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Impact of Electrification and Particle Loading on Velocity Profile of Dusty Fluid Flow Over a Stretching Sheet

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Abstract: The performance of incompressible, laminar, boundary- layer flows over a semi-infinite horizontal stretchable plate is considered. The dusty fluid flow problems are modelled and solved in agreement with two-way coupling model. The particle phase momentum equation in the vertical direction is considered where as that for fluid phase is neglected. Here the electrification term added in not from the supply from outside rather it is the generation due to collision of particles So the effects of particle loading and electrification on velocity profile have been studied. From the result analysis it is concluded that electrification and particle density have significant effect on particle phase velocity, whereas carrier fluid phase has negligible effect. The particle phase velocity increases with increasing of electrification parameter and decreases with increase of loading ratio.

***Keywords* : Loading ratio, collision of particles.**

I. INTRODUCTION

The study of velocity allocation in the boundary layer flow over a surface is crucial for it's application in diversified field. Sharidan[10] offered similarity solutions for velocity allotment in unsteady flow that was generated due to suddenly enlargement of stretchable sheet. Crane [1] has modelled the flow over a linear stretching sheet and solved and got in exponential form. Gireesha et.al[7-9] have modelled and discussed about the impact two phase flow over an unsteady stretchable sheet. Ramesh et.al [14-15] have analysed the flow dynamics of dusty fluid over an inclined stretchable plane.

The analysis of dusty fluid flows is very much essential to model and finding solution of the problems, like environmental pollution, centrifugal separation of particles, blood rheology, etc. As we have taken dusty fluid into consideration, the collision of particles among themselves and with the wall plays an important role. In the present paper, the behavior of incompressible, laminar boundary-layer flows of a dusty gas over a semi-infinite stretching sheet along the whole length of the sheet is considered. The problem of two-phase flow is solved in the way of two-fluid approach.

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The momentum equation for particulate phase in vertical direction is not neglected whereas neglected in fluid phase. The role of electricity generated and loading ratio on velocity profile the boundary layer have been studied.

II. FORMULATION OF THE PROBLEM

Let us Consider a steady two-dimensional laminar boundary layer flow of an incompressible viscous fluid containing dust, over a stretching sheet. The flow is formed by the action of two equal and opposite forces along the horizontal direction (X-axis) . Y-axis is the normal to the flow .As the force is applied in horizontal direction and by virtue of properties of stretching sheet, it expanded i.e stretched with the velocity U w(x) in the direction of x-axis, keeping the origin fixed in the fluid. i.e before the flow. It is assumed that the fluid-particle mixing is uniform throughout the flow
The formulation of the problem is given by

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0 \qquad (2.1)$$

$$\frac{\partial}{\partial x}\left(\rho_p u_p\right)+\frac{\partial}{\partial y}\left(\rho_p v_p\right)=0 \qquad (2.2)$$

$$u\left(\frac{\partial u}{\partial x}\right)+v\left(\frac{\partial v}{\partial y}\right)=\frac{1}{\rho}\frac{\partial^2 u}{\partial x^2}-\frac{1}{(1-\phi)\rho}\frac{1}{\tau_p}\phi\rho_s\left(u-u_p\right)+\frac{1}{1-\phi}\frac{\rho_p}{\rho}\left(\frac{e}{m}\right)E \qquad (2.3)$$

$$\phi\rho_s\left(u_p\frac{\partial u_p}{\partial x}+v_p\frac{\partial u_p}{\partial y}\right)=\frac{\partial}{\partial y}\left(\phi\mu_s\frac{\partial u_p}{\partial y}\right)+\frac{1}{\tau_p}\varphi\rho_s\left(u-u_p\right)+\phi\left(\rho_s-\rho\right)g+\rho_p\left(\frac{e}{m}\right)E \qquad (2.4)$$

$$\varphi\rho_s\left(u_p\frac{\partial v_p}{\partial x}+v_p\frac{\partial v_p}{\partial y}\right)=\frac{\partial}{\partial y}\left(\varphi\mu_s\frac{\partial v_p}{\partial y}\right)+\frac{1}{\tau_p}\varphi\rho_s\left(v-v_p\right) \qquad (2.5)$$

With boundary conditions

$$u=U_w\left(x\right)=cx, v=0 \quad \text{at } y=0$$
$$\rho_p=\omega\rho, u=0, u_p=0, v_p=v \quad \text{as } y\to\infty \qquad (2.6)$$

Where ω is the ratio between particles and fluid in the main stream.

III. SOLUTION OF THE PROBLEM

The governing equations are reduced into system of ODEs by using Shooting method and then solved by using well known RKF-45 method.

Introducing the following non dimensional variables in equation (2.1) to (2.5) we get

$$u = cxf'(\eta), v = -\sqrt{c\nu}\, f(\eta), \eta = \sqrt{\frac{c}{\nu}}\, y, u_p = cxF(\eta), v_p = \sqrt{cx}\, G(x)$$

$$\rho_r = H(\eta), \beta = \frac{1}{c\tau_p}, \varepsilon = \frac{\nu_s}{\nu}, P_r = \frac{\mu c_p}{k}, \gamma = \frac{\rho_s}{\rho}, \nu = \frac{\mu}{\rho}, \rho_r = \frac{\rho_p}{\rho}, M = \left(\frac{e}{M}\right)\frac{E}{c^2 x'}$$

c is the stretching rate

β is the fluid particle interaction parameter. Other symbols have usual meaning.

We get the following non dimensional form.

$$H' = -\frac{(HF + HG')}{G} \qquad (2.7)$$

$$f'''(\eta) = (f'(\eta))^2 - f(\eta) f''(\eta) - \frac{1}{(1-\varphi)}\beta H(\eta) - Gr\theta - \frac{M}{1-\varphi} H \qquad (2.8)$$

$$F''(\eta) = \frac{1}{\varepsilon}\left[G(\eta)F'(\eta) + [F(\eta)]^2 - \beta[f'(\eta) - F(\eta)] - \frac{1}{Fr}\left(1 - \frac{1}{\gamma}\right) - M \right] \qquad (2.9)$$

$$G''(\eta) = [GG' + \beta(f + g)]/\varepsilon \qquad (2.10)$$

With Boundary Condition

$$G'(\eta) = 0, f(\eta) = 0, f'(\eta) = 1, F'(\eta) = 0 \quad \text{as} \quad n \to 0$$

$$f'(\eta) = 0, F(\eta) = 0, G(\eta) = -f(\eta), H(\eta) = \omega \quad \text{as} \quad n \to \infty \qquad (2.11)$$

Here in this problem the value of $f''(0), F(0), G(0), H(0), \theta'(0), \theta_p(0)$ are not known but $f'(\infty) = 0, F(\infty) = 0, G(\infty) = -f(\infty), H(\infty) = \omega, \theta(\infty) = 0, \theta_p(\infty) = 0$ are given. By using Shooting method the value of $f''(0), F(0), G(0), H(0), \theta'(0), \theta_p(0)$ can be obtained. We have supplied $f''(0) = \alpha_0$ and $f''(0) = \alpha_1$. The improved value of $f''(0) = \alpha_2$ is calculated by using interpolation formula of 1st degree. Then the value of $f'(\alpha_2, \infty)$ is calculated by using Runge-Kutta method. If $f'(\alpha_2, \infty)$ is equal to $f'(\infty)$ up to a desired decimal accuracy, then α_2 i.e $f''(0)$ is determined, otherwise the above procedure is repeated with $\alpha_0 = \alpha_1$ and $\alpha_1 = \alpha_2$ until a correct α_2 is obtained. Similarly, the correct values of $F(0), G(0), H(0)$ can be obtained.

IV. RESULT ANALYSIS

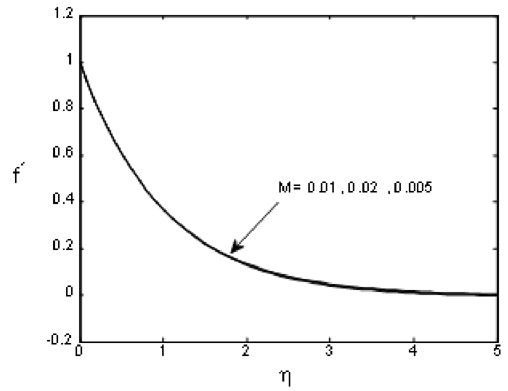

Figure 1. Effect of M on velocity profiles of carrier fluid phase for
$\epsilon = 5.0, \beta = 0.03, \varphi = 0.01 \quad \gamma = 1200,$

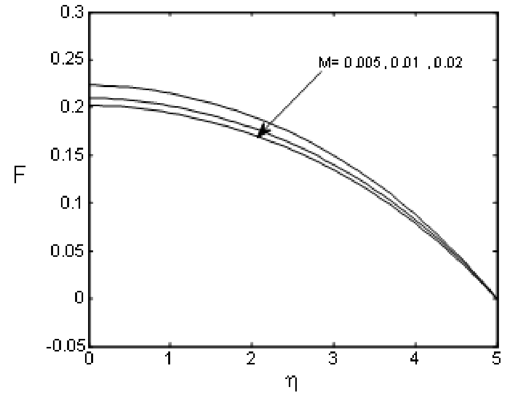

Figure 2. Effect of M on velocity profies of particle phase for, $\epsilon = 5.0, \beta = 0.03, \varphi = 0.01 \quad \gamma = 1200,$

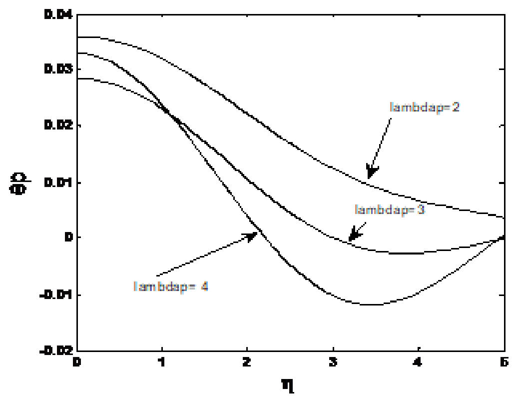

Figure 3. Effect of λ_p (loading ratio)on velocity profies of particle phase for
$\epsilon = 5.0, \ \beta = 0.03, \ \varphi = 0.01, \gamma = 1200,$

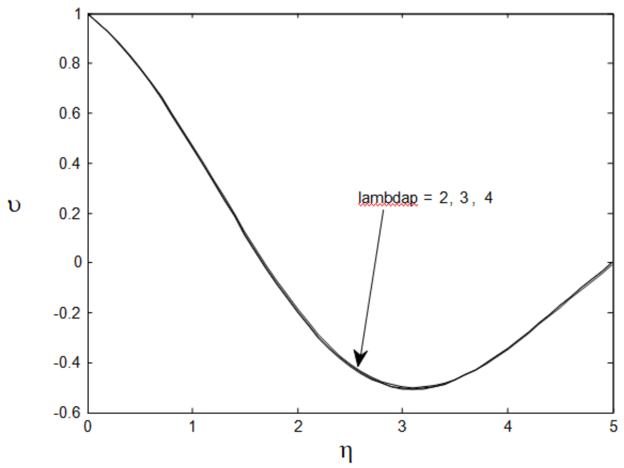

Figure 4. Effect of λ_P (loading ratio) on velocity profies of fluid phase for

$\epsilon = 5.0, \beta = 0.03, \varphi = 0.01 \quad \gamma = 1200,$

Fig(1) describes the effect of M on velocity profiles 'u' of carrier fluid phase. It is observed from graph that M has no significant effect on 'u'

Fig (2) depicts the effect of M on the velocity profile 'u_p'of particle phase. It is seen that the velocity 'u_p' increases with the increase of M .

Fig (3) represents the effects of loading ratio λ_P on u_p , and it reveals that the particle phase velocity decreases with the increase of λ_P.

Fig (4) depicts the effect of loading ratio λ_P on fluid phase velocity u and found tha there is no significant effect of λ_P on fluid phase velocity u.

V. CONCLUSION

(i) The electrification of the flow field has some effect on velocity profile of particle phase, whereas negligible effect on fluid phase.
(ii) The particle density has an influence on particle phase velocity of dusty fluid flow whereas negligible effect on fluid phase

TABLE-1: Showing the initial values of wall velocity gradient $f''(0)$ for different flow parameters

SL.NO	ϵ	β	φ	γ	M	λ	λ_p	$-f''(0)$	F(0)	-G(0)	H(0)
1	5	0.03	0.01	1200	0.01	2	4	.995095	.2094465	1.04179	.1234985
2	5	0.03	0.01	1200	0.01	2	2	.996636	.2097209	1.042302	.1235004
3	5	0.03	0.01	1200	0.01	2	2	.996279	.2094511	1.042565	.1235746
4	5	0.03	0.01	1200	0.01	2	2	.996354	.2074592	1.041176	.1313332
5	5	0.03	0.01	1200	0.01	2	2	.996051	.2090965	1.041665	.1241212
6	5	0.03	0.01	1200	0.01	2	2	.998742	.2092315	1.048862	.1209110
7	5	0.01	0.01	1200	0.01	2	2	.995986	.2087926	1.057738	.1235232
8	5	0.04	0.01	1200	0.01	2	2	.998236	.2094848	1.033856	.1247993
9	5	0.03	1	1200	0.01	2	2	.995680	.2094626	1.042234	.1235049
10	5	0.03	0.5	1200	0.01	2	2	.996154	.2094979	1.042223	.1243293
11	5	0.03	0.01	1200	0.01	2	2	1.00340	.2088673	1.038577	.1236972
12	5	0.03	0.01	1200	0.01	2	2	.9950921	.2094900	1.041723	.1228134
13	5	0.03	0.01	1200	0.02	2	2	.994156	.2233405	1.047134	.1164474
14	5	0.03	0.01	1200	0.03	2	2	.998579	.2022454	1.038749	.1240965
15	5	0.03	0.01	1200	0.01	3	2	.991494	.2090960	1.041101	.1237847
16	5	0.03	0.01	1200	0.01	4	2	1.00754	.2093001	1.041101	.1239388
17	5	0.03	0.01	1200	0.01	2	3	.997158	.2092925	1.041402	.1231887
18	5	0.03	0.01	1200	0.01	2	4	.995095	.2094465	1.041793	.1234985

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