399f Flow-Induced Dilation of Fine Powders in a Rotating Drum

Abdul M. Faqih, Bodhisattwa Chaudhuri, Fernando J. Muzzio, and M. Silvina Tomassone

Storage and flow of cohesive powder is relevant to many industries including food, agriculture, mining, and pharmaceuticals. To this date, the majority of research has been carried out for cohesionless materials with particle size larger than 100 micron. Fundamental studies of fine powders (particle diameter between ~ 1 micron and ~ 100 micron) have been scarce in spite of their commercial importance. The increase in cohesion plays a dominant role in flow dynamics as it directly impacts the bulk flowability of solid material. Increased cohesiveness can cause jamming of the flow of granular material, even under conditions where the cohesionless material flows. Dilation is an important phenomenon in fine powder flow dynamics. Once any granular assembly is perturbed, it has to dilate (expand in volume) in order for flow to commence. While it is known that density of cohesive materials varies substantially depending on shear history, flow-induced dilation has not been studied.

In this study, we investigate dynamic (flow – induced) expansion (dilation) of fine powders inside a rotating drum. Results show that for many common powders the bed dilates visibly up to 25%, depending on the powder composition, particle size and the rotation speed of the drum. Experiments were performed in parallel with numerical DEM simulations for various values of powder cohesion, rotation rates, and drum size. Results show excellent qualitative agreement between experiments and simulations. After initial transient behavior, the density reached at equilibrium for all materials tested is lower than the static “bulk density”. Increase in powder cohesion causes an increase in dilation. Size of the system and speed of rotations are the key variables. These results are further confirmed by analyzing local density fluctuations and coordination numbers, which decrease with increasing cohesion. A hypothesized mechanism for dynamic dilation that does not rely on air entrainment is proposed. The increase in cohesion not only affects the flow dynamics, but it also changes the structure of the granular bed. As cohesive forces become dominant, large pores are formed in the bed, leading to substantial fluctuations in local (micro) density that can have tremendous consequences for product uniformity and quality.