Studying Brazil-Nut Effect History Line using Disk-Formed Objects, Scanner, and Web Browser

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Abstract - Grains configuration snapshots of Brazil-nut effect (BNE) in two-dimension are physically modeled using disk-formed objects, e.g., buttons and magnetic pin. These BNE configurations are artificially designed to mimic the real ones observed in experiments. A computer scanner is used to capture the configurations. Obtained images are then digitized using web browser running a HTML equipped with a JavaScript code, which is built mainly for this work. From digitization process all grains positions (granular bed and intruder) are obtained, which is later analyzed using the simplest model, i.e., potential energy. Since the minimum energy principle (MEP) suggests that a closed system should go to its state with minimum internal energy, our BNE system must also obey it. Evolution of only the intruder seems to violate MEP but not for the whole system. Grains compaction plays important role, so that the system can achieve its configuration with minimum potential energy.

Index Terms - Brazil-nut effect, computer scanner, JavaScript, principle of minimum energy.

1. Introduction

Brazil-nut effect (BNE) is phenomenon in granular materials where an intruder (larger grain) can rise in granular bed (smaller grains), while the whole system are introduced to vibration \cite{1}. It can happen in two- \cite{2} and three-dimension \cite{3}. While three-dimension systems are rather difficult to be observed, which require particular observation techniques such as induction coil \cite{4} or visual-mechanical tracer \cite{5}, two-dimension system promises better observation visually, where grains configurations can be further recorded and the intruder can also be traced automatically, e.g., using OpenCV application \cite{6}.

There is no real BNE phenomenon observed in this work. A grains configuration is designed artificially and grains are positioned based on observed experiments \cite{6-7} and reported research \cite{2-3}. Therefore, the term configuration step is used instead of real time $t$ in identifying configurations order. Grains configurations are recorder using computer scanner, office equipment which are not so common in use for educational or research purposes. Scanner has been used for simulating roots \cite{8}, automatic counting of chemically etched tracks \cite{9}, recording color of leaves related to chlorophyll content \cite{10}, or as office equipment supporting education process \cite{11-12}.

2. Experiment

A two-dimension grains configuration is designed using cloths buttons as granular bed and a magnetic pin as intruder, where all of these objects have disk shape and flat surface. These grains (buttons and pin) are put on the scanning area of a computer scanner and are limited using two steel rulers, which act like a granular container. Figure 1 shows the required materials, tools, and apparatus.

![Fig. 1 Required materials, tools, and apparatus: scissor (SS), adhesive tape (AT), rulers (RL), magnetic pin as intruder (MP), cloths buttons as granular bed (BT), and computer scanner (SC).](image)

-digitizing the image to determine position of all grains (bed particles and intruder) is the next step. A web browser running JavaScript code enhanced HTML is used, where the code is tailored to fit the purpose of this work. Figure 2 shows a screen snapshot of the digitizing application. User can choose an image, digitize it by clicking center of the grains, copy the coordinates into a text file, and save the results. Digitized coordinates are represented in pixels instead of SI unit.
3. Theory

Potential energy $U$ of each grain is given by

$$U = mgy,$$

where $m$ is grain mass, $g$ is gravitation acceleration, and $y$ is vertical position of a grain. For simplicity $g = 1$ is chosen, since $y$ is also represented in pixels, which turns Eq. (1) into

$$U = my \text{ (px)},$$

where px represents pixel unit. Equation (2) can still give potential energy qualitatively even the units do not agree to common units.

Another interesting feature is distance of center of two grains $\Delta r_{ij}$ (px)

$$\Delta r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2},$$

where $x_i$, $x_j$, $y_i$, and $y_j$ are also presented in px unit. If there are $N$ grains in the system, then there will be $M$ different values of $\Delta r_{ij}$, where

$$M = \frac{1}{2} N(N - 1).$$

To distribute those values $O$ classes can be defined where width of each class is

$$\Delta O = \frac{\Delta r_{\text{max}} - \Delta r_{\text{min}}}{O}.$$
This property is similar to contactopy [15], which also increases.

In discussing $\Delta r_{ij}$ only the values related to bed particles are interesting since there is only one intruder in the system. Figure 5 shows distribution of these values for $s = 00$ and 15, where their grains configurations are given in Fig. 6.

Diameter of bed particle is about 32 px, which should be pronounced in grains configuration with $s = 00$ and also integer multiplication of value 32 px as seen in Fig. 5. In grains configuration with $s = 15$, which has a layer of hexagonal close packed (HCP), other value beside 32 px will also be pronounced, which is $\pm \sqrt{3}D$ or about 28 px. These two peaks can be clearly seen as the first two peaks in Fig. 5 (bottom). Existence of other peaks for $s = 15$ can also be found as explained in Fig. 7.

Three series of $\Delta r_{ij}$ can be seen in Fig. 7, which will produce peaks in Fig. 5 (bottom). The most probable peak lies at value about 116 px, which is about $c$ in Fig. 7. Surprisingly this value is more frequent than $a$.

5. Conclusion

Artificial grains configurations have been made in order to study potential energy evolution of system mimicked BNE phenomenon. Analyzing potential energy of all grains instead of only the intruder shows us that BNE does not violate MEP. Compaction that tends to HCP can be analyzed using distribution of distance of center of two grains, where shows more pronounce peaks in HCP configuration. The most probable peaks is observed at position about 116 px or about $3.625D$.

Acknowledgment

This work is supported by Riset Desentralisasi DIKTI (876/AL-J/DIPA/PN/SPK/2014) and RIK-ITB in year 2014 (914/AL-J/DIPA/PN/SPK/2014).

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