HYDRODYNAMICS OF FREE SETTLING AND FLUIDISATION

THESIS SUBMITTED BY

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ABSTRACT

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A critical review of the experimental and theoretical investigations, describing flow around a spherical particle settling at its terminal velocity, reveals that the standard drag curve and the various analytical and numerical solutions of the Navier-Stokes equations are not in agreement because, not only the various solutions do not take into consideration the actual magnitude of viscous drag but also the drag coefficient, C_d, defined by Rayleigh (139), includes only the effect due to inertial drag. Even, Maxworthy's (149) method of non dimensionalising the total drag with respect to the Stokes' drag is in direct contradiction with his own conclusion regarding the Stokes' law being applicable at Re = 0. In order to incorporate the effect due to viscous drag, the drag coefficient, in the present work, is redefined as:

$$C_{dm} = \frac{D}{\lambda \mu dV + \frac{1}{2}\rho V^2 \frac{\pi d^2}{4}}$$

It is shown that the same experimental data, which has been used to represent the standard drag curve, can be used to graphically represent the relation between the modified drag

coefficient and the Reynolds number, in the form of a modified drag curve. Further, the modified drag coefficient helps in evaluating the respective magnitudes of viscous and inertial drag in the intermediate region. For example, it is shown that the two forces are equal when Re = 2.546. Furthermore, it is proposed that for the same particle-fluid system, the drag acting on a particle settling in a bounded medium cannot increase as compared to that in an unbounded medium due to the simple reason that the net gravitational force balancing the drag exerted on the particle is same in both the cases.

In the present study on fluidisation, it is shown that the average relative velocity of fluid with respect to particles cannot be equal to U/E, but equal to the free settling velocity, V_t, of solid particles. Based on Richardson - Zaki(197) equation, it is shown that U/E^n represents the average relative velocity of fluid with respect to particles and E^n is shown to represent the average area fraction of the bed through which fluid flows during fluidisation. Finally, a simple explanation of the physical phenomenon of the appearance of parvoids and bubbles in fluidised beds is proposed. It is shown that the minimum voidage of a freely suspended bed of particles is dependent upon solid and fluid densities in the following manner:

$$E_{mfs} = \frac{\rho_s}{\rho_s + \rho_f}$$

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