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Auto-granulation of fine cohesive powder by mechanical vibration

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Abstract

As the size of individual particles is reduced below several microns, the interparticle cohesive forces begin to play a major role in the bulk powder behavior. Fine powders generally exhibit poor flowability as well as an affinity to agglomerate and form clusters due to this cohesion. This clustering behavior of dry, binderless particles is known as auto-granulation and can often cause difficulties in processing and handling of powders. In this study, a titania powder is vibrated under controlled conditions to induce clustering and promote agglomerate growth. The amplitude and frequency of the mechanical vibration is varied to view the effect of the input energy on the equilibrium agglomerate size. Furthermore, the densities of the formed agglomerates are measured to investigate the role of consolidation as a mechanism of auto-granulation. Given that the size of the agglomerates formed by this auto-granulation process is affected by the balance between the cohesive energy of the particles and the disruptive energy of vibration, this work provides insight into the mechanism controlling the growth of these agglomerates to an equilibrium size.

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Keywords: Agglomeration; Cohesion; Granulation; Vibration

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1. Introduction

A wide range of products are produced by ceramic powder processing, including electronics, structural materials, chemical processing components, and refractories [1]. Whenever dealing with a dry powder process, difficulties may occur when the individual particles within the powder have an affinity to clump or cluster together due to interparticle, attractive forces. The scale of this clustering is dependent on the particle properties and can range from the creation of relatively small agglomerates up to large ones [2]. If during the process, the dispersion of the powder into individual particles is necessary, enough force must be applied to deform and break the particle clusters. This deformation is again dependent on particle properties as the attractive force between particles must be overcome for separation to occur [3].

When dealing with the cohesion between two particles, the contributing factors, in addition to attractive surface forces, are particle size and shape, and the degree of compression. With the larger particle sizes, the interactions are dominated by gravitational forces, but with the smaller particles adhesion has a much larger role [4]. This is the reason fine particles tend to aggregate with one another, especially when the size of individual particles becomes smaller than several microns. At this scale, the attractive forces between particles become comparable to the gravitational forces pulling those particles apart [5].

This paper investigates the auto-granulation behavior of a powder, i.e. the formation and growth of clusters in a dry, fine powder bed under vibration. Due to the powder bed being dry and void of any binder fluid, the primary mechanism of the auto-granulation behavior is the bulk cohesion of the particles. The effect of the mechanical vibration on the size and density of the formed granules is presented.

Nomenclature

A	amplitude of sinusoidal motion
a	acceleration due to vibration
E	energy of vibration
f	frequency of sinusoidal motion
k	wave number of sinusoidal motion
m	mass of sample under sinusoidal motion

2. Powder granulation

Fine cohesive particles with relatively high interparticle attractive forces have a tendency to clump together or self-agglomerate to form granules. This behavior has been studied in an effort to model the size enlargement, or granulation, process of cohesive particles. Ennis *et al.* [2] approached the modeling work by viewing the causes of granulation in particles at a micro-level. In the studied system, the particles were coated with a viscous binder and the sticking of two colliding particles depended on two competing factors: the energy dissipation of the binder layer and the rebounding kinetic energy of the collision [2]. As the size of the colliding particle directly affects the energy of collision, this theory explains the snowball-effect of granulation. If a small particle collides with a stationary large granule, the kinetic energy will be low. This increases the likelihood of the binder dissipating the impact energy of the particle onto the granule. Conversely, if a large agglomerate or a granule collides with another granule, the kinetic energy will be relatively large, more likely resulting in rebound.