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Modeling electrification of suspended particulate matter (SPM) in a two phase laminar boundary layer flow and heat transfer over a semi-infinite flat plate ☆

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ABSTRACT

The present paper envisages the effects of electrification of particles, volume fraction and diffusion of SPM on the boundary layer flow and heat transfer over a semi-infinite flat plate. Irrespective of the particle material density, it has been observed that the range of validity of the solution remains fixed and at $x = 2.12$ the nature of the profiles of the flow variables changes. Electrification of particles causes the particles to move faster for $x < 1.0$ and slows down for $x > 1.0$ but particle temperature increases with increase of M. It has been observed that heat transfer always occurs from the fluid to plate.

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1. Introduction

The atmospheric boundary layer is the layer of atmosphere where the direct effect of the surface which functions as a source or sink of momentum and energy, is noticeable. Knowledge of the structure of the boundary layer is therefore basic to understand the atmosphere's capabilities to dispose of pollutants. In the count of suspended particulate matter (SPM), world has focused international interest in the urban pollution. This provides ample justification to make thorough study of the boundary layer both theoretical and experimental.

The detailed history, peculiarities and several investigations of the boundary layer flow of a fluid containing dust particles have been discussed and documented. Chiu [1] analysis of boundary layer equations is inadequate since the conservation of particle momentum equation in the transverse direction has been neglected. Also he has assumed that the particle density is constant and his analysis is applicable when effects of the particles on the gas are of higher order than the gas inertia or viscous forces. Datta and Mishra [2] have investigated the boundary layer flow of a dusty fluid over a semi-infinite flat plate at zero incidences by series expansion method which is valid throughout the whole region i.e. large slip as well as small slip regions. Unlike Jain and Ghosh [3], they have considered the particle momentum equation in the transverse direction and also considered the effect of transverse force on the flow field in addition to Stokes drag force. They have shown that the particle boundary layer thickness is less than that of the fluid boundary layer thickness. Jain and Ghosh [3] have solved the gas-particulate boundary layer equations with (i) a fourth degree profile for the fluid phase satisfying the compatibility condition on the surface and (ii) a third degree profile not satisfying the compatibility condition. Also particle velocity and density do not satisfy the compatibility conditions. Jain and Prabha [4] have employed Crank-Nicholson scheme of finite differences to study the gas particulate boundary layer equations with no pressure gradient. Their analysis is not adequate, as they have neglected the particle momentum equation in the transverse direction. Kartushinsky et al. [5] have suggested a mathematical expression based on the probabilistic approach for the calculation of the magnitude of deposition of solid particles along the surface of a flat plate under conditions of vertical laminar boundary layer which includes the special features of hydrodynamic flow, the adhesive properties of the particles and surface and the probabilistic pattern of the process of entrapment of particles by the surface. Koh et al. [6] have obtained the numerical solution of two phase boundary layer equations arising in laminar film condensation and have studied the effects of the interfacial shear on heat transfer. Marble [7] has reviewed the developments in the constitutive theory of particulate suspension. Marble [9] has given solutions for boundary layer flow over a flat plate by series expansion method which is essentially valid for down-stream region of the plate where the slip velocity is small. He found that up to the first order terms the particulate velocity on the surface remains zero. Hussainov et al. [10] have presented a method based on a probabilistic approach for the assessment of the deposition of fine particles in a vertical two-phase laminar flat plate boundary layer with the inclusion of both hydrodynamics of the flow past the plate and the adhesive properties of particles and the plate surface. They have derived an overall expression for the particles

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