Modeling of granular media with electrostatic interactions

In granular materials composed of sub-millimeter particles, electrostatic charges can arise due to multiple contacts and friction. These charges result in attractive or repulsive interactions, playing a significant role in flow behavior and agglomeration phenomena [1]. Electrostatic interactions often have a negative impact on powder processing operations, due to issues such as particle agglomeration, dust accumulation on surfaces, or equipment clogging. These effects are also critical in space exploration, where in the absence of water, fine particles easily adhere to measuring instruments, impairing their functionality.

In dry grinding processes —commonly used in various industrial sectors (mining, cement, agri-food, biomaterials…)— fine grinding efficiency is often limited by particle agglomeration due to electrostatic charging [2]. Conversely, these charges can be leveraged to sort materials of different chemical nature, based on their specific triboelectric properties. This type of sorting, already used in electronic waste recycling (e.g., separating plastic and metal components), holds great promise in fields such as plant biomass biorefining.

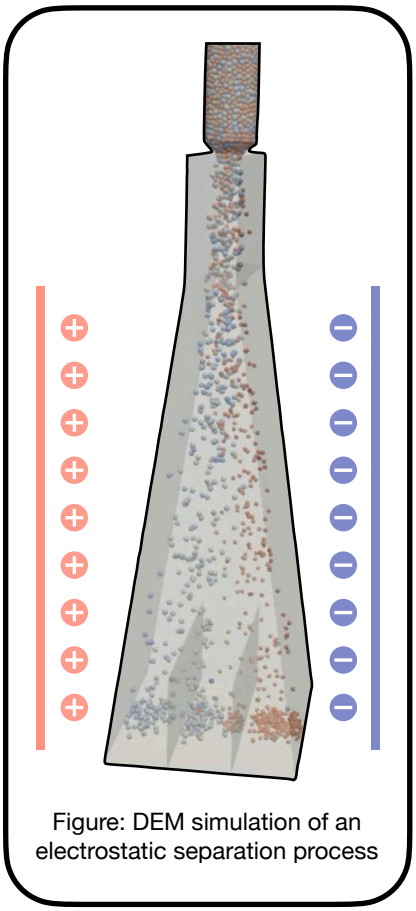

Figure: DEM simulation of an electrostatic separation process

Despite the industrial relevance, the conditions of particle charging and the influence of these charges on granular material behavior remain poorly understood. Several factors affect charging and the intensity of electrostatic interactions: the nature of the materials in contact, their conductivity, grain size, and environmental conditions. Recent developments in the laboratory have enabled precise measurement of the charging kinetics in grains rubbing against each other and a polymer surface under vertical vibration. Experimental results led to the development of an analytical charge transfer model at the contact scale, which has been implemented in a Discrete Element Method (DEM) code that reproduces the experimentally observed kinetics well [3].

This PhD project will build on these initial results to further investigate triboelectric charging in granular media. Three research axes will be explored, both experimentally and through numerical modeling:

- The effect of mixing grains of different chemical natures and size polydispersity on charging kinetics;
- The influence of environmental conditions (temperature, humidity);
- The study of the motion (e.g., free-fall deflection) of one or more charged grains in an electric field.

Each of these areas will be addressed using the team's long-standing expertise in granular materials and associated processes. Novel experimental setups will be developed during the thesis, with potential for patent applications.

Candidate Profile:

Master's degree or engineering background in physics, mechanics, civil engineering, or process engineering, with an interest in experimentation and numerical modeling.

Location:

Campus de la Gaillarde, 2 Place Pierre Viala, Montpellier, France

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