excretory discharge through porous skin.Because of its importance in soil mechanics the study of oscillatory flow in a porous channel has gotten a lot of attention recently.Vidhya*et al.*[7]examined the impact of chemical reaction on Oscillatory MHD flow in an asymmetric channel.

Makinde [4] investigated the effect of MHD through porous medium and radiative oscillatory flow. Makinde & Chinyoka [5] investigated MHD channel flow through porous medium – numerical approach. This paper deals with the radiative heat and convective cooling. Soundalgekar [1] studied the oscillatory MHD flow past a semi-infinite plate.Singh [6] numerically solved an oscillatory MHD flow in a porous medium-filled channel. Aldoss et al. [3] examined convection mixed flow from a embedded vertical plate in a porous medium in the existence of a magnetic field.Ananthaswamy*et al*.[8]studied an unsteady flow of porous medium saturated in the occurance of magnetic field.Using the quasilinearization technique, Bhattacharyya et al. [9] investigated the impact of chemical reaction on theMHD boundary layer stagnation -point of an electrically conducting fluid.Pravat Kumar Rath et al. [10] investigated 3D free convective flow with chemical MHD HMT through a porous medium using the perturbation method. Sarma and Mahanta [11] used the perturbation technique to examined the impact of chemical reaction on 3D HMT.Muthucumaraswamy and Janakiraman [12] considered MHD thermal radiation effects on flow past vertical plate.

The prime focus of this paper is to examine the combined effect of chemical process and thermal diffusion on the radiative oscillatory MHD flow through a symmetric channel. In the presence of relevant boundary conditions, the fluid flow governing equations are solved.The effects of various parameters on velocity, temperature, and concentration have been investigated, and the results have been graphically presented using MATLAB.

MATHEMATICAL ANALYSIS

Consider the flow of an electrically conducting and chemically reacting oscillatory fluid in a symmetric channel through saturated porous medium under the impact of thermal diffusion, magnetic field and radiative heat transfer as show in Fig.1.

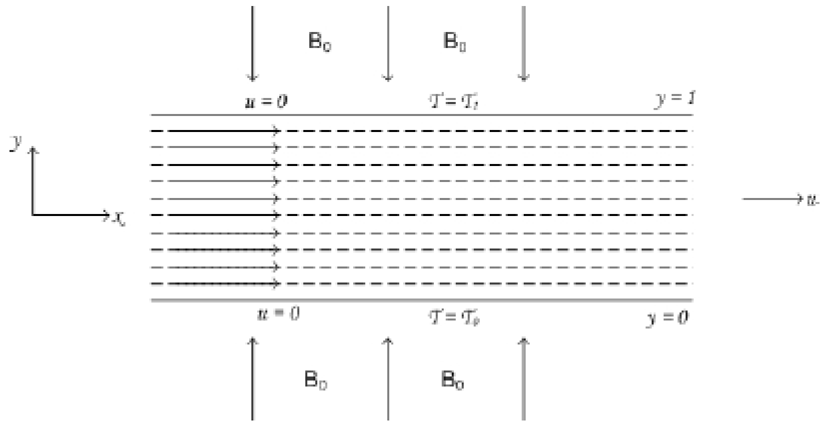


Fig. 1 Physical Model of the Problem

To induce radiative heat transfer, channel wall temperatures are kept constant at T0 and T1. Consider the Cartesian coordinate system $(\vec{x}, \vec{y})$, where $\vec{x}$is the distance measured in the normal section and $\vec{y}$ is the distance measured along the channel's centre. We make the following assumptions:

- Except for density, all fluid properties are assumed to be constant.

- Temperature affects the density property.
- The flow is unsteady oscillatory flow, because we assumed pressure gradient is oscillatory at the ends of the channel.
- The induced magnetic field is insignificant.
- With constant permeability of the porous medium, viscous and Darcy's resistance terms are taken into account.
- The equations governing the flow under the usual Bousinesq approximation are as follows:

The flow's governing equations are,

Momentum Equation

$$\frac{\partial u}{\partial t} = -\frac{1}{\rho}\frac{\partial P}{\partial x} + g\beta^*(C + \gamma\frac{\partial^2 u}{\partial y^2} - \frac{\sigma {B_0}^2}{\rho}u - \frac{\gamma}{k}u + g\beta(T - T_0) - C_0) \qquad (1)$$

Energy Equation

$$\frac{\partial T}{\partial t} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T}{\partial y^2} + \frac{1}{\rho C_p}\frac{\partial q}{\partial y} + \frac{Q}{\rho C_p} \qquad (2)$$

Concentration Equation

$$\frac{\partial C}{\partial t} = D_M\frac{\partial^2 C}{\partial y^2} + \frac{Dk_T}{T_m}\frac{\partial^2 T}{\partial y^2} - {K_c}'(C - C_0) \qquad (3)$$

with the boundaryconditions,

$$u = 0,\ T = T_1,\ C = C_1 \text{on} y = 1 \qquad (4)$$

$$u = 0,\ T = T_0,\ C = C_0 \text{on} y = 0 \qquad (5)$$

Radiative heat flux is given by,

$$\frac{\partial q}{\partial y} = 4\alpha^2(T - T_0) \qquad (6)$$

Dimensionless variables are,

$$\vec{x} = \frac{x}{a};\ \vec{y} = \frac{y}{a};\ \vec{u} = \frac{u}{U};\ Re = \frac{Ua}{\gamma};\ \theta = \frac{T - T_0}{T_1 - T_0};\ \varphi = \frac{C - C_0}{C_1 - C_0};\ M^2 = \frac{\sigma {B_0}^2 a^2}{\rho\gamma};\ \vec{t} = \frac{tU}{a};\ \vec{P} = \frac{Pa}{\rho\gamma U};$$

$$Da = \frac{k}{a^2};\ s^2 = \frac{1}{D_a};\ Sc = \frac{D_M}{Ua};\ Sr = \frac{Dk_T}{T_m Ua}\left(\frac{T_1 - T_0}{C_1 - C_0}\right);\ Gr = \frac{g\beta(T_1 - T_0)}{\gamma U}a^2;\ Gc = \frac{g\beta^*(C_1 - C_0)}{\gamma U}a^2;$$

$$Pe = \frac{Ua\rho C_p}{k};\ N^2 = \frac{4\alpha^2 a^2}{k};\ K_c = \frac{{K_c}' a}{U};\ \alpha = \frac{Qa^2}{K(T_1 - T_0)} \qquad (7)$$

SOLUTION OF THE PROBLEM

$$Re\frac{\partial u}{\partial t} = -\frac{\partial P}{\partial x} + \frac{\partial^2 u}{\partial y^2} - (S^2 + M^2)u + Gr\theta + Gc\varphi \quad (8)$$

$$Pe\frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\partial y^2} + (N^2 + \alpha)\theta \quad (9)$$

$$\frac{\partial \varphi}{\partial t} = Sc\ \frac{\partial^2 \varphi}{\partial y^2} + Sr\ \frac{\partial^2 \theta}{\partial y^2} - K_c\varphi \quad (10)$$

with the boundary conditions,

$$u = 0,\ \theta = 1,\ \varphi = 1 \ \text{ on} y = 1 \quad (11)$$

$$u = 0,\ \theta = 0,\ \varphi = 0 \ \text{ on} y = 0 \quad (12)$$

METHOD OF SOLUTION

Assuming pressure gradient for purely oscillatory flow as,

$$-\frac{\partial P}{\partial x} = \lambda e^{i\omega t} \quad (13)$$

Let us assume the solutions for $u(y,t), \theta(y,t)$and $\phi(y,t)$ be in the form,

$$\left.\begin{aligned} u(y,t) &= u_0(y)e^{i\omega t} \\ \theta(y,t) &= \theta_0(y)e^{i\omega t} \\ \phi(y,t) &= \phi_0(y)e^{i\omega t} \end{aligned}\right\} \quad (14)$$

Substituting (13) and (14) in (8), (9), (10), we obtain

$$\frac{d^2\theta_0}{dy^2} + m_1\theta_0 = 0 \quad (15)$$

$$\frac{d^2\varphi_0}{dy^2} - {m_2}^2\phi_0 = \frac{Sr}{Sc}{m_1}^2\theta_0 \quad (16)$$

$$\frac{d^2u_0}{dy^2} - {m_3}^2u_0 = -\lambda - Gr\theta_0 - Gc\phi_0 \quad (17)$$

with the boundary conditions,

$$u = 0,\ \theta = 1,\ \varphi = 1 \ \text{ on} y = 1 \quad (18)$$

$$u = 0,\ \theta = 0,\ \varphi = 0 \ \text{ on} y = 0 \quad (19)$$

where$m_1 = \sqrt{N^2 + \alpha - Pei\omega}$, ${m_2}^2 = \frac{K_c + i\omega}{Sc}$ and $m_3 = S^2 + M^2 + i\omega Re.$

Equations (15), (16) and (17) are solved using equations (18) and (19). we obtain,

$$\theta(y,t) = \frac{sinm_1 y}{sinm_1}e^{i\omega t} \quad (20)$$

$$\phi(y,t) = \left[\frac{sinhm_2 y}{sinhm_2} + \frac{Sr}{Sc}\frac{m_1}{(m_1{}^2+m_2{}^2)}\frac{sinhm_2 y}{sinhm_2} - \frac{Sr}{Sc}\frac{m_1}{(m_1{}^2+m_2{}^2)}\frac{sinhm_1 y}{sinhm_1}\right]e^{i\omega t} \quad (21)$$

$$u(y,t) = \left\{\begin{array}{c} \frac{\lambda}{m_3{}^2}[1+2sinhm_3(1-y)-2sinhm_3 y] \\ -\frac{Gr}{m_1{}^2+m_3{}^2}\left[\frac{2sinhm_3 y}{sinhm_3}+\frac{2sinhm_3(1-y)}{sinhm_3}-\frac{sinhm_1 y}{sinhm_1}\right] \\ -\frac{Sr}{Sc}\frac{m_1}{(m_1{}^2+m_2{}^2)}\left[\left(1-\frac{1}{(m_1{}^2+m_3{}^2)}\right)2sinhm_3 y-\frac{sinhm_2 y}{(m_2{}^2+m_3{}^2)sinhm_2}-\frac{sinhm_1 y}{(m_1{}^2+m_3{}^2)sinhm_1}\right] \\ -\frac{Gc}{m_2{}^2+m_3{}^2}\frac{1}{sinhm_2} \end{array}\right\}e^{i\omega t} \quad (22)$$

RESULTS AND DISCUSSIONS

To investigate the effects of chemical reaction and thermal diffusion on the radiative Oscillatory MHD flow in a symmetric channel are graphically depicted against for various physical parameters such as heat source, Hartmann number, Schmidt number, chemical reaction parameter, and so on.

Fig. 2 Effect of Heat Source on temperature

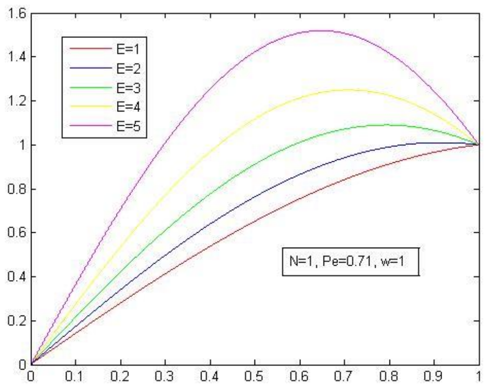


Fig. 3 Effect of Gr on velocity

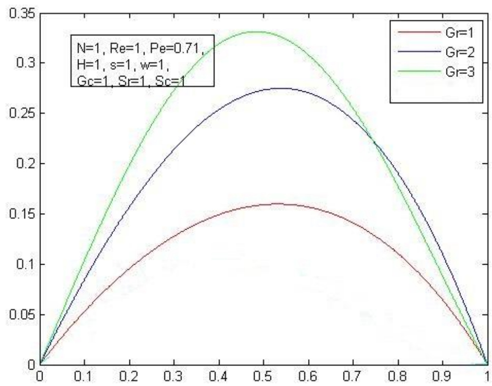


Fig. 4 Effect of radiation parameter on temperature

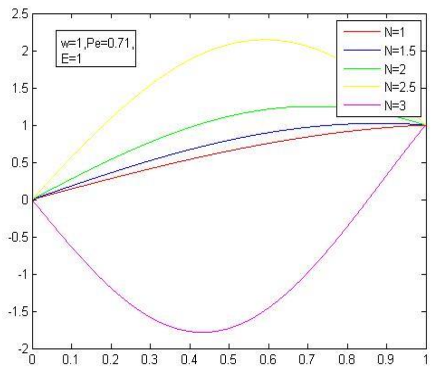
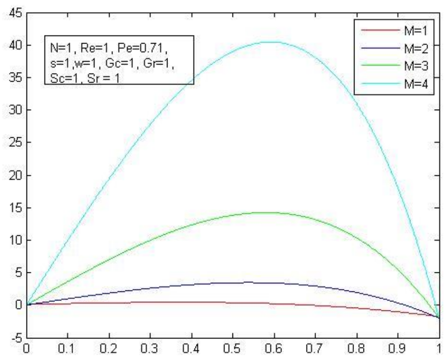


Fig. 5Effect of Hartmann number M on velocity



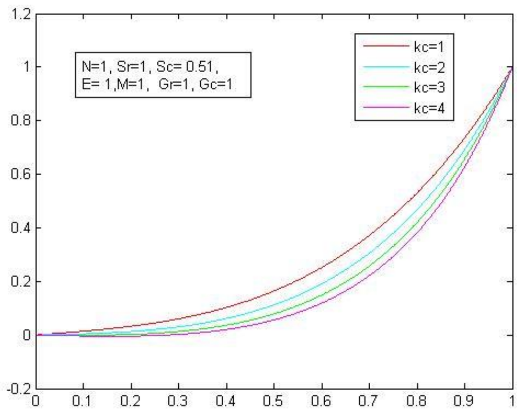


Fig. 6Effect of chemical reaction on concentration

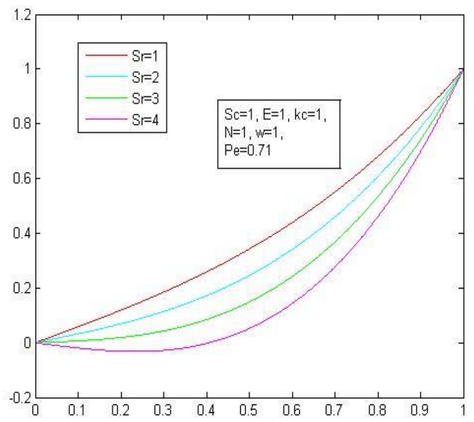


Fig. 7 Effect of Soret number Sr on concentration

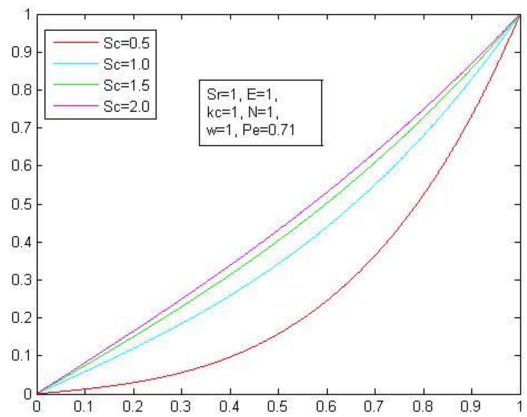


Fig. 8Effect of Schmidth number on concentration

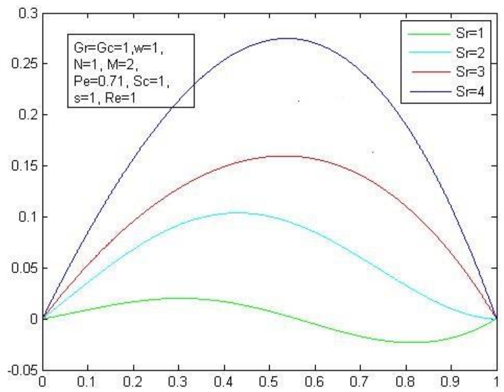


Fig. 9 Effect of Soret number on velocity

Figure 2 depicts the impact of a thermal radiation on temperature. It is noticed that as the heat source increases, so does the temperature profile. Figure 3 depicts the influence of the Grashof number on velocity u. The velocity profiles are found to increase steadily as the Grashof number increases. Figure 4 depicts oscillatory temperature increases, thermal radiation parameter N is also increases. We discovered that increasing thermal radiation thickens the thermal boundary layer, which improves heat transfer. The temperature distribution improves as the thermal radiation parameter is increased. Increased thermal radiation parameter values heat the working fluid more, increasing temperature and thermal boundary layer thickness. The concentration distribution in flow is unaffected by the thermal radiation parameter.Figure 5 depicts the increasing effect of magnetic field decreases the velocity.It is because increasing the magnetic field parameter improves the Lorentz force, which is the opposite force to the flow of direction. As a result, an electrically conducting fluid's motion is slowed by the Lorentz force.

In the concentration field, the effect of the chemical reaction parameter is very important. Figure 6 shows that as the chemical processis increased, the concentration of the fluid decrease. This is due to the fact that increasing the chemical process accelerates the reactants rate process on the flow, reducing the concentration of the reacting species. The chemical reaction speeds up interfacial MT. The chemical reaction reduces the local concentration while increasing the gradient and flux of concentration.The chemical reaction parameter has little or no effect on the temperature profile of the flow. It is clear that as the Soret number Sr increases, the concentration profiles decrease uniformly. Figure 7 depicts this.

Figure 8 depicts the effect of Schmidt number on concentration profiles. It is clear that as the Schmidt number Sc increases, the concentration profiles increase uniformly. Figure 9 depicts the soret effect on the velocity profile. This demonstrates that velocity increases as the Soret number increases.

CONCLUSION

The combined influence of chemical and soret effect on oscillatoryMHD flow in a porous medium with HMT is investigated in this paper. Converting the governing PDE into ODE yields exact solutions. MATLAB is used to graphically analyse velocity, temperature, and concentration profiles for various flow parameters.

The current investigation's findings are as follows:

- It has also been observed that velocity increases as flow parameters such as Grashof number and soret number increase.
- Temperature profiles oscillate as the radiation parameter N changes. It has also been discovered that as the heat source increases, so do the temperature profiles.
- Concentration profiles decrease as the chemical reaction parameters K_c and Sr increase, and the pattern reverses as the Schmidt number Sc increases.It is also observed that velocity is increasing when flow parameters like Grashof number and soret number increase.

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