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Combined effect of thermophoretic force and other influencing parameters on the particle deposition rate on a tilted rough surface

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ABSTRACT

In this study a modified v2-f turbulence model, ($\varphi-\alpha$), is used to simulate a non-isothermal air flow. The model is compatible with a two-phase Eulerian approach to predict the deposition rate of particles on cooled and warm tilted rough surfaces. The effects of drag force, lift force, turbophoretic force, thermophoreric force, electrostatic force, gravitational force and Brownian/turbulent diffusion as well as the surface roughness were examined on the particle deposition rate. The combined effects of the thermophertic force with electrostatic force/surface roughness/tilt angle on the particle deposition rate were investigated separately. This study highlights the paramount effect of thermophoretic force for a cooled surface on the particle deposition rate and clearly shows that when the temperature difference exceeds a certain limit the electrostatic force/the surface roughness/tilt angle has insignificant effect on the particle deposition rate. The effect of electrostatic force and roughness on the particle deposition rate becomes insignificant for small-size particles while the effect of tilt angle on the particle deposition rate becomes insignificant at intermediate-size particles. Furthermore, the results surprisingly show that when the wall temperature is higher than the flow temperature, increasing the temperature difference reduces the effect of electrostatic force and the surface roughness on the particle deposition rate for small-size particles.

1. Introduction

The deposition of suspended particles from turbulent gas flow on adjacent surfaces has been extensively investigated during the last 30 years. The understanding and prediction of deposition mass flux is of great interest in areas like pollution control, gas cleaning, design of industrial reactors or transport of particles in two-phase flow systems. Many publications explain calculations of the inertial deposition of particles in 2-D flow fields while the effect of turbulent flow has not been considered. Most researchers used a Lagrangian approach in which the particle equations of motion were integrated along the particle path-lines [1,2]. In such deterministic flows, a necessary number of path line calculations for statistics convergence give a good representation of the particle velocity field. Gosman and Ioannides [3] obtained the flow field using the random sampling of a crude turbulence model at each time-step. A similar method was reported by Kallio and Reeks [4], but problems remained in coping with very small particles when Brownian diffusion was important. Li and Ahmadi [5] developed a near-wall model using direct numerical simulation (DNS) analysis to capture the near wall fluctuations. Ounis et al. [6] and Brooke et al. [7] predicted the motion of particles where the fluid motion was predicted by DNS. Using Large Eddy Simulation (LES) [8] or DNS methods [9] improved representations of the turbulence but consumed larger computational time. Healy and Young [10] showed that the particle concentration field can also be predicted accurately and efficiently if the so-called full-Lagrangian approach is used, but it necessitates to carefully model the particle-turbulence interactions using stochastic terms, in particular for low-inertia particles that respond fully to flow turbulence when RANS [11] or LES [12] approaches are used. Tian and Ahmadi [13] successfully applied the near-wall model with a Reynolds Stress Model (RSM) to predict particle deposition in channel flows. Lai and Chen [14] adopted the RNG $k-\varepsilon$ turbulence model to predict indoor particle dispersion, and deposition rate to quantify wall-normal turbulent fluctuations within the viscous layer near the wall. However, Lagrangian approach typically involves the determination of trajectories of a very large number of particles (to establish statistically meaningful average quantities) and may be too time consuming to be effective as a practical calculation method, especially for small particles. Therefore, the two-phase Eulerian approach which is computationally less expensive in time was

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