MAGNETOHYDRODYNAMIC FLOW OVER A STRETCHING SHEET EMBEDDED WITH POROUS MEDIUM IN THE PRESENCE OF SUSPENDED DUST PARTICLES UNDER THE CONSIDERATION OF SLIP CONDITION.

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Abstract

The MHD viscous two-phase dusty flow and heat transfer over a stretching sheet in the presence of suspended particles are studied. The wall boundary is subjected to a linear deformation and a quadratic surface temperature. The impact of various pertinent parameters for the velocity and temperature profiles are analyzed through detailed graphs.Also, friction factor are discussed and presented in Table.

Keywords: MHD, dusty fluid, heat transfer, flip flow and convective boundary condition.

Formulation

Consider a steady two-dimensional flow over a stretching sheet through a quiescent incompressible viscous electrically conducting non-newtonian walter's dusty fluid embedded with porous medium. The stretching/shrinking sheet coincides with the plane $y = 0$. It is assumed that the velocity of the sheet is linear, that is $u_w(x) = cx$, with $c > 0$ for a stretching sheet and $c < 0$ for a shrinking sheet. A uniform magnetic field B_0 is applied in the transverse direction $y > 0$ normal to the plate.

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

- The particle of dusty fluid is assumed to be spherical in shape, having a uniform radius and a non-deformable nature
- Reynolds number of the relative motion between dust and fluid is small compared to unity.
- The number density of the dust particle is constant through the motion.

Under these assumptions, along with the usual boundary layer approximations, the governing equations for the flow are,

Fluid Phase

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}+\frac{KN}{\rho}\left(u_p-u\right)+\frac{\sigma B_0^2}{\rho}u, \quad (2)$$

Dust Phase

$$\frac{\partial u_p}{\partial x}+\frac{\partial v_p}{\partial y}=0, \quad (3)$$

$$u_p\frac{\partial u_p}{\partial x}+v_p\frac{\partial u_p}{\partial y}=\frac{K}{m}\left(u-u_p\right), \quad (4)$$

with the fluid and dust particle boundary conditions

$$u=u_w+K_1\frac{\partial u}{\partial y}, v=0, \text{ at } y=0,$$

$$u\to 0, u_p\to 0, v_p\to v, \text{ as } y\to\infty. \quad (5)$$

In the above expressions, where here (u, v) and (u_p, v_p) are the velocity components of the fluid and dust particle phases along x and y directions, respectively. ν, N, ρ are the kinematic viscosity of the fluid, the number of dust particles per unit volume and the density of the fluid, respectively.m is the mass of the dust particle.K_1 is the velocity slip factor, (1),

The mathematical analysis of the current physical problem is simplified by introducing the subsequent similarity transformations based on the dimensionless boundary layer coordinate η,

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

$$u_p=cxF'(\eta),\; v_p=-\sqrt{c\nu}F(\eta), \quad (6)$$

The governing equations of motion for the two-phase fluid flow and (2), (3), and (4) are then reduced to,

Fluid Phase

$$f'''+f\,f''-(f')^2+k_1(f'f'''-ff''''-(f'')^2)+\ l\beta_v[F'-f']-(M+k_p)\,f'(\eta)=0, \quad (7)$$

Dusty Phase

$$F'^2-F\,F''+\beta_v[F'-f']=0, \quad (8)$$

The corresponding boundary conditions will take the following form,

$$f'(\eta)=1+Bf''(\eta),\;\; f(\eta)=0 \quad \text{at} \quad \eta=0, \quad (9)$$

$$f'(\eta)\to 0 \quad F'(\eta)\to 0,\;\; F(\eta)\to f(\eta) \text{ as } \eta\to\infty, \quad (10)$$

Where$l=\frac{\rho_p}{\rho}$ is the mass concentration of dust particles.$\rho_p=Nm$, standing for the density of the particle phase. $\beta_v=\frac{1}{c\tau_v}$ is the fluid particle interaction parameter for velocity, $\gamma=\frac{c_m}{c_p}$ is the specific heat parameter. $M=\frac{\sigma B_0}{\rho c}$ is the magnetic parameter and $B=K_1\sqrt{\frac{c}{\nu}}$ is the velocity slip parameter.

Numerical Method and Result and Discussion

The nonlinear ordinary differential equations (9)-(12), along with the boundary conditions (13) are solved numerically using the RKF-45 order method. In our numerical computations, the step size is chosen as $\Delta\eta = 0.001$and the convergence criteria were set to 10^{-6}.We have presented the non-dimensional velocity profile shown in Figure 2-16 for several values of different physical parameters. To validate the employed method, the authors have compared the results of $f''(0)$ with published works by Akbar et al [14] and Fathizadeh et al [15] for the different values of magnetic parameter. These comparisons are given in Table 1,showing that the results are in very good agreement.

Table 1: Comparison values of Skin friction co-efficient ($l = \beta_v = 0$).

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M	Akbar et al [14]	Fathizadeh et al [15]	Present result
1	-1.41421	-1.41421	-1.41421
5	-2.44948	-2.44948	-2.44949
10	-3.31662	-3.31662	-3.31662
50	-7.14142	-7.14142	-7.14143
500	-22.3830	-22.3830	-22.38302
1000	-31.6386	-31.6386	-31.63858

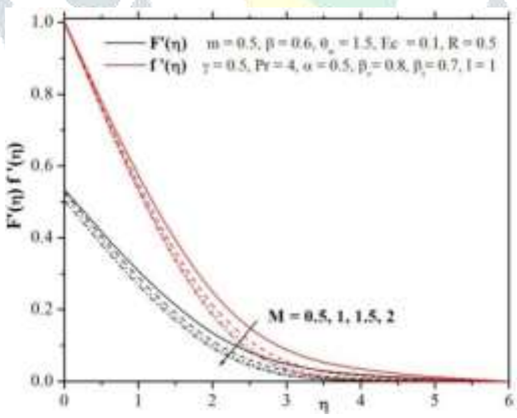

Figure 1 Impact of the magnetic parameter (M)

Figure 1 shows the impact of the magnetic parameter (M) on the velocity profile. This figure declares that larger magnetic parameter values enhanced the momentum boundary layer thickness. Physically, it justifies that applying transverse magnetic field normal to the flow of an electrically conducting fluid tends to produce a drag-like force called the Lorentz force, which acts in the opposite direction of flow, thus reducing its velocity. The results also show that momentum boundary layer thickness decreases.

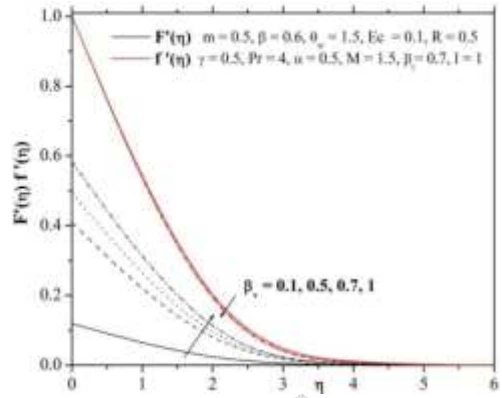

Figure (2). velocity distribution with $\boldsymbol{\eta}$ for fluid particle interaction parameter $\boldsymbol{\beta}$

The velocity distribution with $\boldsymbol{\eta}$ for various value of fluid particle interaction parameter $\boldsymbol{\beta}$ is as shown the **Figure (2).** It clearly show that if $\boldsymbol{\beta}$ increase we can find the decrease in the fluid phase velocity and in the dust phase velocity.

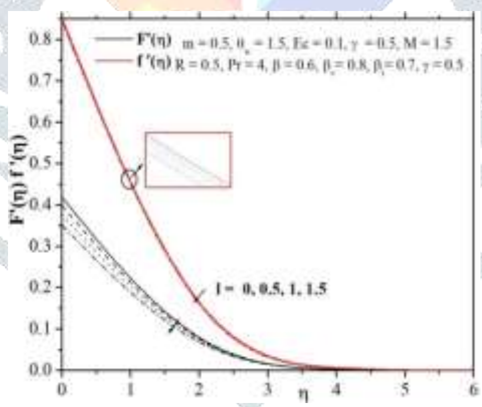

Figure 3 effects of dust particles mass concentration

Figure 3 shows the effects of dust particles mass concentration, l on velocity, profiles. Introduction of dust particles in a clean fluid cause an internal friction within the fluid, which results retardation in fluid flow. This physical behaviour is clarified through the figures 5 That is by increasing l ,the velocity, profiles of both the phase as well as corresponding boundary layer thickness will decreases.

Table 2: Numerical values of local skin friction coefficient for the different physical quantities

B	M	β_v	l	$C_{fx}Re_x^{\frac{1}{2}}$
0.5				0.48348
1				0.66378
1.5				0.74967
	0			0.47066
	0.5			0.33751
	1			0.23703
		0.5		0.33742
		1		0.13920
		1.5		0.13879
			0	0.14016
			0.5	0.10006
			1	0.06302

Conclusion

This paper addresses the MHD boundary layer flow of electrically conducting non-newtonianwalter's B dusty fluid over a stretching sheet in the presence of velocity slip boundary conditions. The effects of various parameters on the flow observed from the graphs and are summarized as follows:

- The velocity profile decayed with higher values of the magnetic parameter.
- Momentum boundary layer thickness decreases by increasing values of magnetic parameter.

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