Role of particle size and surface roughness on intermolecular interactions during particle resuspension from a turbulent flow

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Resuspension describes the physical process that leads to particle detachment from a surface and eventually its suspension in the ambient air due to the act of an external force. On the other hand, intermolecular interactions describe purely physical interactions that are essentially of electromagnetic origin and involve attractive or repulsive forces between the bodies. Adhesion is closely related with these forces. Adhesive forces bind the particles on the surface and arise when the two bodies are in close contact. The contact characteristics arise from the elastic properties of the materials involved.

The present study evaluated intermolecular interactions and the role of particle size and surface roughness during particle resuspension from a turbulent flow. A model was used to employ both intermolecular interactions and external excitations. Particle-surface interactions were modelled via the integrated Lennard-Jones intermolecular potential. Modelled interactions include particle deformation due to elastic flattening and no particle deformation. In the first case, the contact geometry involves a common contact area created between the particle and the surface due to particle deformation, whereas, in the second case the particle was considered to rest between the asperities of the surface. The resuspension rate was estimated by a numerical procedure of force-balance approximations using the kinetic approach proposed by Reeks and Hall (2001), neglecting resonant energy transfer. Accordingly, the bound particle moves quasi-statically in the potential well under the influence of the external flow. When the instantaneous joint contribution from the lift and drag forces (moments) exceeds the adhesive force (moment), the particle resuspends. Surface roughness was incorporated into the model by introducing a log-normal probability density function characterized by a reduction and a spread (σ) in the adhesive force.

The model was applied to two experimental data sets. Figure 1a presents model predictions with and without elastic flattening applied for 20 μm alumina particles on a stainless steel surface. It suggests that at low friction velocity (<0.5 m/s), where big and weakly adhered particles resuspend, the elastic flattening contribution is important and the model with elastic flattening reproduces the experimental data. On the contrary, at higher friction (where smaller and strongly adhere particles resuspend) particle deformation becomes insignificant and the model without particle deformation is in agreement with the experimental data. These results indicate that bigger particles experience limited surface roughness due to their size and due to a relatively broad distribution of adhesive forces used in this set of data ($\sigma = 10.4$): a common contact area is created between the particle and the surface, where particles are considerably deformed. On the other hand, smaller particles interact more strongly with surface roughness and they rest on top of asperities.

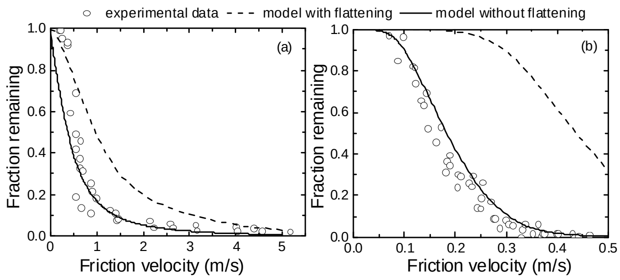

Figure 1: Comparison of model predictions with a) 20 μm alumina particles on a stainless steel surface (Reeks and Hall 2001), and b) 70 μm stainless steel particles on a glass surface (Ibrahim et al. 2003).

For the second set of data particle deformation due to elastic flattening does not seem to be important. This behaviour is associated with particle size. Higher particle size (70 μm) together with the surface roughness the particle feels due to its size has significant impact on particle resuspension. The results imply that the particles are big enough to rest between the asperities on a surface which is characterized by higher roughness ($\sigma = 2$ in these data).

In summary, the present study highlighted the importance of particle size and surface roughness to particle resuspension. Particle size and the associated surface roughness the particle feels due to its size determine contact characteristics, thus have great impact on resuspension.

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