Particle entrainment due solely to electrostatic forces

S. Peillon, M. Sow

Institut de Radioprotection et de Sûreté Nucléaire (IRSN), PSN-RES, SCA, LPMA, Gif-sur-Yvette, 91192, France
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Presenting author email: samuel.peillon@irsn.fr

In nuclear installations, radioactive contamination is often carried by aerosol particulates. Because of the ionizing radiation of the radionuclides they contain, radioactive aerosols can naturally self-charge, making them liable to electrostatic forces. However, despite the efforts devoted to the study of aerosols entrainment mechanisms such as airflow, electrostatic interactions are often ignored.

In this study we designed an experimental set-up to assess the electric field strength required to overcome the adhesive forces of micron size powdery materials laying on a surface. To do so, two circular stainless steel electrodes of 16 cm in diameter were placed in parallel and separated by a 4 mm gap. The top electrode was hooked to a high voltage source while the bottom one was earthed. A layer of particles was spread out on the top electrode near the extraction hole. Then, increasing electric field (E) strengths were applied to the particles from 0 to 27.5 kV/cm by steps of 2.5 kV/cm. For each applied E, the lifted particles were pumped up to a *Palas® Welas 2100* particle counter that measured the particle number concentration.

Three polydispersed powdery materials of different mean diameter (D_{50N}) and electrical properties were used in our experiments: aluminium oxide (Al_2O_3) that is insulating material, silver that is conductive material, and tungsten particles that are supposed to be conductive as well. Our results are displayed as normalized cumulative fractions relative to the applied electric field strength (fig.1). For all the tested powders, the number of entrained particles increases undoubtedly with the electric field strength. For the silver conductive particles, one can observe a significant effect of the particles size. Indeed at 15 kV/cm, the cumulative collected silver particles are nearly 10%, 60% and 80% for 0.5 µm, 0.64 µm and 1.8 µm mean diameters respectively. This result shows that larger particles are detached more easily from the upper electrode than the smaller ones. For all the silver powders, the detachment threshold (i.e. 50 % of the particles mobilized during the test) stands between 8 kV/cm and 23 kV/cm. The entrainment of a single conductive particle laying on a conductive surface by an electric field has been studied extensively (Pohl, 1951). The resulting electrical polarization force is size dependent and can be approximated by the following expression (Sow *et al.*, 2013): $F_E = 1.37\pi\varepsilon_0 d_p^2 E^2$, where ε_0 is the permittivity of free space, d_p the particle diameter and E the electric field. For the insulating dielectric Al_2O_3 particles, our results exhibit the same trend regardless the particle mean size used in the experiments. In this case the detachment threshold is around 20 kV/cm for the two mean sizes of aluminium oxide powders used. Note that this threshold value was also reported by Cooper *et al.* (1988). Furthermore, the tungsten powders tested appear to follow the same detachment behaviour than the insulating Al_2O_3 particles with no noticeable effect of the particle mean size (fig. 1). Conductivity test run on the tungsten particles revealed them as dielectric materials, which suggest the presence of a large surface oxide film that screens their conductivity.

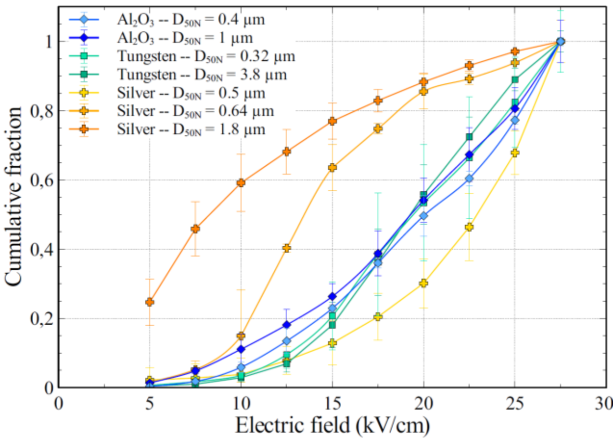

Figure 1 – Normalized cumulative number fraction of silver, alumina and tungsten particles of different mean sizes experiencing increasing electric field strengths.

The entrainment of dielectric materials experiencing an electric field involves other electrical forces such as image forces and Coulomb forces, and is complicated by the lateral interactions when particles carry electric charges (Yoshimatsu *et al.*, 2016).

At this stage of the study we do not fully understand the non-size dependence of the insulating material, and further tests in a more controlled way are planned, especially in vacuum to eliminate relative humidity effect. However our first results support the idea that electrostatic forces should be considered when investigating the resuspension of particulate matter in presence of high electric field.

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