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Research Article

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3-Dimensional Motion of an Intruder in Brazil Nut Effect

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Abstract

The purposes of this article were to experimental setup for finding the position of an intruder inside a vibrating granular bed which is the important information for one to understand the mechanism of the Brazil nut effect. However the intruder is difficult to be observed without using some sophisticated methods. And then shown is a simple method to reconstruct the 3-dimensional motion of an intruder inside a vibrating granular bed in annular container case.

Keywords: 3-Dimensional motion; Vertical vibration; Brazil nut effect; Annular container

Introduction

A hollow acrylic annular with glass on bottom is supported on the horizontal platform of a vibration exciter which can be driven to move vertically with a displacement y = A • sin(2π *f* t), where A and f are the amplitude and frequency of vibration, respectively. The strength of vibration is characterized by the dimensionless vibration acceleration $\Gamma = A\,(2\pi f)^2/g$, where g is the acceleration duo to gravity (g = 9.8 m/s^2). A large sphere (intruder) is placed at the bottom of the annular, and small spherical particles are poured into the annular to make a granular bed with a height H. [1] The segregation time, i.e., the rise time of the intruder from bottom to top of the granular bed, will be measured. The ratio of the mass density of intruder (ρ) to that of small particle (ρb), density ratio (ρ/ρb), is used for discussing the influence of mass density, and the rise time (Tries) of the intruder will monotonically decrease with increasing the density ratio [1]. Position of an intruder inside a vibrating granular bed is important information for one to understand the kinematic of BNE. However it is difficult to be observed without using any sophisticated method [2]. Therefore, we introduced an invasive but simple method to reconstruct the 3-dimensional trajectory of an intruder inside a vibrating granular bed. We rely on purely geometrical principles to reconstruct 3-D particle positions, concentrations, and velocities. The methods are able to handle position and motion ambiguities, as well as particle-occlusion effects, difficulties that are common in the case of dense dispersions of many identical particles. Fluidization cell experiments allow validation of the concentration estimates. A mature debris-flow experimental run is then chosen to test the particle-tracking algorithm [3-5].

Experimental Procedure

Figure 1 shows experimental setup for finding the position of an intruder inside a vibrating granular bed which is the important information for one to understand the mechanism of the Brazil nut effect. However, the intruder is difficult to be observed without using some sophisticated methods [1]. Here, we introduced an invasive but simple method to reconstruct the 3-dimensional trajectory of an intruder inside a vibrating granular bed. We used TrackEye Motin Analysis 2.6 for tracking the movement of the intruder inside annular container. (TrackEye Motion Analysis 2.6 is a software package for motion analysis, based on the Track Eye technology from Image System AB.) We connected one end of a thin bar of length *l*=20 *cm* and diameter = 0.1 *cm* to the center of intruder and let the other end of the bar emerges from the surface of vibrating bed as the sketch shown in Figure 1. 3-D trajectory of an intruder inside a vibrating granular bed for annular container. We used the diameter of bed particles *Db* =0.2

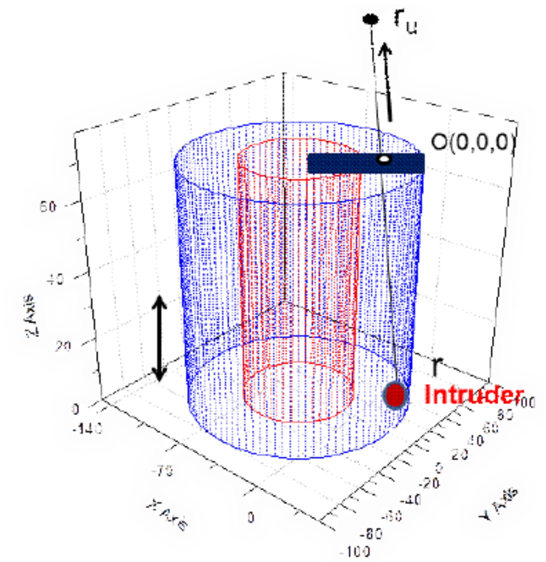

Figure 1: Shown connecting one end of a thin bar of length *l* and diameter σ to the center of intruder and let the other end of the bar emerges from the surface of vibrating bed as the sketch for annular container.

cm, air pressure at *P* = 101 *kPa,* frequency *f* = 13 *Hz,* the vibrational acceleration 2.24 *g,* 3.06 *g,* amplitude *A* = 0.45 *cm,* granular bed of a height H = 6 *cm* and the annular container where radial inner R1= 4 *cm*, and radial outer R2= 1.5 *cm*. If we can trace the position $\vec{r}_u$ (x, y_u, z_u) of the emerged end of the thin bar then the we have to be careful about a few important restrictions of this method. First, the mass of the attached bar has to be small comparing to the intruder mass. Second, the diameter of the bar has to be small enough so that it affects the flow of bed particle as little as possible. Third, the attached bar limited the rotation of intruder thereby this method can only be used in the cases which rotation plays no crucial role. The problem is how to determine the position $\vec{r}_u$. This problem can be easily solved by

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using two synchronized cameras to record the image from two different viewpoints. However, we used one camera instead of two, and captured picture of the object from two different viewpoints simultaneously by manipulating four mirrors. The setups of the apparatus are shown in Figure 2a and a sample of image in Figure 2b. By using this method, we have two sets of two-dimensional coordinates (γ_l,δ_l) and (γ_r,δ_r) of the target from two different viewpoints in each frame. With some algebraic calculation, we can easily transform the two sets of two-dimensional coordinates into the actual three dimensional coordinate $\vec{r}$ (x, y, z) of the target.

Results and Discussion

In the shaking experimental by the same way in the pseudo 3D annular container we have an annular container, track movement of the sphere intruder particle rise to the top at f = 13 *Hz*, = 3.06*g* in Figure 3a. The rising time as a function of relative dependence density ratio $0.18 \le \rho/\rho b \le 2.22$, the size ratio ($R2/R1$ = 1.5/4) of annular containers and we also shown the rise time intruder of annular on different height of bed in container by following three density ratio ($\rho/\rho b$ =0.32, 1.08, 1.92) at f = 13 *Hz*, = 2.24*g* in Figure 3b. We compared the minimum cave around $\rho/\rho b$ =0.32 (~ red line), maximum cave around $\rho/\rho b$ =1.08, 1.92 (~ black line and ~blue line) by obtained to conspicuous mismatched trajectory of Figure 3b. When the rising time was normalized by convection, namely, when the rising time of the intruder was divided by the rising time of the bed particles (which was measured with no intruder inside the bed), the curves in Figure 3 for annular containers with different height distances approximately collapsed into a single curve. This implies that the gap distance of the annular container changes the strength of the convection but does not affect the general behavior of Trise as a function of density. It is known that the intruder can affect the strength of convection [6]. A few tracers were placed beside the intruder before vibration began. The rising time of the tracer tries that emerged first from the surface was recorded, and it was found that Tries, as a function of intruder density, is a concave up curve for annular container. In 3D trajectory of the sheared intruder is moving slowly to the center of the gap and then move faster into the top surface. Velocity of the intruder and convection bed inside container was speed of the lower and upper no difference clear (Figure 3a). There is a difference of more speed in the area near the surface. And we show trajectory motion of the intruder inside the annular container in Figure 4.

Research Highlights

The methods find for 3-dimensional motion of an intruder inside a vibrating granular bed in annular container case are experimented. The appearance of the intruder affects the strength of the motion in a non-linear way; a condition such that the behaviors of intruder are 3-dimensional is derived.

Various experiments of an intruder on vibrating granular bed in

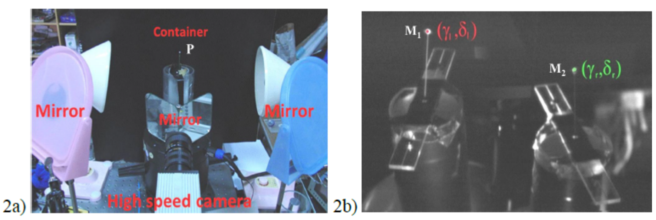
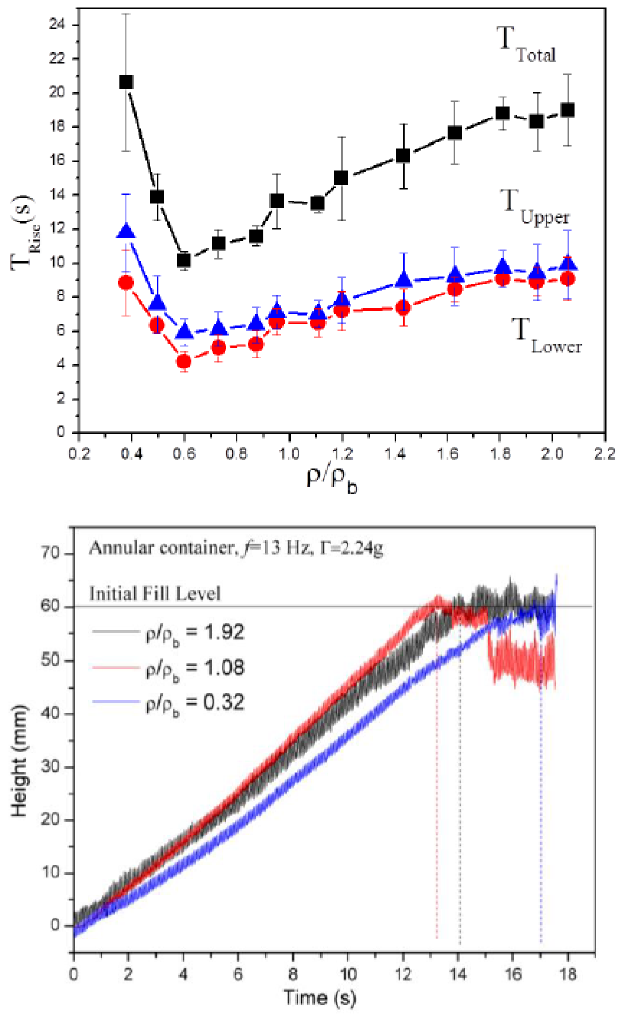


Figure 2: Imaging geometry: (2a) Experimental setup of three- dimensional trajectory focus to physical point P. (2b) Two dimensional coordinates sets of the image projection M1 (γ_1 , δ_1,) and M2 (γ_r , δ_r) on the two stereo view.



3a) 3b)

Figure 3: Shown the rise time of intruder in annular container in the glass bed at P = 101 *kPa*. 3a) The diameter of glass Db =0.2 *cm*, H = 6 *cm*, *f* = 13 *Hz*, Γ = 3.06 g, A = 0.45 *cm*, R1= 4 *cm*, R2= 1.5 *cm*. 3b). The depth dependence density ration of the intruder when being pushed slowly into a granular bed. As show in annular container the plunging forces show immersion depth dependence having a transition from sub linear to supra linear. (*f* = 13 *Hz*, Γ = 2.24g, A = 0.45 *cm*)

annular container are carried out by technical methods of physics. The experimental results are analyzed and compared two methods. It turns out which mysterious inside container are 3-dimensional motion mechanics of intruder shows better performances.

This paper are experimental to our findings suggest that a good understanding of how the trajectory motion is changed by the transform the two set of 2-dimensional coordinates into the actual 3-dimensional coordinate of the target and how it is affected by the appearance of an intruder is crucial before one can fully decode the Brazil nut effect.

Conclusion

The experiments can be used for calculation and analysis of segregation time and velocities. The parameter in the method, the minimum vibration acceleration Γ, amplitude A, and frequency f are related to the vibration control of moving between the intruder and bed

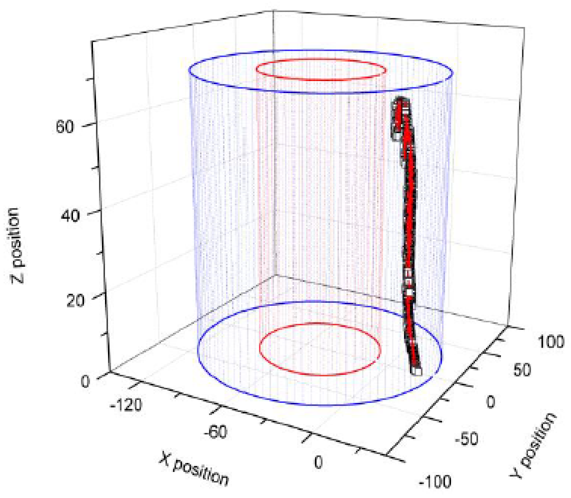


Figure 4: Three-dimensional positions of the intruder in glass bed, obtained by vertical vibration. The intruder of mismatched trajectory is directory to the height on the upper surface of bed particle.

particles. The elasticity of the intruder and small particles can influence not only the segregation mechanism but also the segregation time. We should be taken into consideration when discussing the segregation phenomenon in 3D. Three-dimensional imaging techniques were developed for the measurement of near wall particulate flows from the bottom container. The methods include special matching and tracking algorithms, which exploit the properties of projective geometry and diagrams to reconstruct 3D particle positions and velocities. Fluidization cell tests and an open-channel solid–liquid flow experiment were used to demonstrate the potential of the proposed techniques, as well as point out some of their limitations. It is hoped that they will prove valuable tools for the measurement of particulate flows of scientific and industrial interest.

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