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ANALYSIS OF MHD MIXED CONVECTION FLOW PAST A STRETCHING SHEET IN POROUS MEDIUM

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ABSTRACT

In this study, we are examining the combined effects of magnetohydrodynamics (MHD), with mixed convective flow over a linearly stretching sheet imbedded in a porous medium. The mathematical formulation utilizes appropriate similarity transformations to generate a system of coupled, nonlinear ordinary differential equations (ODEs) that are influenced by important physical parameters on velocity, temperature, and concentration fields. The Runge-Kutta-Fehlberg (RKF) method is employed to numerically solve these ODEs. The dimensionless velocity, and temperature profiles are graphically illustrated and discussed in detail in relation to the effects of a variety of governing parameters, such as the magnetic parameter, Eckert number, and porosity parameter. Potential applications in industrial, chemical, and engineering processes are provided by the results, which offer valuable insights into the behavior of MHD flows in porous media environments.

1. INTRODUCTION

The investigation of the boundary layer behavior of a fluid over a continuously stretching surface reveals numerous significant applications in engineering processes. Some of these applications include the production of glass fiber and paper, the extrusion of polymers, the drawing of plastic films and filaments, the growth of crystals, and the processing of liquid films in the condensation process. The study of fluid flow and heat transmission over a stretching sheet has been rekindled by the ever-increasing applications of these industrial processes. In the past few years, there has been a significant amount of research conducted to investigate the flow and thermal transfer of fluids as they pass through a stretching surface. A stretching sheet is a traditional model that is employed to investigate boundary layer fluxes in which the surface velocity is dependent on distance. The development of boundary layer flow analysis over a stretching plate was initiated by Crane [1]. A subsequently expanded to encompass heat and mass transfer effects having applications in Metallurgy, glass fiber production, and plastic sheet manufacturing are all dependent on the stretching of sheet fluxes with suction reported by Gupta and Gupta [2]. Takhar et al. [3] conducted a study on the flow and mass transfer on a stretching sheet with a magnetic field. They found that the magnetic field substantially increases the surface skin friction, while the surface mass transfer is slightly reduced. Hayat et al. [4] carried out research on the mixed convection flow of a micropolar fluid across a non-linearly stretching sheet. Cebeci and Bradshaw [5] explored the physical and computational aspects of convective heat transfer. Singh and Poply [6] investigated the influence of free stream velocity and variable heat flux on a permeable stretching surface. The effects of unconstrained stream velocity on the suction parameter, heat generation parameter, and heat flux parameter on heat transfer and flow predominance have been the subject of the current investigation.

Lorentz forces are introduced by the application of a transverse magnetic field, which alter flow behavior by inducing electrical currents and damping effects. MHD flows are indispensable in aerospace propulsion systems, plasma confinement, and nuclear reactors. Many researchers focus on the chemical effects on MHD fluid flow over linear stretching sheets within a porous medium (PM), given its wide-ranging applications in aerodynamics, geophysics, and astrophysics. Singh et al. [7] have investigated the impact of porosity parameter on the MHD flow those results from the straining of a sheet in porous media. Mukhopadhyay [8] conducted an analysis of the flow of the boundary layer over a porous nonlinearly stretching sheet with partial slip at the boundary. She stated that the suction parameter has the effect of suppressing the velocity field, which in turn results in an increase in the skin-friction coefficient for a viscous incompressible fluid. Alhadhrami et al. [9] have conducted a numerical simulation of the flow and heat transmission of a non-Newtonian Casson fluid in a porous media. Ahmad et al. [10] performed a study on the MHD flow of a viscous fluid over an exponentially stretching sheet in a porous medium. In a porous medium, Jat et al. [11] have conducted MHD heat and mass transfer for viscous flow over a nonlinearly stretching sheet. In their study, Mandal and Mukhopadhyay [12] examined the heat transfer analysis of fluid flow over an exponentially stretching porous sheet with surface heat flux in a porous medium. It has been determined that the skin-friction coefficient increases as the permeability parameter and the suction parameter are increased. Devi et al. [13] researched the influence of aligned MHD flow with an inclined outer velocity on a Casson nanofluid over a stretching sheet. Taneja et al. [14] investigated the fluid properties of an erratic MHD free stream flow over a stretching sheet in the presence of radiation. Connective heat transport over stretching sheet has been discussed by Vajravelu and Nayfeh [15].

Mixed convection is a phenomenon that influences various environments, such as the cooling of electronic devices, the climatic effects of lakes and oceans, reservoirs, greenhouse conditions, and soil moisture. It arises from the combination of free and forced convection. Over the years, numerous researchers have explored fluid movement over-stretching sheets. The analysis of heat transfer in fluids over linear stretching sheets, particularly in the presence of chemical reactions, plays a crucial role in applications such as nuclear reactors, heat exchangers, geothermal systems, chemical engineering, and solar physics. Many studies have focused on the effects of chemical reactions on stretching sheets. This research aims to examine the impact of mixed convection on magnetohydrodynamic flows over a linear stretching sheet within a porous medium (PM). The study presents graphical representations of the effects of various flow parameters on dimensionless velocity, temperature, and concentration in the transformed ordinary differential equations (ODEs). The problem is solved numerically using the RKF Method.

2. MATHEMATICAL FORMULATION

We investigate two-dimensional, steady, incompressible fluid flow over a linear stretching sheet subjected to a chemical reaction. In this model, shown in Fig. 1, the y-axis oriented normally to the sheet and the x-axis aligned with the direction of the sheet. Two identical yet distinct forces act along the x-axis, leading to the linear stretching of the sheet. Furthermore, a uniform transverse magnetic field B is applied along the flow direction. It is also assumed that the movement of the fluid generates a negligible induced magnetic field.

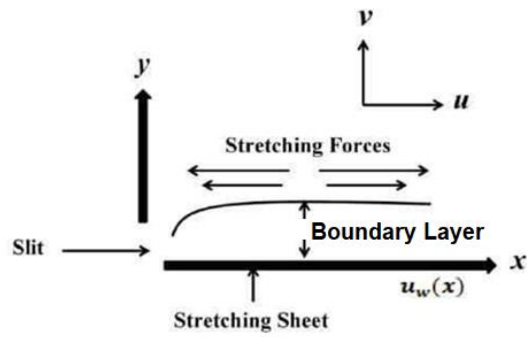

Fig. 1: Schematic diagram of problem

The continuity, momentum, and energy equations for steady, incompressible flow are

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}-\left(\frac{\sigma B^2}{\rho}+\frac{\nu}{K}\right)u+g\beta_T(T-T_\infty) \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2} \tag{3}$$

u is velocity components in x direction and v is velocity components in y direction, ν is kinematic viscosity, σ is the electrical conductivity, ρ is the fluid density, g is the gravitational force due to acceleration, β_T is thermal expansion coefficient, , k is the heat conductivity, and B is the magnetic intensity.

The corresponding B.C.'s are:

$$u=u_w=ax,\quad v=0,\ T=T_w, \qquad at \quad y=0 \qquad 5(a)$$

$$u\to 0,\qquad T\to T_\infty \qquad at \quad y\to\infty \qquad 5(b)$$

3. SIMILARITY TRANSFORMATION

$$u=\frac{\partial\psi}{\partial y},\qquad v=-\frac{\partial\psi}{\partial x} \qquad 6(a)$$

$$\psi=\sqrt{a\nu}\,xf(\eta),\ \eta=\sqrt{\frac{a}{\nu}}\,y,\quad \theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty}, \qquad 6(b)$$

The governing equation (1)- (4) then reduce to

$$f'''+ff''-(f')^2-Mf'+\lambda\theta-K^*f'=0 \tag{7}$$

$$\theta''+\Pr f\,\theta'=0 \tag{8}$$

The transformed boundary condition is

$$\eta=0,\quad f=0,\quad f'=1,\quad \theta=1 \qquad 10(a)$$

$$\eta\to\infty,\quad f'=0,\quad \theta=0, \qquad 10(b)$$

The key thermophysical parameters are defined by:

$$K^* = \frac{V}{Ka}, \qquad M = \frac{\sigma B^2}{\rho a}, \qquad \lambda = \frac{g\beta_T(T_w - T_\infty)}{a^2 x}, \qquad P_r = \frac{V}{\alpha} \qquad 11(a)$$

Here K^*, M, λ, P_r, enotes the porous parameter, magnetic parameter, mixed convection parameter, Prandtl number,

4. RESULTS AND DISCUSSION

The resulting equations (7) to (9), along with the boundary condition (10), are solved analytically using MATLAB software, employing the RKF Method.

Figures 2 and 3 illustrate the effects of magnetic parameter on the velocity and temperature, profiles graphically. In Figure 2, it is observed that the velocity profiles decrease as the magnetic parameter increases. An increase in M leads to declines fluid velocity due to the increased resistance. Additionally, Figure 3 shows that the temperature profiles increase with higher values of the magnetic parameter as fluid velocity decreases.

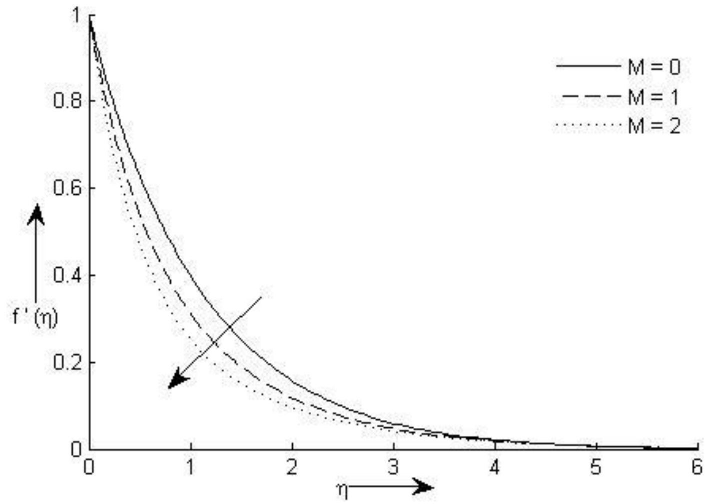

Fig. 2: Velocity for distinct *M*

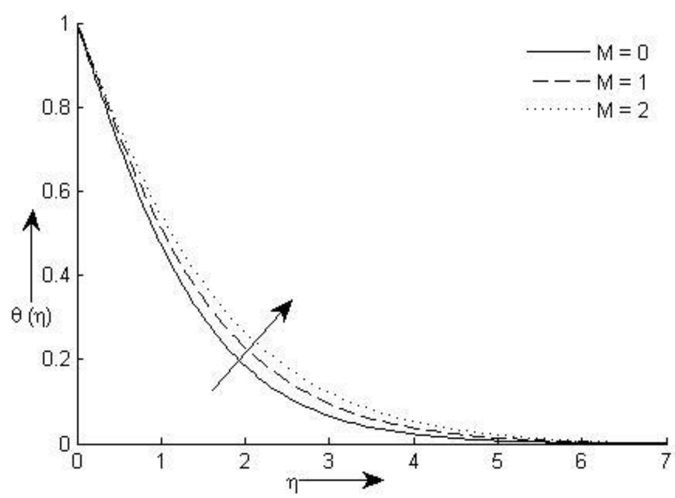

Fig. 3: Temperature for distinct *M*

Figures 4 and 5 illustrate the effects of mixed convection parameter on the velocity and temperature, profiles graphically. In Figure 4, it is observed that the velocity profiles increase as the mixed convection increases. An increase in λ leads to increasing the influence of buoyancy forces relative to forced convection. Furthermore, Figure 5 shows that the temperature profiles declines with higher values of the mixed convection as fluid velocity rises.

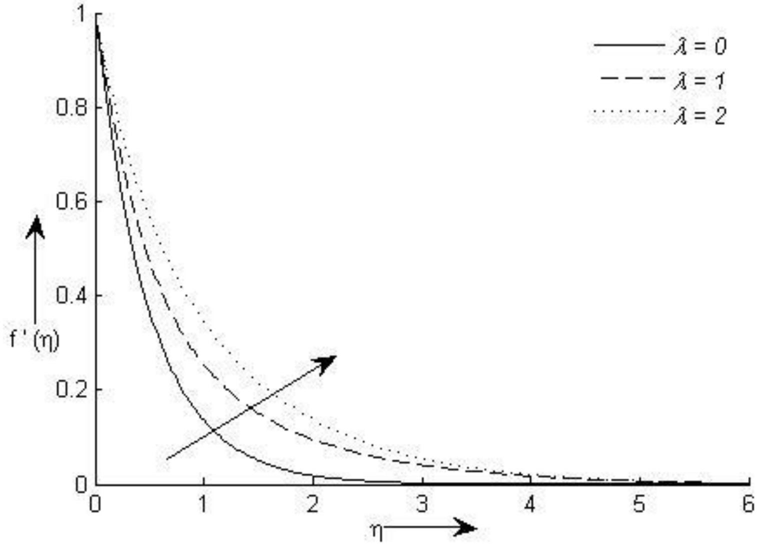

Fig. 4: Velocity for distinct λ

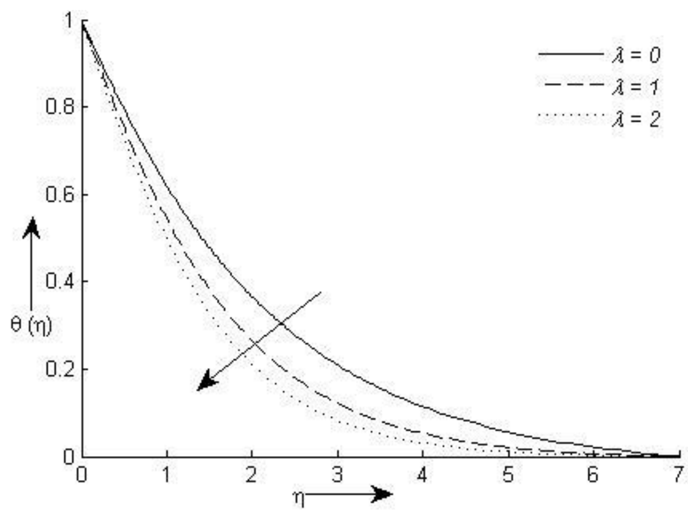

Fig. 5: Temperature for distinct λ

Figures 6 and 7 illustrate the effects of porous parameter on the velocity and temperature, profiles graphically. In Figure 6, it is observed that the velocity profiles decrease as the porous medium increases. An increase in K^* leads to increasing the porosity in the medium. Also, Figure 7 shows that the temperature profiles rises with higher values of the porosity as fluid velocity declines.

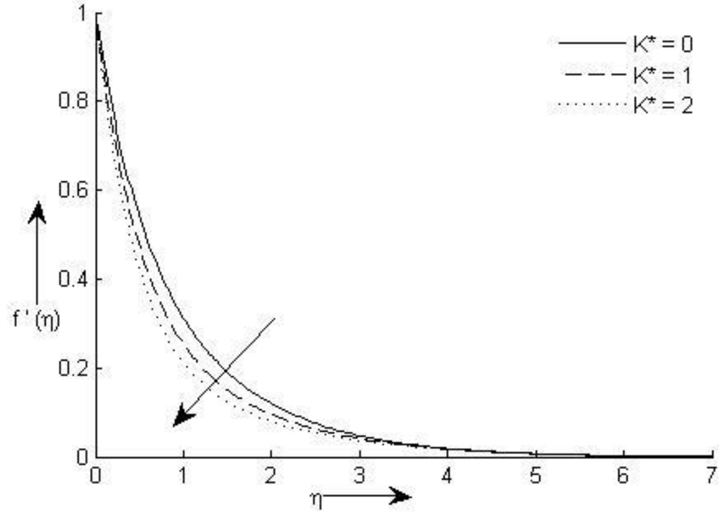

Fig. 6: Velocity for distinct K^*

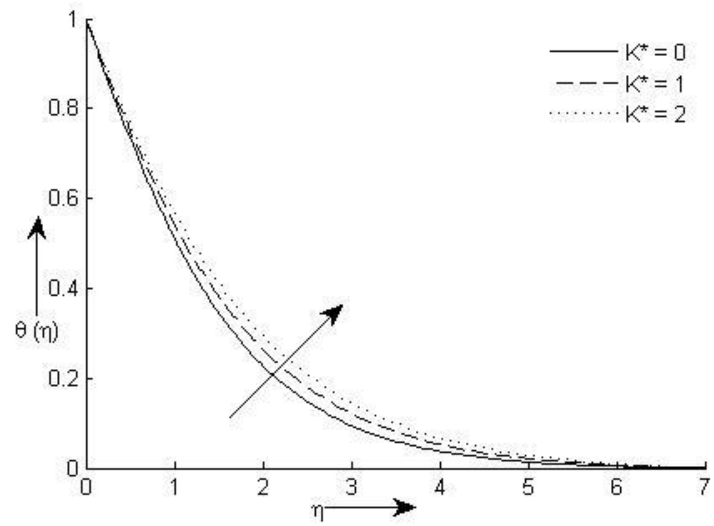

Fig. 7: Temperature for distinct K^*

5. CONCLUSION

This study investigates the numerical solution of the MHD mixed convection flow over a linear stretching sheet in porous media. The RKF method has successfully been implemented to carry out a relative analysis. Under the impact of various physical conditions, the performance of dimensionless velocity, temperature profiles are discussed. The important observations of this report are outlined and detailed below:

- The velocity decline as the values of magnetic and porous parameter increases.
- The velocity decreases as mixed convection parameter increases
- The temperature profiles rise with increasing magnetic and porous parameter.
- The temperature decreases with increasing xed convection parameter

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CONFLICT OF INTEREST

None.

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