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Mathematical modeling on aligned magnetic field of two-phase dusty Casson fluid

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ABSTRACT – The influence of aligned magnetic field on the two-phase flow of Casson fluid and dust particle with heat transfer over a stretching sheet subjected to convective boundary conditions (CBC) is analysed. The governing equations are transformed into ordinary differential equations by employing similarity transformation which then solved numerically by Runge-Kutta Fehlberg fourth-fifth method (RKF45). The effects of aligned angle and fluid particle interaction parameter are presented graphically for both phases by fixing several physical parameters. It has been found that aligned angle strengthens the magnetic field and led to decrease the velocity profile for both phases.

1. INTRODUCTION

A considerable amount of effort has been made on the topic of non-Newtonian fluid due to its practical applications, for instance in manufacture of plastic film and in extrusion of polymer sheet from a die. Numerous non-Newtonian fluid models have been developed to exhibit its physical properties. One of them is Casson fluid which possesses the interactive behaviour of solid and liquid phases. Such fluids are honey, jelly, tomato sauce and concentrated fruit juices. Human blood which contained protein, fibrinogen and globulin in an aqueous base plasma also can be categorized as Casson fluid [1].

The two-phase flow of solid spherical particles is scattered in a fluid and can be observe in sediments, environment pollution, centrifugal separation of particle and blood rheology. Moreover the flow in the channel of magnetohydrodynamic (MHD) generators is affected by the accumulation of ash or soot [2]. The two-phase fluid model is used to analyse the alkaline anion exchange membranes (AAEMs) conductivity and a numerical simulation is carried out for blood purification auto-transfusion dialysis hybrid devices [3,4].

2. METHODOLOGY

2.1 Mathematical formulation

The boundary layer flow of dusty Casson fluid with velocity $u_w(x) = ax$ is considered. An aligned magnetic field with an acute angle α_1 is applied to the flow as shown in Figure 1. Supposed, the dust particles are in spherical shape, uniform size and number density of these are taken as constant throughout the flow.

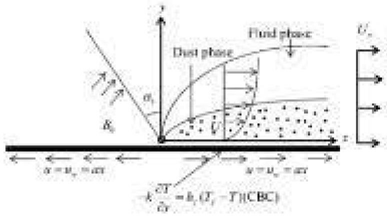

Figure 1 Flow configuration.

Under Boussinesq and boundary layer approximations, the governing equations can be written as two part:

Fluic phase:

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

$$\rho_\infty \left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} \right) = \mu\left(1+\frac{1}{A}\right)\left(\frac{\partial^2 u}{\partial y^2}\right) - \frac{\rho_p}{\tau}(u_p - u) - \sigma u {B_0}^2 \sin^2 \alpha_1, \tag{2}$$

$$\rho_\infty c_p \left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} \right) = k\left(\frac{\partial^2 u}{\partial y^2}\right) + \frac{\rho_p c_s}{\gamma_T}(T_p - T), \tag{3}$$

Dust phase:

$$\frac{\partial u_p}{\partial x} + \frac{\partial u_p}{\partial y} = 0, \tag{4}$$

$$\rho_p \left(u_p\frac{\partial u_p}{\partial x} + v_p\frac{\partial u_p}{\partial y} \right) = \frac{\rho_p}{\tau}(u - u_p), \tag{5}$$

$$\rho_p c_s \left(u_p\frac{\partial T_p}{\partial x} + v_p\frac{\partial T_p}{\partial y} \right) = -\frac{\rho_p c_s}{\gamma_T}(T_p - T). \tag{6}$$

The boundary conditions associated with the model are

$$\begin{aligned} &u = u_w(x), v = 0, -k\left(\partial T / \partial y\right) = h_f\,(T_f - T) \text{ at } y = 0 \\ &u \to 0, u_p \to 0, v_p \to v, T \to T_\infty, T_p \to T_\infty \text{ at } y \to \infty \end{aligned} \tag{7}$$

In order to reduce the complexity of Equation (1)-(7), the similarity transformations are introduced: