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Impact of Radiation and Chemical Reaction on Magnetohydrodynamic Flow over a Vertically Moving Porous Plate.

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Abstract

This study investigates the impact of magnetohydrodynamic force and buoyancy on convective heat and mass transfer flow along a moving vertical porous plate, considering the presence of thermal radiation and chemical reaction. The governing partial differential equations are transformed into a set of self-similar equations using similarity transformations. These resulting equations are then numerically solved employing the fourth-order Runge-Kutta method in conjunction with the shooting technique. The outcomes encompass velocity, temperature, concentration, skin-friction, Nusselt number, and Sherwood number.

Introduction

Natural convection occurs within a fluid when temperature variations lead to changes in density, prompting buoyancy forces to act on fluid elements. Recently, the exploration of heat and mass transfer in free convective flows through porous media under the influence of a magnetic field has garnered significant attention from researchers. This interest arises due to the potential applications across diverse scientific and technological domains, including cooling strategies for re-entry vehicles and rocket boosters, surface texturing on ablative materials, and film vaporization within combustion chambers. Among the fundamental models of such flows, the simplest is the two-dimensional laminar free convection along a vertical flat plate. Numerous researchers, such as Merkin [1], Lloyd and Sparrow [2], Wilks [3], and Raju et al. [4], have extensively investigated various aspects of this flow type. In parallel, flows through porous media hold substantial importance in engineering and geophysical contexts. Applications span chemical engineering, encompassing filtration and purification processes, as well as agriculture engineering for assessing underground water resources. Additionally, flows through porous media find relevance in petroleum technology, aiding the study of natural gas, oil, and water movement within oil reservoirs. Given these practical applications, a multitude of researchers have explored magnetohydrodynamic (MHD) free convective heat and mass transfer flows within porous media. Notably, Raptis [5] conducted an investigation into flow through a porous medium in the presence of a magnetic field.

Consequently, the aim of this study is to examine the influence of thermal radiation on the dynamics of magnetohydrodynamic (MHD) free convection flow along a vertically moving porous plate [6]. This investigation takes into account both thermal radiation effects and a first-order chemical reaction. The governing equations undergo an unsteady similarity transformation, leading to a set of dimensionless equations [7-9]. These equations are then solved numerically through the application of the shooting technique. By analyzing the obtained solutions, we assess the impact of diverse governing parameters on the velocity, temperature, and concentration profiles [10].

Mathematical analysis

Examine an unsteady, two-dimensional free convection flow occurring within a viscous, incompressible, electrically conducting fluid [11-13]. This fluid possesses thermal radiation and

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chemical reaction properties. The flow takes place along a vertically moving porous plate submerged in a porous medium. The x-axis is aligned with the plate, oriented upward, while the y-axis is perpendicular to the plate.

Conservation of mass

$$\frac{\partial v}{\partial y} = 0 . \tag{2.1}$$

Conservation of momentum

$$\frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2} + g\beta(T - T_\infty) + g\beta^*(C - C_\infty) - \frac{\sigma B_0^2}{\rho}u - \frac{\nu}{K^*}u . \tag{2.2}$$

Conservation of energy

$$\rho c_p\left(\frac{\partial T}{\partial t} + v\frac{\partial T}{\partial y}\right) = k\frac{\partial^2 T}{\partial y^2} - \frac{\partial q_r}{\partial y} . \tag{2.3}$$

Conservation of concentration

$$\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} - Kr^*(C - C_\infty) \tag{2.4}$$

The boundary conditions for the velocity, temperature and concentration are

$$\begin{aligned} &t \le 0: u = 0, \quad v = 0, \quad T = T_\infty, \quad C = C_\infty \quad \text{for all} \quad y, \\ &t > 0: \begin{cases} u = U, \quad v = v(t), \quad T = T_w, \quad C = C_w \quad \text{at} \quad y = 0, \\ u \to 0, \quad v \to 0, \quad T = T_\infty, \quad C = C_\infty \quad \text{as} \quad y \to \infty. \end{cases} \end{aligned} \tag{2.5}$$

$$q_r = -\frac{4\sigma_s}{3k_e}\frac{\partial T^4}{\partial y} . \tag{2.6}$$

Results

We address the scenario of unsteady magnetohydrodynamic (MHD) free convection fluid flow passing over a vertically moving porous plate situated within a porous medium. This study incorporates thermal radiation, chemical reaction, and the influence of suction. It physically relates the relative thickness of the hydrodynamic boundary layer and mass transfer (concentration) boundary layer. As the Schmidt number Sc increases the concentration decreases. This causes the concentration buoyancy effects to decrease yielding a reduction in the fluid velocity.

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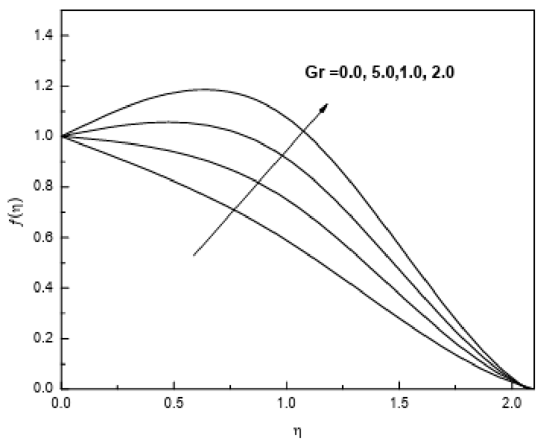

Fig.1. Velocity profiles for different values of Gr.

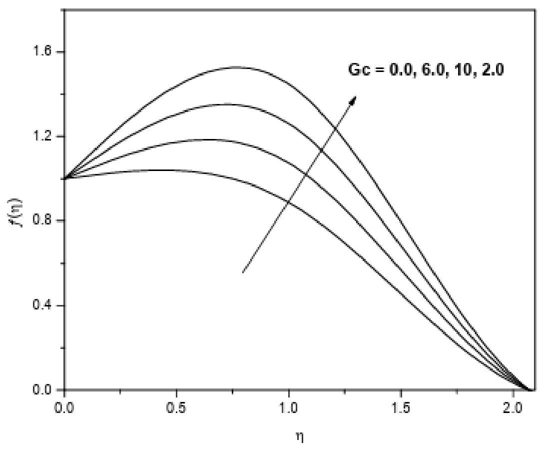

Fig.2. Velocity profiles for different values of Gc.

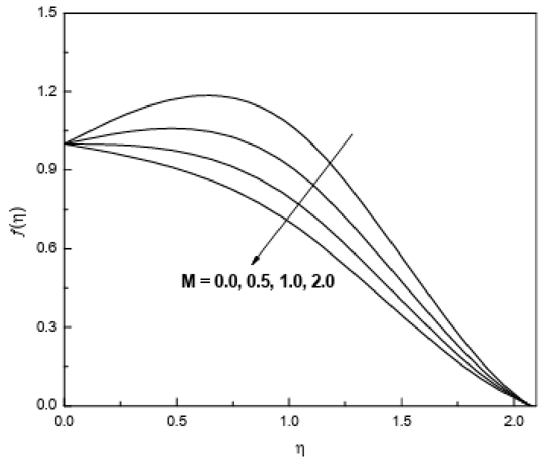

Fig.3. Velocity profiles for different values of *M*.

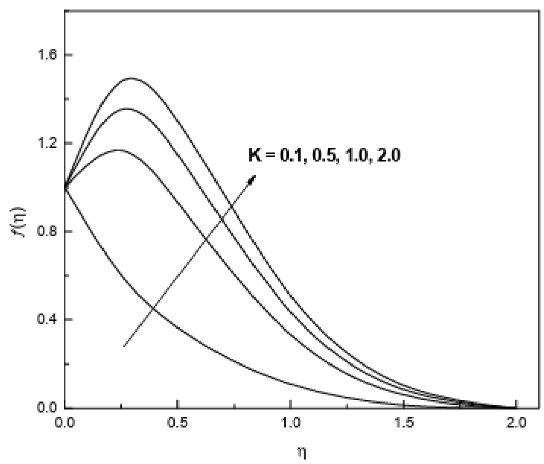

Fig.4. Velocity profiles for different values of *K*.

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