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EFFECT OF HALLCURRENT AND CHEMICAL REACTION IN MHD FLOW WITH HEAT AND MASS TRANSFER OVER A POROUS MEDIUM

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Abstract

The present paper aims at investigating the effect of Hall current and Chemical reaction in MHD flow with Heat and Mass transfer in the presence of a porous medium. This model plays a vital role in many industries. Similarity transformation are employed to transform the governing partial differential equations into ordinary differential equations and solved by exact method. For different values of governing parameters graph is drawn using Mathematica software. From the graphs and results it is observed that the Velocity profile is accelerated when the Hall parameter, Grashof number and porosity parameter are increased but it has the reversal effect with Hartman number, Prandtl number and Chemical reaction.

Key Words : *Heat transfer, Mass transfer, Porous medium, Halleffect, Chemical reaction.*

1. Introduction

Magnetohydrodynamics (MHD) is the branch of continuum mechanics which studies the flow of an electrically conducting fluid in the presence of an electromagnetic field. There are many natural phenomena and engineering problems susceptible to MHD analysis. In general, it is useful and important in Astrophysics as most part of the universe is filled with widely spaced charged particles and permeated by magnetic fields. In the early 1930's Chapman and Ferraro [1] developed the theory of magnetic storms. In 1937, Johannes F. Hartmann [2] made studies on flow of conducting fluids across a magnetic field. Later Alfven [3] worked on this subject and discovered a new type of wave known as Alfven wave. After Alfven's investigation, the subject has undergone an explosive development. The subject has gained momentum in recent times because of the era's interest in high-temperature gases, nuclear engineering and space technology.

Heat is the form of energy that can be transformed from one system to another as a result of temperature difference. A thermodynamic analysis is concerned with the amount of heat transfer as a system undergone a process from one equilibrium state to another. The science that deals with the determination of the rates of such energy transfer is the heat transfer. The transfer of energy as heat is always from high temperature medium to the lower temperature one and heat transfer stops when the two mediums reach the same temperature.When a system contains one or more components whose concentration vary from point to point, there is a natural tendency for mass to be transformed, minimizing the concentration differences within the system. The transport of constituents from a region of higher concentration to that of lower concentration is called mass transfer. Mass transfer flows have applications in meteorology, solar physics, cosmic fluid dynamics, astrophysics, geophysics and in the motion of the earth's core.

When new molecules are formed by the re-arrangement or re-distribution of the constituent atoms, a chemical reaction is said to occur. Chemical reactions are generally accompanied by the evolution or absorption of energy due to differences in the structures of the products and the reactants. Chemical kinetics deals with the quantitative study of the rate at which chemical reaction occur. This rate may vary from a very large value to essentially zero. In the presence of a strong magnetic field, the charged particles are tied to the lines of force, and this prevents their motion transverse to the magnetic field. Then the tendency of the current to flow in a direction normal to both the electric and magnetic fields is known as Hall effect and the corresponding current is known as Hall current.

In many engineering processes, heat and mass transfer take place simultaneously. The interest in analytical studies and experimental designs of heat pipes started growing rapidly in following the publication of Grover et. al. [4]. The flow along the vertical plate in the presence of heat and mass transfer was analyzed by Elbashbeshy [5]. The influence of heat and mass transfer with MHD free convection over a vertical surface was studied by Chen [6]. Makinde [7] presented the similarity solution of hydromagnetic heat and mass transfer over a vertical plate with a convective surface boundary condition. The combined effect of heat and mass transfer by natural convection from a semi-infinite plate submitted to a magnetic field with Hall current was investigated by Joaquin et. al.[8]. The heat and mass transfer flow past an infinite vertical plate with variable thermal conductivity heat source and chemical reaction was analyzed by Uwanta [9].

There is a great need from the industrial sector of different methods or techniques for augmenting the heat and mass transfer with chemical reaction in many areas so as to design reliable, economic and user-friendly devices that are specific to the required application. The purpose of the present analysis is to study the combined effect of heat, mass, chemical reaction, Magnetic parameter and Hall parameter in a porous medium.

2. Formulation of the Problem

Consider an incompressible electrically conducting, viscous fluid past an infinite vertical flat plate occupying the plane $y = 0$. The x-axis is taken in the direction of the motion of the plate and z-axis lying on the plate normal to both x and y-axis. Initially it is assumed that the y-axis normal to the plate are at the same temperature T and concentration C everywhere in the fluid. At time $t > 0$, the temperature of the plate is raised/lowered to T_∞ and the concentration is also raised/lowered to C_∞. A uniform magnetic field H_0, parallel to y-axis is imposed. The schematic representation of the problem is given below.

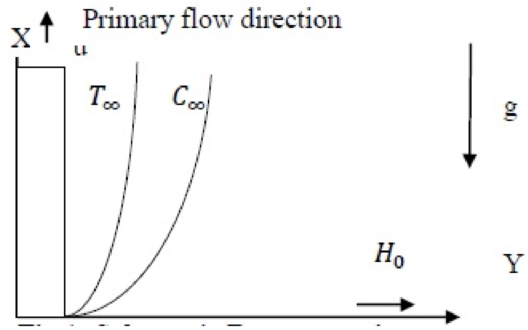

Fig 1 : Schematic Representation

All the fluid properties considered constant except that the influence of the density variation with temperature is considered. The influence of the density variation in other terms of the momentum and energy equation and the variation of the expansion coefficient with temperature is considered negligible. Under these assumptions, the governing boundary layer equations with Boussinesq's approximation are given by:

$$\text{Equation of continuity,} \quad \nabla \cdot \overline{q} = 0 \tag{1}$$

$$\text{Equation of motion,} \quad \frac{\partial q}{\partial t} + (\overline{q} \cdot \nabla)\overline{q} = v\nabla^2\overline{q} + \frac{1}{\rho}(\overline{J} \times \overline{B}) + \frac{1}{\rho}(\rho\overline{g}) - \frac{v}{k}\overline{q} \tag{2}$$

ρ is the density, v is kinematic viscosity, $\overline{H} = (H_x, H_0, H_z)$ is the magnetic induction, $\overline{J} \times \overline{B}$ is the Lorentz force, k is the permeability of the fluid and $\overline{g}$ is the acceleration due to gravity.

$$\text{The Energy equation,} \quad \rho C_P\left[\frac{\partial T}{\partial t} + (\overline{q} \cdot \nabla)T\right] = K\nabla^2 T \tag{3}$$

where C_p is the specific heat at constant pressure and K is the thermal conductivity.

$$\text{The Species Concentration equation,} \quad \frac{\partial C}{\partial t} + (\overline{q} \cdot \nabla)C = -k_1 C?C/?t + (q?.?)C = -k_1 C \tag{4}$$

where k_1 is the rate of chemical reaction.

$$\text{The Ohm's law,} \quad \frac{\overline{J}}{\sigma} = (\overline{E} + \overline{q} \times \overline{B}) - \frac{\overline{\times}\overline{B}}{n \cdot e} \tag{5}$$

where σ is the electrical conductivity, $\overline{J}$ is the current density, $\overline{E} = (E_x, 0, E_z)$ is the electro static field,ρ is density, v is kinematic viscosity, e is the electric charge, τ is the mean collision time, n is the electron number density and m_e is mass of an electron.

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

$$u = 0, T = T_w, C = C_w \quad \text{at} \quad y = 0$$

$$u = 0, T = T_\infty, C = C_\infty \quad \text{at} \quad y \to \infty. \tag{6}$$

Consider the following non dimensional parameters

$$u = \frac{u}{U_0}, t = \frac{tU_0^2}{v}, y = \frac{yU_0}{v}, T = \frac{T - T_\infty}{T_w - T_\infty}, C = \frac{C - C_\infty}{C_w - C_\infty}, N = \frac{\beta'(C_w - C_\infty)}{\beta(T_w - T_\infty)}$$

$$K = \frac{kU_0^2}{v^2}, P_r = \frac{v}{\alpha}, M = \frac{\sigma B_0^2 v}{\rho U_0^2}, M_1 = \frac{M}{1 + m^2}, Kc = \frac{K_c v}{U_0^2}, G_r = \frac{vg\beta(T_w - T_\infty)}{U_0^2} \tag{7}$$

where P_r is the Prandtl number, G_r is the Grashof number, N is the buoyancy term, M is the magnetic parameter, K is the permeability parameter, m is the hall current parameter, K_c is the chemical reaction parameter and . Under these conditions, the problem is governed by the following system of equation:

By introducing the non-dimensional parameters into the basic equations it reduces to

$$\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = G_r(T + NC) + \frac{\partial^2 u}{\partial y^2} - \left(M_1 \frac{1}{K}\right) u \tag{8}$$

$$\frac{\partial T}{\partial t} - \frac{\partial T}{\partial y} = \frac{1}{P_r} \frac{\partial^2 T}{\partial y^2} \tag{9}$$

$$\frac{\partial C}{\partial t} - \frac{\partial C}{\partial y} = K_c C \tag{10}$$

and the corresponding boundary conditions are given by

$$u = 0, \quad T = 1, \quad C = 1 \quad \text{at} \quad y = 0$$

$$u = 0, \quad T = 0, \quad C = 0 \quad \text{at} \quad y \to \infty \tag{11}$$

The equations (8)- (10) are solved by exact method with the assumptions

$$u(y, t) = u_0(y) e^{-nt}, \tag{12}$$

$$T(y, t) = T_0(y) e{-}nt, \tag{13}$$

$$C(y, t) = C_0(y) e^{-nt} \tag{14}$$

The solutions of Equations satisfying the boundary conditions are givenby

$$u = [(A_1 + A_2) e^{-m_3 y} - A_1 e^{-m_1 y} - A_2 e^{-m_2 y}] e^{-nt}$$

$$T = e^{-m_1 y} e^{-nt}$$

$$C = e^{-m_2 y} e^{-nt}$$

where the constants m_1, m_2, m_3, A_1, A_2 used above are functions of the physical parameters involved in the problem.

3. Result and Discurrion

The aim of this study is to analyze the effect of Hartmann number, Hall Parameter, heat transfer, mass transfer and chemical reaction in a porous medium. To get a physical insight into the problems, various graphs are drawn as follows.

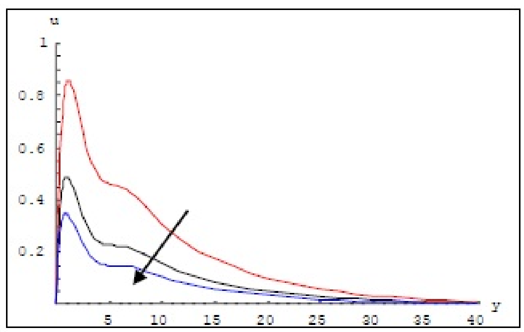

Fig 2. Velocity u versus y, under the effect M=2,4,6, for Pr = 0.71, m = 0.5, Gr = 1, Kc = 0.02, K = 100.

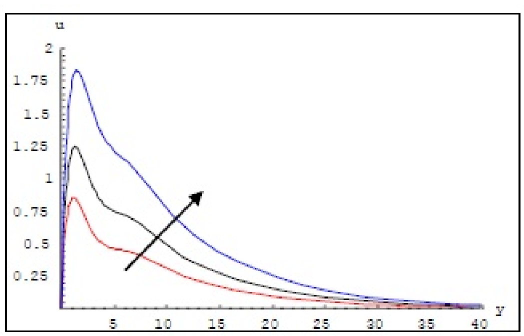

Fig 3. Velocity u versus y, under the effect m=0.5,1,1.5, for Pr=0.71, Gr = 1, M = 2, Kc = 0.02, K=100.

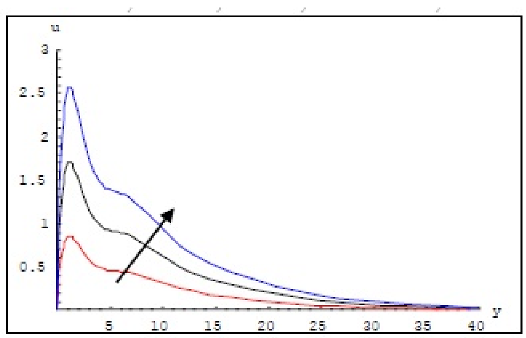

Fig 4. Velocity u versus y, under the effect Gr=1,2,3, for Pr =0.71, m = 0.5, M = 2, Kc = 0.02, K = 100.

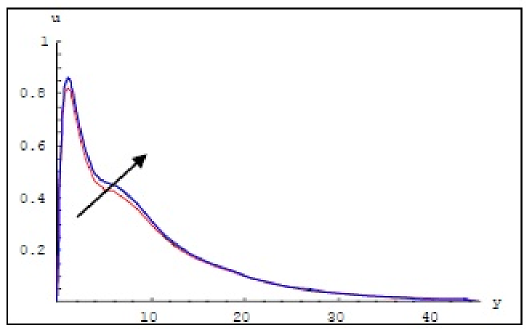

Fig 5 : Velocity u versus y, under the effect $K = 10, 100, 200$, for $P_r = 0.71, m = 0.5, G_r = 1, K_c = 0.02, M = 2$.

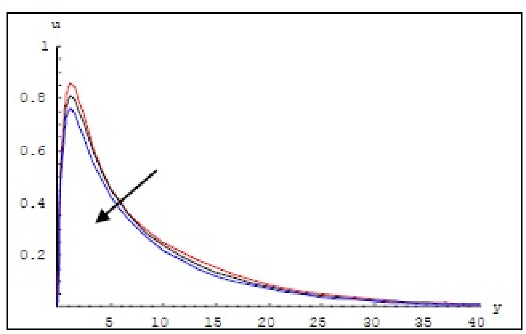

Fig 6. Velocity u versus y, under the effect Kc=1,2,3, for Pr = 0.71, m = 0.5, Gr = 1, K=100, M = 2.

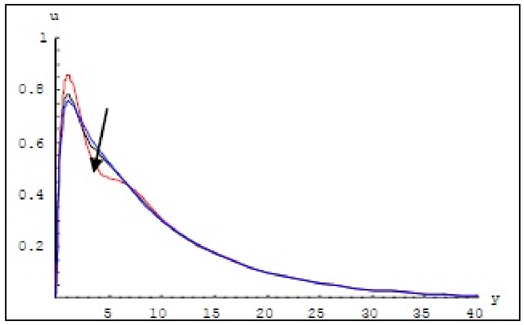

Fig 7. Velocity u versus y, under the effect Pr = 0.71, 1.25, 1.75, for m = 0.5, Gr = 1, Kc = 0.02, M = 2, K=100.

From the graph the following results are obtained.

Figure 2 shows velocity for various values of Hartmann number. When the strength of the magnetic field is increased, the velocity of the fluid decreases.This is due to the established fact that the application of a magnetic field to an electrically conducting fluid gives rise to a force, known as Lorentz force, which tends to resist the fluid motion. The effect of Hall parameter in velocity profile is depicted in the figure 3. It clearly show that the velocity increases with increase in Hall parameter.

Figure 4 clearly show the effect of thermal Grashof number in velocity component. The significance of Grashof number represents the ratio between the buoyancy force due to density variation to the viscous force of the fluid. The positive values of Grashof number indicate the cooling effect near the plate. Figure clearly show that the velocity increases with increasing values of thermal Grashof number.

When the Porosity parameter is increased the velocity profiles also increases. The graph 5 depicts the variation of velocity for various values of porosity parameter.

The effect of Chemical reaction parameter on the velocity are indicated through the figure 6. When the value of chemical reaction parameter is increased, velocity profile retard in its motion.

Prandtl number being the ratio of momentum diffusivity to the thermal diffusivity induces the temperature. The effect of Prandtl number on velocity component is depicted in the graph 7. Here it is observed that the velocity decreases with increasing values of Prandtl number.

4. Conclusion

In this paper, an attempt is made to study the effect of Hall current and Chemical reaction in MHD flow with Heat and Mass transfer over a porous medium. From the results and discussion, the conclusion is the Velocity profile is accelerated when the Hall parameter, Grashof number and porosity parameter are increased but it has the reversal effect with Hartman number, Prandtl number and Chemical reaction.

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