Multilayer resuspension rate of deposits in turbulent flows

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The resuspension of deposited particles involves the process where particles under the influence of an external force detach and entrain into the ambient air. Morphology of the deposit plays a significant role in inter-particle interactions: particles may interact with the surface they are in contact with (monolayer deposit) or the interaction may include particle-particle (inter-layer) interactions (multilayer deposit).

The present model considered an idealized description of the deposit where k layers of the identical particles were stacked on top of each other. The total number of particles was considered the same in each layer and interactions were assumed only between particles at different layers. The fraction of remaining particles in each layer was determined using two approaches:

$$\frac{dp_i}{dt} = -Jp_i\left[1-\frac{p_{i-1}(t)}{p_{i-1}(0)}\right] \text{ (1)}, \quad \frac{dp_i}{dt} = -Jp_i\left[1-\frac{p_{i-1}(t)}{p_i(t)}\right] \text{ (2)},$$

where, p_i is the fraction of remaining particles in layer i at time t, J is the resuspension rate and 0 denotes the initial number of particles in a given layer. Eq. (1) corresponds to the kinetics proposed by Lazaridis and Drossinos (1998), LD, while Eq. (2) corresponds to Friess and Yadigaroglu (2001), FY, kinetics.

All intermolecular interactions were modelled using the Lennard-Jones pair potential. A multilayer deposit involves the interaction between particles and between particles and the surface. The resuspension rate constant J was estimated using a kinetic approach for the bound particles, which oscillates into a potential well. A turbulent flow was considered to act on the particles, that were resuspended when the moments of the aerodynamic forces (lift, drag) generated by the flow, broke the particle-particle or particle-surface contact.

The objective of the present study was to model particle resuspension from multilayer deposits and investigated single layer kinetics using both LD and FY kinetics. Additionally, the fractional resuspension rate $\Lambda(t)$ was examined at different layers and the influence of the exposure time and friction velocity was studied.

Preliminary results indicated that both models (LD, FY) provide similar resuspension rates, although represented by different kinetics. In detail, the two models differ in the expression of exposed particles in each layer, where the LD model estimates the maximum resuspension rate. Boundary conditions for J ($J>>0$ or $J=0$) found to have a strong impact on the results. Moreover, model results suggested that top (exposed to the flow) layers resuspend easier than bottom layer. Lower adhesion between particle-particle interactions is likely responsible for easier detachment.

The influence of the exposure time and friction velocity to $\Lambda(t)$ is presented in Figure 1. Two regimes are observed: a short-term at low friction with high rates and a long-term at higher friction characterized by considerably reduced resuspension rates (left plot). The two regimes are associated with adhesion forces: weakly bound particles resuspend easier and with higher removal rates. On the other hand, at long-term regime only the strongly adhered particles remain with $\Lambda(t)$ decreasing with time. Model results confirm the *1/t* law, although, higher rates were found.

Additionally, a reverse of the relative position of the curves is observed in long-term regime, which corresponds to lower rates at higher friction. It is likely that all weakly adhered particles are already resuspended and the resuspension rate decreases substantially with higher friction velocity. Finally, Figure 1 (right plot) indicates that irrespectively of the layer number, $\Lambda(t)$ in long-term regime retains similar rates. These results suggests that in terms of a long exposure to a constant flow the resuspension rates become similar.

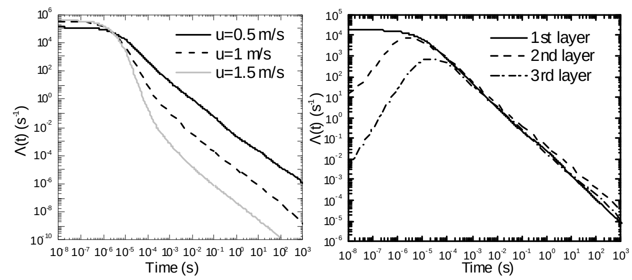

Figure 1: Effect of exposure time and friction velocity on Λ(t) of the top layer of a two-layer deposit of 70 μm stainless steel particles (left). Λ(t) for a three-layer deposit of the same particles at friction 0.3 m/s (right).

The present study evaluated the multilayer resuspension rates by turbulent flow. It was found that intermolecular interactions play a significant role with two regimes (short- and long- term) dominating the particle resuspension.

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