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PARTICLE DEPOSITION ONTO A FLAT PLATE WITH VARIOUS SLOPES

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INTRODUCTION

Much attention has been devoted in recent years to study the deposition of suspended submicron and micron particles upon adjoining surfaces. The phenomenon is not only of scientific interest but also of importance to a variety of technologies such as microelectronics industry, inhalation toxicology, clean of enclosed environments (rooms), etc. Deposition of particles in laminar flow is relatively well understood. Deposition onto surfaces in turbulent flow, typical of indoor environments, is a much more complicated problem (see for example, Malet et al., 2000; Tsai & Liang, 2001). Furthermore, the majority of studies available in literature are devoted to the particle deposition on the walls of channels flow.
In this work, a numerical simulation of the deposition of small suspended particles onto a flat plate with various degrees of inclination is performed. The particle deposition rates are obtained for various Reynolds and Rayleigh number groups.

MATERIALS AND METHODS

The computational code developed by Silva and Coelho (1995) was used to simulate the flow field (this code includes a κ-ε turbulent model). The simulation of particle motion was based on the assumption that the particles do not affect the flow field. The particles are considered spherical, non-rotating and with a density larger than the air. The following forces are considered to affect the particle motion: gravity, drag, Brownian and thermophoretic forces. The particles' equation of motion is

$$\frac{d\vec{v}_p}{dt} = \frac{2(S-1)}{2S+1}\vec{g} + C_D\vec{F}_D + \vec{F}_B + \vec{F}_T \qquad (1)$$

where v_p represents the particle velocity, S the particle-fluid density ratio, C_D the drag coefficient, F_D the drag force, F_B the Brownian force, F_T the thermophoretic force, g the gravitational acceleration and t the time. Expressions for the above forces were taken from Tsai & Liang (2001) and Chen & McLaughlin (1995).
An explicit-implicit numerical technique was used to incorporate the equations for the transport of particles in the flow field. The equations were solved employing a finite difference technique.
Based on this approach, the deposition of small suspended particles onto flat plates (inclination 0º, 45º, 90º, 135º and 180º) was examined.

SIMULATION RESULTS AND DISCUSSION

For convenience and efficiency, the numerical results were presented in terms of deposition velocity (the ratio of flux of particles to the plate divided by the mean bulk concentration of particles), friction velocity (square root of the ratio between the shear stress at the plate and the fluid density) and particle relaxation time (τ^*) defined by

$$\tau^* = (C\rho_p d_p^2 \omega^2 / 18\rho_f \nu_f^2) \qquad (2)$$

where C is the Cunningham slip factor, ω the friction velocity, d the diameter, ν the kinematic viscosity and ρ the density. The subscripts f and p mean fluid and particle, respectively.

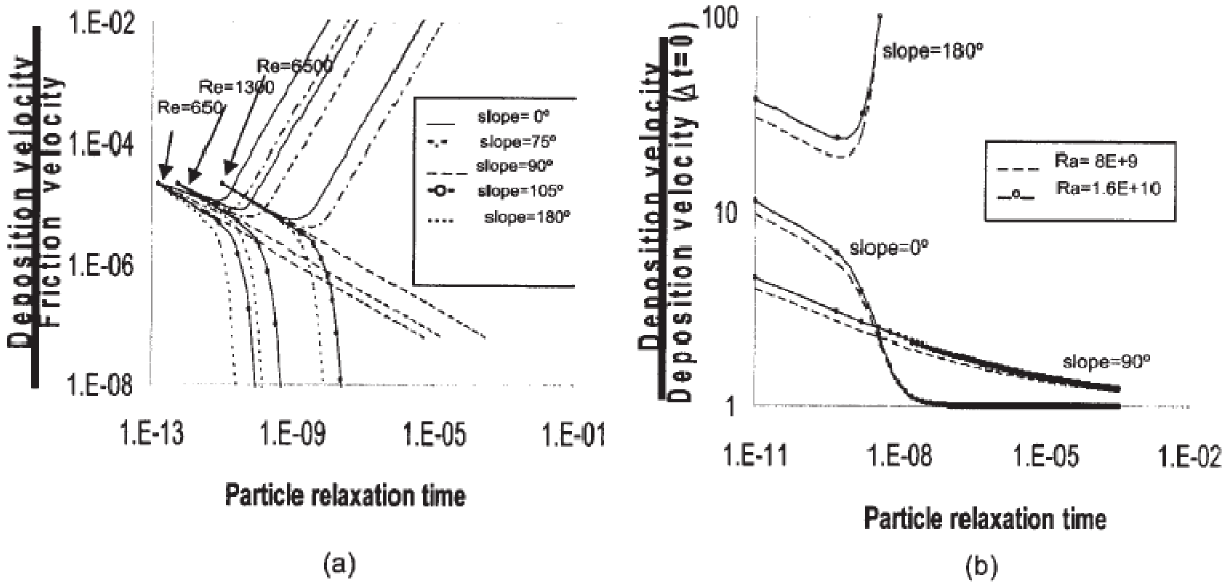

Fig. 1. *(a)* Variations of non-dimensional deposition velocity with τ^* for flat plates having various slopes (isothermal conditions T_{air}=T_{plate}=298 K) for various Reynold numbers ; *(b)* Variations of ratio between the deposition velocity (T_{air}>T_{plate}; Re=6500) and the deposition velocity when the air and the plate are isothermal with τ^* for two different Rayleigh numbers.

Figure 1(a) shows that increasing the Reynolds number increases the deposition rate. Moreover, deposition rate decreases with an increase in relaxation time, except for plates having slopes lower than 90º above some value of relaxation time (τ^* larger than ~10^{-11} (Re=650), ~10^{-10} (Re=1300) and 10^{-6} (Re=6500)). Besides, Figure 1(b) shows that thermophoresis effect dominates the deposition at very small τ^*, except for plates with slope 180º. Furthermore, when τ^* is larger than ~10^{-8} and ~10^{-1} this effect is negligible for plates having slopes of 0º and 90º, respectively. It is also observed that the effect of Rayleigh number (Ra) is more effective for τ^*<~10^{-9}.

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