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MHD FLOW OF FLUID-PARTICLE SUSPENSION OVER AN IMPERMEABLE SURFACE THROUGH A POROUS MEDIUM OVER AN INCLINED STRETCHING SHEET

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ABSTRACT

The analysis has been carried out to study the flow of dusty fluid over an inclined stretching sheet in a porous medium, where the flow is generated due to linear stretching sheet and influenced by uniform magnetic field. The governing partial differential equations for the flow are transformed into coupled non-linear ordinary differential equations using the suitable similarity transformation. The resultant system of ordinary differential equations is then solved numerically using Runge-kuttaFehlberg fourth- fifth method. The effects of different flow parameters like fluid-particle interaction parameter, magnetic parameter, permeability parameter, Prandtl number and Eckert number on the velocity are computed and presented graphically.

Keywords: MHD, Dusty Fluid, Heat Transfer, Flip Flow and Convective Boundary Condition

1. INTRODUCTION

Consider two-dimensional steady laminar boundary layer flow of an incompressible viscous dusty fluid over a vertical stretching sheet which is inclined with an acute angle α. The x-axis moves along the stretching surface in the direction of motion with the slot as the origin, and the y-axis is measured normally from the sheet to the fluid. Further, the flow field is exposed to the influence of an external transverse magnetic field of strength B_0 (along y-axis) as shown in Figure 1.

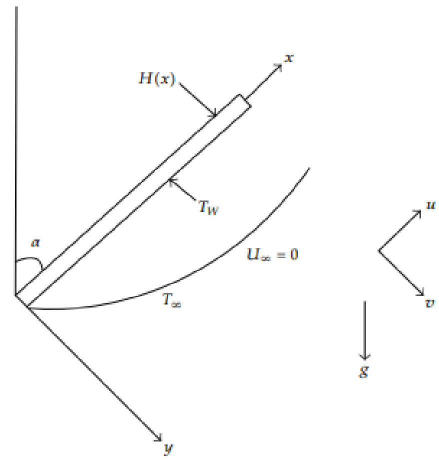

Figure 1 Flow diagram of problem

The analysis of the present paper is based on the following assumptions:

1) The particles of dusty fluid are assumed spherical in shape having uniform radius and non deformable nature.
2) Reynolds number of the relative motion between dust and fluid is small compared to unity.
3) The induced magnetic field is neglected as the magnetic Reynolds number is small.
4) The number density of the dust particles is constant throughout the motion.

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad (1)$$

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=\mu\frac{\partial^2 u}{\partial y^2}+kN(u_P-u)-\sigma B_0^2 u-\frac{v}{k_p}u+g\beta^*(T-T_\infty)cos \propto \quad (2)$$

Dust Phase:

$$u_P\frac{du_p}{\partial x}+v_p\frac{\partial u_P}{\partial y}=\frac{k}{m}(u-u_P) \quad (3)$$

$$u_P\frac{\partial v_p}{\partial x}+v_p\frac{\partial v_p}{\partial y}=\frac{k}{m}(v-v_p) \quad (4)$$

$$\frac{\partial(Nu_P)}{\partial x}+\frac{\partial(Nv_p)}{\partial y}=0 \quad (5)$$

Where (u,v) and (u_p,v_p) are the velocity component of the fluid and dust particle phase along the x and y direction respectively.μ,ρ and N are the co-efficient of viscosity of the fluid, density of the fluid, number density of the particle phase, ρ is the fluid electrical conductivity, B_0 is the induced magnetic field, k_p permeability of the porous medium, K is the stokes's resistance (drag co-efficient), m is the mass of the dust particle. In deriving these equations, the drag force is considered for the interaction between the fluid and particle phases.

Boundary condition:

$u=u_w(x)$, v=0 at y=0

$u\to 0$, $u_P\to 0$, $v_P\to 0$ $N\to\omega\rho$ as $y\to\infty$ (6)

Where $u_w(x)=cx$ is the stretching sheet velocity, c > 0 is stretching rate,ω is the density ratio

To convert the governing equations into a set of similarity equations, we introduce the following transformation as mentioned below,

$u = cxf'(\eta), \quad v = -\sqrt{vc} \quad f(\eta), \eta = \sqrt{\frac{c}{v}}y,$

$u_P = cxF(\eta), \quad v_P = \sqrt{vc}\,G(\eta), \quad \rho_r = H(\eta).$ (7)

Where ρ_r=N/ρ is the relative density.

The transformations defined in equation (7) are identically satisfies (1). Substituting (7) into (2) to (5),

We obtain the following non-linear ordinary differential equations,

$f'''(\eta) + f''(\eta)f(\eta) - [f'(\eta)]^2 + l^*\beta H(\eta)[F(\eta) - f(\eta)] + G(\eta)cos \propto - \left(Q + \frac{1}{S}\right) f'(\eta) = 0$ (8)

$G(\eta)F'(\eta) + [F(\eta)]^2 + \beta[F(\eta) - f'(\eta)] = 0,$ (9)

$G(\eta)G'(\eta) + \beta[f(\eta) + G(\eta)] = 0,$ (10)

$H(\eta)F(\eta) + H(\eta)G'(\eta) + G(\eta)\mathrm{H}'(\eta) = 0,$ (11)

Where a prime denotes differentiation with respect to ηand $G_r = \frac{g\beta^*(T_n - T_\infty)}{c^2 x}$, $l^* = m\frac{N}{\rho}$, $\tau = \frac{m}{k}$ is the relaxation time of the partical phase, β=1/cτ is the magnetic parameter,

$S = \frac{Ck_p}{v}$ the permeability parameter.

The boundary conditions defined as in (6) will reduces to

$f(\eta) = 0,\ f'(\eta) = 1\ at\ \boldsymbol{\eta} = 0, G(\eta)$

$f'(\eta) = 0, F(\eta) = 0, G(\eta) = -f(\eta), H(\eta) = \omega\ as\ \boldsymbol{\eta} \to \infty.$ (12)

2. RESULTS AND DISCUSSIONS

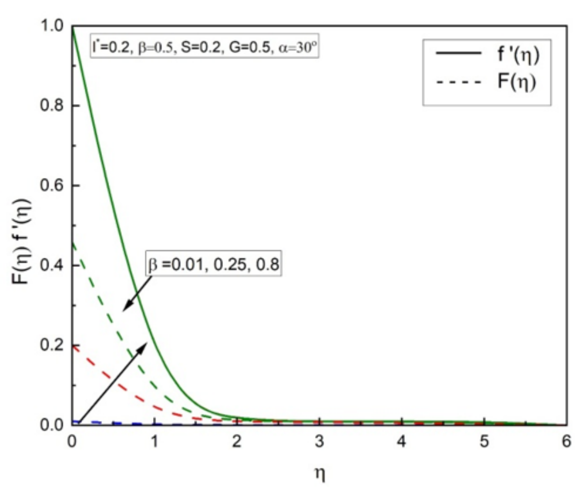

Figure 2. Effect of fluid particle interaction parameter on velocity distribution

The velocity distribution with η for various values of fluid particle interaction parameter β is as shown in figure 2. It clearly shows that if β increases we can find the decrease in the fluid phase velocity and increase in the dust phase velocity. Further from figure 2, it reveals that for the large values of β i.e., the relaxation time of the dust particle decreases ultimately as it tends to zero then the velocities of both fluid and dust particle will be same.

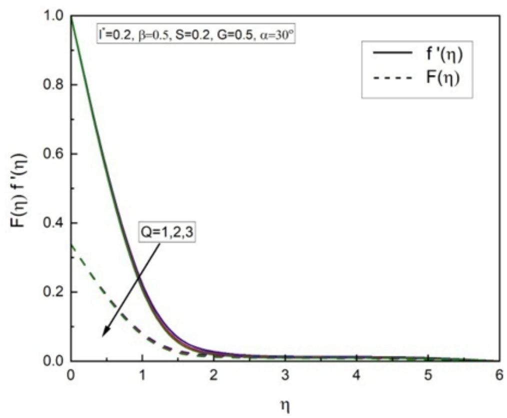

Figure 3. Effect of magnetic parameter on velocity distribution

Figure 3, illustrates the variation of velocity profile with ηfor various values of Q. From this plot it is observed that the effect of increasing values of Q is to decrease the velocity distribution of both the fluid and dust phases. This is due to the fact that the presence of a magnetic field normal to the flow in an electrically conducting fluid produces a Lorentz force, which acts against the flow.

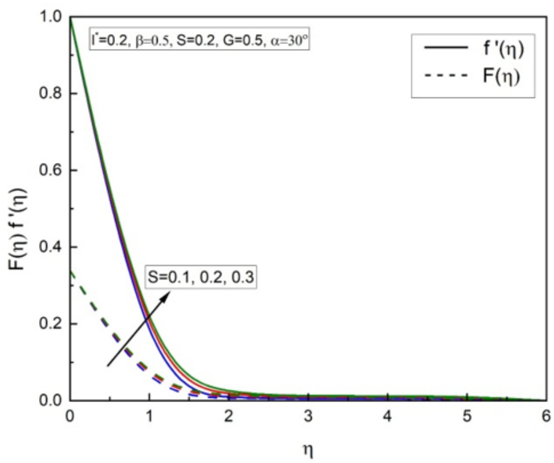

Figure 4. Effect of permeability parameter on velocity distribution.

Variation of velocity profile for different values of permeability parameter S is depicted in figure 4, demonstrate the effects of permeability parameter on velocity profiles. It is observed that with increasing permeability parameter, the resistance to the fluid motion also increases and hence velocity decreases

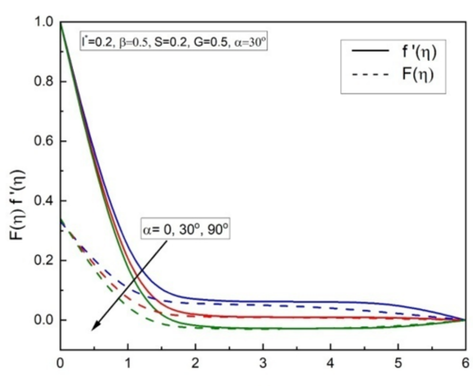

Figure 5. Velocity profile for different values of angle of inclination.

The graph of velocity profiles for typical angles of inclination α 0 ∘ , 30 ∘ , 90 ∘ versus η is plotted in Figure 4. It is noted that the angle of inclination increases, and the velocities of fluid and dust phase decrease.

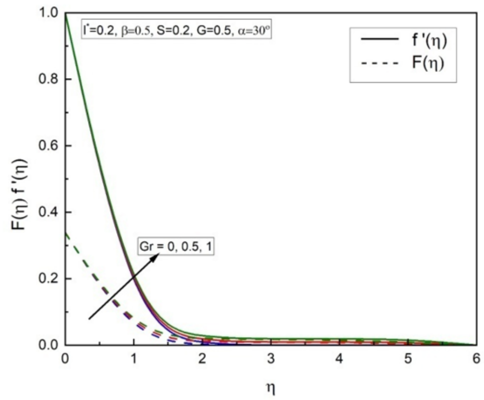

Figure 6. Velocity profile for different values of local Grashof number.

The graph of local Grashof number Gr on the velocity field is shown in Figure 6. From this plot, it is observed that the effect of increasing values of local Grashof number is to increase the velocity distribution of both the fluid and dust phases.

3. CONCLUSION

The paper addresses the MHD flow of fluid-particle suspension over an impermeable surface through a porous medium over an inclined stretching sheet in presence of connective boundary conditions. The effects of various parameters on the flow are observed from the graphs and summarized as follows:

- Fluid particle interaction parameter increases we can find the decrease in the fluid phase velocity and increase in the dust phase velocity.
- Increasing values of magnetic parameter is to decrease the velocity distribution of both the fluid and dust phases.
- Increasing permeability parameter, the resistance to the fluid motion also increases and hence velocity decreases
- The angle of inclination increases, and the velocities of fluid and dust phase decrease.
- The effect of increasing values of local Grashof number is to increase the velocity distribution of both the fluid and dust phases.

CONFLICT OF INTERESTS

None.

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None.

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