364a Cluster Model of Particle Segregation in Vibrated Granular Media

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The dynamics of granular materials is a topic of enormous practical and industrial importance as well as a subject of considerable scientific interest. Segregation of particles in a vibrated granular medium is a commonly observed, yet deceptively complex, phenomenon that has attracted serious research efforts. The Brazil-nut effect (BNE) is an example illustrating how immersed larger particles separate by rising to the top of a granular medium composed of smaller grains. Generally, particles with a larger size or different density compared to grains in the medium will rise under conditions of low vibrational intensity, but may sink if the bed is fluidized by vigorous agitation. The rise or fall depends on a variety of factors including vibrational frequency and amplitude, vessel geometry, relative particle-grain size and density, particle position in the medium, and air temperature, pressure, and humidity. The objective is to apply to this separation problem the general concepts for the distribution kinetics and dynamics of granular materials. The model has provided a new approach for analyzing granular mixing and densification. In granular mixing by tumbling operations, loose particles slide down the inclined surface and/or particle clusters fragment and fall down the incline. In vibrational settling and compaction, clusters evolve during the densification process according to easily solved differential equations for the moments of the cluster size distribution. Essential to the new approach is the consideration that a granular medium has a heterogeneous, clustered structure unless vigorous agitation thoroughly fluidizes the medium. Thus, we model the BNE by hypothesizing that granules form clusters that fragment and aggregate. This provides a heterogeneous medium in which the immersed intruder particle rises (BNE) or sinks (reverse BNE) according to relative convection currents and buoyant and drag forces. A simple relationship proposed for viscous drag in terms of the vibrational intensity and the particle to grain density ratio allows simulation of published experimental data for rise and sink times as functions of particle radius, initial depth of the particle, and particle-grain density ratio. The proposed model correctly describes the experimentally observed maximum in rise time.