PARTICLE RESUSPENSION FROM SURFACES: CURRENT KNOWLEDGE AND LIMITATIONS

C. Henry*,[1], J.P. Minier[2]

[1]Université Côte d'Azur, INRIA, 2004 Route des Lucioles, 06902 Sophia Antipolis, France
[2]EDF R&D, MFEE, 6 quai Watier, 78400 Chatou, France
*Courriel de l'orateur : christophe.henry@inria.fr

RESUME

Nous présentons ici un modèle pour la resuspension de particules exposées à un écoulement turbulent et déposées sur un substrat rugueux dans le contexte de sûreté nucléaire. Ce modèle prend en compte les méchanismes révélés par des mesures expérimentales récentes dans la communauté des écoulements multiphasiques. Néanmoins, malgré ces avancées significatives, les capacités de prédiction des modèles souffrent toujours des incertitudes liés aux mesures incomplètes des états de surfaces, lesquelles ont un impact majeur sur l'adhésion entre les particules et les substrats.

ABSTRACT

Here, we present a recent model for particle resuspension from complex rough surfaces that can be used in the context of nuclear safety analysis. This model relies on the main mechanisms that have been identified by experimental data obtained in the multiphase flow community. Yet, despite these recent advances, the predictive capcacities of existing models for particle resuspension are still limited by uncertainties in the measurements of surface properties, which play a significant role in the attachment of particles to substrates.

MOTS-CLÉS : particule, resuspension, surfaces / **KEYWORDS:** particle, resuspension, surfaces

1. INTRODUCTION & CONTEXT

Particle resuspension is the process whereby particles deposited on a surface are detached from it and re-entrained into the fluid flow. It has received renewed attention over recent years due to its role in various environments (see e.g. Henry et al. (2014a) or Ziskind (2006)), including in sediment dynamics, in atmospheric sciences (re-entrainment of radioactive particles after nuclear power plant accidents) or in medical applications (walking-induced resuspension of airborne particles in hospitals).

One of the main challenges related to particle resuspension comes from its multidisciplinary aspects. Indeed, particle resuspension results from the competition between two opposite forces/torques: on the one hand, hydrodynamical forces that tend to pull/drag particles from/along the wall and, on the other hand, adhesion forces that tend to maintain these deposited particles on the wall.

The aim of this study is to highlight the role played by surface roughness on the resuspension of nano- and micro-sized particles and, in particular, the need to extract more information from measurements of the surface profile in order to obtain more accurate predictions of particle resuspension.

2. METHOD & RESULTS

In this study, particle resuspension is simulated using a recent dynamic Lagrangian model where the rolling motion of each particle on the substrate is explicitly calculated. Rolling has indeed been shown to be the predominant mechanism for the resuspension of colloidal particles (which are embedded within the viscous sublayer). Rolling occurs when the balance between hydrodynamic torques and adhesive torques is ruptured. Once set into motion, particles can accelerate/decelerate depending on the forces acting on it during its rolling motion. A rolling particle can then detach from the surface when it hits a large-scale roughness element on the substrate and if its kinetic energy is higher than the adhesion energy.

This model thus couples CFD simulations of particle-fluid interactions with a stochastic model to calculate the adhesion forces between a particle and a rough substrate, whose properties are known from AFM measurements (usually the average roughness R_a, the rms roughness R_{rms}).

This model has been first validated by comparing the results obtained for the adhesion model to experimental measurements of adhesion force distribution between rough surfaces (see Henry et al. (2011)). Numerical results have also been validated to existing experimental data on particle resuspension.

Here, we compare numerical results to recent experimental data from Barth et al. (2014), where the roughness profiles have been measured with AFM/SEM techniques, giving typical roughness values such as the average roughness R_a and the rms roughness R_{rms}. The analysis of these results reveals that the threshold velocity, i.e. the velocity at which 50% of the particles initially deposited on the substrate are resupensded, can be properly captured by the model. However, the resuspension of particles tightly attached to the surface can only be properly captured with more detailed representations of surface roughness that include information on the distribution of the curvature radius and surface coverage of roughness features (see Figure 1).

3. CONCLUSION & PERSPECTIVES

Particles tightly attached to the surface are thus not properly captured by current resuspension models given the limited amount of information on the tails of distributions for surface roughness or adhesion forces. This limitation has severe consequences when studying long-term resuspension, which corresponds to the removal of particles that are still attached to the after long-time. With more detailed information on surface profiles/adhesion force distributions, accurate predictions could be made in the near future.

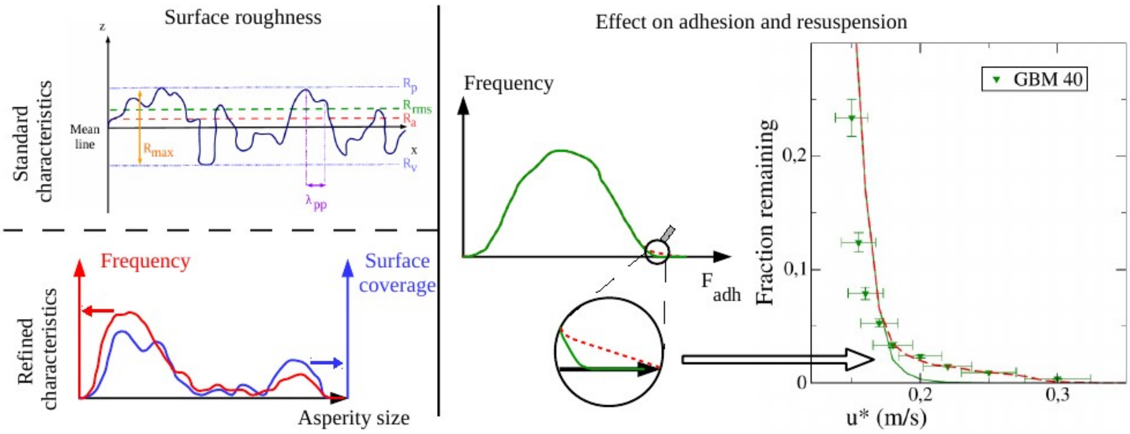

Figure 1. Comparison between experimental data and numerical results showing the limitations in present measurements of surface roughness.

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