Study of the flow properties of particulates at process conditions

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Several processes and unit operations involve solids in particulate form. The design of these units often requires a proper description of the flow of the particulates involved. The concepts of continuum mechanics are traditionally employed to describe the mechanics of fine powders, based on the hypothesis that powder behaviour can be reasonably approximated using appropriate constitutive equations at the mesoscale level. Dedicated shear testing procedures and equipment have been developed to characterise powders by evaluating the key parameters in such equations.

In recent decades, Discrete Element Method (DEM) modelling has shown promise in directly linking interparticle interactions, modelled at the particle level, to the macroscopic behaviour of powders. Given the large number of particles in real systems and the complexity of particle shapes and interparticle interactions, DEM models require proper calibration the many parameters within the sub-models describing these interactions. This calibration typically involves a combination of experimental and modelling approaches.

For either the evaluation of constitutive equations or the calibration of DEM models to be meaningful, characterisation methods or experiments must be carried out under conditions similar to those of the target process.

This work presents the approaches adopted in the Particle Technology Lab at the University of Salerno to study particulate flow behaviour under process-relevant conditions. These include the development of new procedures and equipment for testing, such as shear testing at high temperatures and humidity, powder rheometry under high humidity, and powder layer spreading at elevated temperatures. An overview of the fundamental phenomena occurring at the microscopic level, as revealed by these techniques, is also provided. Additionally, a new setup for studying the flow properties of iron ore pellets in the hydrogen-based direct reduction process is discussed, along with the results of some preliminary experiments intended for DEM model calibration.

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