Advantage Materials Letters (AML)

First draft received MAR 2020
Accepted August 2020
PJN.6202008
SNY: 000020200828
ONLINE VERSION

Vol.40, No, 1 Aug 2020
Vbbripress.org

www.Vbbripress.org

Experimental Low Density Materials Segregation Using Electromagnetic Shaker

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Abstract

Segregation phenomenon is a key process in industry. Segregation of granular material is done by stirring, opposite of what is expected from stirring. There are a lot of factors that play a significant role in granular segregation. This paper aims to study the granular segregation phenomenon by running a set of experiments using an electromagnetic shaker machine. The effect of changing the large sphere (intruder) diameter on the rise speed was tested and investigated. Also, the effect of increasing the shaking frequency of the machine on the rising speed was investigated. It was found that the rise speed is proportional to the diameter of the intruders. Also, the rise speed increases as the frequency increases. The behavior that investigated in this experiment was compared against different diameters and frequencies.

Keywords: *Segregation, Electromagnetic Shaker, acrylic beads*

I. INTRODUCTION

A lot of artificial and natural substances exist in scatter structure. That denotes they are composed of particles different in size and format. The division of particle size can be defined as the quantity of different size particles which is in charge of the chemical and physical features such as: taste, conductivity, surface reaction, miscibility, characteristics of filtration, and attitude of mechanistic bulk [1].

Nowadays, the sieving which is utilized when there is not a source of electricity is manual, for example, to examine an under-size and over-size on-site arbitrary samples. It's utilized only for guidance aims. On the other hand, the sieve analysis utilized in the lab for the confirmation of quality is done by using shakers. In fact, current sieve shakers are identified by their mechanistic parameters, for example, capacity, speed and time of sieving. There is a made variation in the lab between throw-action sieve and horizontal sieve shakers.

Particle-size analysis can be defined as the quantification of the ratio of the different sizes of particles which compose the main soil. This ratio can be specified either by the rate of sedimentation of the particles in water or by the particles ability to move through a series of varied size screens. The demonstration is done by plotting the proportional weights of these particles within the specified size grades. The boundaries of these grades vary in diverse utilized systems of the categorization of soil particle-size [2].

In fact, there is no agreement on the best process to analyze the particle-size. But in a specific situation the selection of a process is based on the soil nature of the existed soil, the aim of the test, time restrictions and limits, and the obtainable apparatus. For this reason, particle-size data should be identified because the results are based on the utilized process. It's significant to assign a particular process when the data is presented.

There are equations that should be utilized while using hydrometer to form the particle-size. In addition to that, distilled water must be used. Furthermore, the specific gravity of distilled water is lower than the used liquid specific gravity due to the utilization of spread agent. As a result of this, there is needed to utilize a correction.

Correction of results is needed because of additional reasons, such as [3]:

- The hydrometers which are used are standardized at 20ºC and any differences in temperature from the typical temperature will provide inexact results. There is a direct proportion between the divergence and inaccuracy which means that, as the divergence from the typical temperature raises the total inexact results will raise.
- Hydrometers are included to denote the curved upper surface of liquids on gauge. Because it is impossible to obtain these readings, they should

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be secured from the top but it's necessary to utilize a correction.

II. LITERATURE REVIEW

A. Particle segregation

It's known that any granular material will segregate. Any differences in size lead to particle segregation. The granular material segregation is considered very complex as well as the phenomenon is not fully understood. The issues of segregation are practically unavoidable; industrial formulas are multi component and require different mixing steps as well as require invariably solving problems related to segregation. Design decisions can be made routinely without a deep understanding of the phenomenon [1].
Segregation as well as mixing is very important in factories ranging from ceramics and pharmaceuticals and food. Generally, there are significant advances in the cohesive particles as well as free-flowing understanding. The cohesion effects on particulate segregation as well as mixing in even the simple devices were not understood.

The granular material physics are of interest to scientist. The granular medium consists of different macroscopic heterogeneous small particles plus dissipative interactions. Moreover, Brazil nut effect is an outstanding problem; when intruder large particles are placed on the vibrated bed at bottom, they head for the top of the bed. Furthermore, the segregation of size is produced from the non-equilibrium as well as dissipative property of the media. Generally, granular material is used in different industries. Industrial machines which transfer granular materials use vertical vibration in order to fluidize the material, and additionally, the product quality can be influenced by segregation [2].
A counter-intuitive and interesting feature related to the granular materials was the binary assembly's segregation. The initial uniform particles mixture can de-mix from their constitutive components. Generally, the particles are not similar as well as can differ in density, size, surface properties or rigidity. This difference may lead to particle separation. Segregation does not happen always, since the prediction of occurrence conditions is very difficult. The involved issues with systematic account were extensively found in the reviews by [1] [3] [4].

This phenomenon had been known for a long period of time but the underlying of the involved mechanisms nature is not understood. One part of difficult fundamental questions is segregation knowledge that is important for different applications. Particles segregation with different characteristics is an pervasive process as well as it has great important in geophysics, agriculture, material science as well as almost all engineering branches such as; preparation of drugs, food detergents, ceramics as well as cosmetics [2]. Transport as well as processing of mixtures may lead to unwanted separation.
Segregation may be brought by many processes includes shaking, pouring, vibration, and shear as well as it can be observed in processes that designed for mixing of particle [5]. Since there is no obvious framework to understand the segregation, the topic stays controversial for all environments. Furthermore, developing good as well as predictive models can be essential when the understanding of segregation avoids some related problems.

B. Electro mechanical shaker

The electro-dynamic shaker is used to transmit a force to the voice soil. Moreover, this machine is used in activities such as stress screening, product evaluation, modal analysis as well as rattle and squeak. The shakers can be usually driven by transient, random or sinusoidal signals based on the desired application. Furthermore, they can be driven in variably by amplifier of audio-frequency as well as can be also used under closed loop or open loop when the driving amplifier input is actually servo-controlled in order to achieve the wanted motion level. As mentioned in [6], sediments as well as soils are granular particles which have very intricate network. The orientation as well as structure of these pores network can identify the material contaminants as well as transported fluids. A common soil scientific practice is to get very homogeneous medium as well as simplify experiments in order to analyse the equations of transport. For packing a two-dimensional column or cell, soil is sieved as well as broken up for removing big particles which may cause unnatural measurements and they are then re- packed to the cell. Moreover, this can lead to destroy the natural structure as well as produce a new arrangement. Furthermore, the material can appear for having very similar bulk characteristics such as bulk porosity. The demonstration of structural characteristic can be represented as a relation of the used method to repack as well as it is improbable to achieve very uniform distribution.

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C. The particles motion of single intruder in the grains of vibrated bed

One phenomenon which is regime characteristic when the interstitial fluids are very critical is called actually the reverse buoyancy: intruders which have higher density than the density of granular material sink. According to [10], shedding light on the work of the interstitial fluid effect on the sinking/ rising of the intruder of vibrated bed for glass beads. The light intruder sinking was found in vacuum.

The intruder related motion in the oscillation single cycle, with the induced air flow from vibration during granular column, complemented that the behaviour's difference is shown by light or heavy intruders because of the different method in that they were affected. While the implementation of this technique in easy quantitative method is very good to predict the heavy intruder's behaviour, it was very hard for predicting the light intruder's behaviour. Recently, experimental evidence was found and indicated that the very light intruder could still sink when the air is dragged on it is substantially reduced. One of the reasons for that is the low inertia which is sensitive in relation to the heavy liquid. Therefore, the effect of the fluid interface is able to explain the behaviour. Most studies of the impact of the light intruder's behaviour remain unsolved. Even though a lot of computer simulations study the insulation problem, but they did not give any attention to drown light intruders.

Granular materials are known for their ability to segregate when it is shaken. Generally, the most popular strategies for light shed on the segregation basic mechanisms is the investigation of large single intruder within the smaller grains of vibrated vertically bed, a rising intruder being the most frequent outcome [7]. Moreover, the large objects sinking had been studied by a lot of researchers. Depending on the oscillation amplitude as well as frequency, the granular material properties as well as the container size and the shape, there are different systems when the intruder's behaviour can associate with specific mechanisms, such as smaller grain percolation, convection, arching, the interstitial fluid effect or temperature gradients [8].

The phenomenon of reverse flotation of infiltrators in granular systems is the result of combining interstitial fluid that interacts with granular bed. Also the mechanisms depend on other factors like the dimensionless acceleration, the fluid viscosity, and the system size etc. In order to consider when the intruders' displacement with respect for the granular material, it can be shown that how heavy and light intruders represent various movements qualitatively [9]. The light intruders follow the direction of the flow of air which results from the vibration, while resulting from the movement of the heavy intruders not directed by flow of air [10].

This works go for step further since that mechanism could not be blending in quantitatively form that successfully showed the downward movement of light intruders. The downward zone movement is not easily accessible as the curves of the simulation are not complete representation of the knot paradox, where that the problem with the model is the difference in the effect of air accounts globally. Alternatively of the main elements to model the impact of air intruder to taking into account the dynamic natures of bed, and local variations made of porous. Another way proposed to model the impact of interstitial fluid; however it was only used to study the movement of the single heavy intruder.

Finally, it should be noted that, in our effort to isolate the mechanisms based on intruders, exclude process task are often perceived in experiments (and some simulation), i.e. the heat load, by excluding the side walls. It is clear that is important to study the impact of different processes separately and various stages of the bumping cycle to fully understand of the phenomenon of reveres flotation [8].

D. Many kinds of granular materials

Granular materials are everywhere in the world around us. They have characteristics that differ from those normally associated with any of solids materials, liquids, or gases. They consist of a combination of discrete macroscopic solid particles. Examples of granular materials are nuts, coal, sand, coffee, etc. For this review authors locate some of the exclusive properties of granular materials that describe recent advances in research. Granular materials are simple: they are large gathering of single macroscopic particles. If they are non-cohesive, then all their troops repulse so that the shape of material is determined due to the foreign border and gravity. Whether grains are dry, any interstitial fluid, like air, is often neglected in much identification, but not everything, of flow and static characteristics of system. But in spite of this apparent simplicity, a granular material acting differently from other types of familiar materials solids, liquids, or

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Vbbripress.org

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gases must therefore be regarded as an additional the status of this issue in itself [11].

In this article, studying the conversion unusual behaviour that granular material shows when considered to be a solid material, liquid, or gas. For example, sand pile in the rest with low slope from the comfort angle, acting like a solid: the remnants of the material despite the rest of the gravitational powerful create macroscopic stresses on their surface. If the pile is inclined several degrees above comfort angle, cereals start flowing.

Nevertheless, it is clear that this is not a regular flow of fluid because they do not exists only in the border layer on the surface of the pile with no motion in the most part at all. (Clay, where grains are blended with a fluid, have a phenomenology on an equal basis complex as in dry powders).

There are two important types that contribute in the unique features of granular materials: normally temperature does not play any role, and reactions between the cereals are wasted because of the static friction and the inflexibility of collisions. It may at first a tendency to view the flow of granular as the dense gas from the gas, which consists of particles separate forces of cohesion among them weak. On the other hand to ordinary gases, nevertheless, the energy gauge kBT is reckoned here. The appropriate energy gauge which is the potential energy mgd in a grain mass m increases by its own diameter d in the Earth's gravity g. For model sand, the energy is 1012 times kBT at least in room the temperature [1].

Because kBT is unrelated, ordinary thermodynamic proofs become useless. For example, several studies shown that shaking or rotations in the granular material will urge particles of different sizes in order to separate into many regions of the container. Where there are no power attraction between the particles, this secede should at first appear to infringe the rise of entropy principle that normally prefer mixing. In a granular material, from another side, kBT; 0 implies that the entropy concerns can easily be outweighed by dynamical impact that becomes one of important paramount [5].

E. Segregation proportions for a combination of various sorts of granular substances

A granular substance blending gives interesting instances of self-regulation and type formulation. Additional blending behaviour -for instance the forcing raising for stronger vibrating or quicker dropping - doesn't ensure a preferable-blended system. This is due granular blends of various substances segregate due to its size and concentration. Actually the quite identical forcing applied to blend may lead to strip the confusion. Self-regulation ensues from two contend procedures which are disordered blending or disordered advection which is as same as of fluids, and flow-encouraged separation which is considered unmatched phenomena of fluids. There is a substantial arrangement of attitudes that is preferably appropriate for dynamics which are constructed on examination especially which is nonlinear. Furthermore, the experiences of interchange are considered instant. These frameworks actually have to specify the easiest instance of cohabitation among self-regulation and disorder which can be examined in the lab. It will be offered a brief summary of the abstract surrounding and physical notions which are joined by exemplifying empirical outcomes to assist in the scouting of this fresh field [4].

At this moment assume segregation procedures. Although granular blends of partially different substances will be vibrated, they will segregate in various cases. There are many examples of this phenomenon but the most well-known one is the Brazil-nut as mentioned by [4][5] where big particles climb to the vibrated vessel's top of nuts which are blended. There is a big chance to tinnier particles to make a wiper to slide beneath a bigger one -not in the opposite- over the crowding of the particles through a vibration. In such procedure the tinnier particles progressively are led to act down to the vessel's bed while the bigger particles will be carried up. Through the granular substances convective movement, the influence of segregation in some cases has been seen to be led. There is a second instance of segregation includes a type of separation which is obtained through the granular substances flux. During the shedding of the granular blends in a very fine area between dual perpendicular dikes, the constituents will be detached into strata. The established style is as same as the style which is existed in the sedimentary type of crags and it is considered accountable for the described phenomena. In addition to these instances, there is an extra instance of flux-encouraged separation which is segregated by putting it in a roller blender that the various constituents detach in the vertical orientation to the turning centre line. From where the mission of flux which is symbolized as (r) and the concentration regression which is symbolized as (rc), they are considered on

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the same line or its relation is collinear. For this reason, a construction which is radially separated in a round plane is counted constant construction. To imagine the flux-encouraged separation in a material view, assume a blend of particles of various classes of size in a stable fall flux. It was noticed, since over a hundred years ago, that during the flux of granular substances, the particles expand and through the expansion of the substances, spaces will be formed. Minute particles can press into very tinny spaces beneath a big particle but the reciprocal is more less probable to happen which is producing in a clear separating flow of the tinnier particles falling onward from the release plane. It was explained that the ideal attitude of frameworks with separation standard. In the same way, when various concentrations blends travel over a stratum of shear, the thicker particles are more preferable to drown into a lower stratum [11].
In extended rotary drums, radial separation is frequently accompanied by pivotal separation. The forecasting of the separation of granular substances which are formulated of various sizes is considered a really difficult problem. Granular substance blends which is created of various sizes of particles, concentrations, or any else characteristics offer a tendency to separate at the time which it is exposed to exterior eruption, for example shear or shaking. In special view, sheared grainy blends which are varied in dimensions of particles submit a testing and mutual issue in a lot of manufacturing cases because of their propensity to compose unfavourable diverse particle arrangements in piles, tumblers, slide channels and cells. These isolated or in other words pure arrangements are considered as a result of size separation which is happened in normal phenomenon, for example; ruins fluxes. Different research studies explained implicit techniques and improved predicted structures for separation of size and formulation of style in sheared, multi-scatter grainy flux. These researches have specified sundry driving techniques for separation, style formulation and blending of bi-scatter particles. In diluted active flux systems, the particles react at most through dual crashes, the tendency of grainy temperature can force separation of size which is shaped by kinetic notion. On the other hand, in the thick grainy flux system, the dimensions of particles seem the essential driving technique. There is a technique called percolation which is mean that junior particles are more probable to down over shear created spaces than greater particles. This technique leads to that the tinnier particles travel down however bigger particles travel up which effects on the rate of infiltration. Separation which is occurred because of infiltration, in addition to other impacts such as convection, advection through minor flux and crashed dispersal compute allocations of particles in bi-scatter thick flux, often resulting complicated styles [12].

There are different attempts for size segregation modeling in bounded flow. A model of screening layer which is proposed in that the layer can be divided to three layers; small particles, mixed particles as well as large particles – from the flowing layer surface to its bottom. Moreover, the conservation of mass in each layer as well as accounting the migration of particles between the layers, It has derived a new model which predict the concentration of local particle qualitatively for all types with different in discriminately adjustable parameters like the ratio of velocity of several sub layers as well as the rate of penetration of components segregating. The particle exchange is modeled between the layer as well as a static bed by using a lot of functions which are unknown as well as incorporated the collision functions to the conservation of mass equations for all species. Moreover, this model can predict the concentrations of qualitatively local particle, but there is need of parameter fitting without physical interpretation .The fitting parameters are necessary as well as the quantitative agreement is lack with experiments for both models and are very likely because of the simplification of kinematics flow [12].

III. Experimentals Works

In this research, a set of experiments were performed using electromagnetic shaker to find all parameters that affect the segregation of relatively large solid sphere particles in the fine media of other particles. The idea of the electromagnetic shaker is to monitor the movement of large steel sphere in a fine particle bed of quartz when making vibration for the bed using the shaker machine.

A. Apparatus

The apparatus used in this research is illustrated in Fig.1. The main components of this apparatus are:

1. Fine particles of 6 mm acrylic beads.
2. Electrical shaking machine to apply required vibration.
3. Steel structure to carry the apparatus component and overcome the vibration and movement during shaking.
4. Spring to improve elastic support of the particle bed

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Vbbripress.org

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5. Connection rod to move the vibration from electrical shaker to the glass bed
6. Fluidized bed contains fine particles with glass surface to monitor the movement of the sphere during the experiment

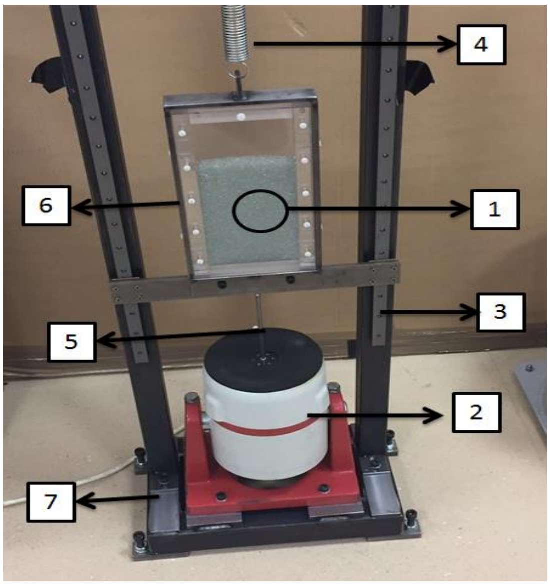

Fig.1: Electromagnetic shaker apparatus

Note: The granular bed height is 180 mm, filled with 6 mm acrylic beads.

B. Procedure

The following steps summarize the procedure:

1. The glass bed was filled with fine particles with specific size finer than the size of studied steel sphere
2. The studied steel sphere was put on the surface of the bed and the bed is closed carefully
3. The bed was fixed using the spring (part 4 in Fig.1) and the connection rod (part 5 in Fig.1)
4. The electrical shaker was turned on and the movement of solid sphere through the fine particles bed was monitored and recorded by a camera
5. The required time to move the solid sphere from the bed's bottom to the bed's surface was recorded (rise time)
6. The same procedure was repeated at different intruded diameter (size).

Note: the shaking speed is 8 Hz (setting of "2" on the amplifier (arb.units))

7. For intruder size 12.68 mm, the frequency of shaker was changed and the vertical displacement was measured for each frequency to find the effect of changing frequency on the rise velocity.

C. Data and Records

The first aim of the experiment is to find the effect of changing intruder size on the settling (rise) time for the sphere to reach the bottom of the granular bed. To achieve this aim, the following readings were recorded from experiment:

Table 1: Vertical position with time for 8.5 mm intruder

Time (seconds)	Vertical position (mm)
0	5
5	22
10	31
15	37
20	46
25	56
30	79
35	100
40	130
45	155

Table 2: Vertical position with time for 12.68 mm intruder

Time (seconds)	Vertical position (mm)
0	9
5	25
10	55
15	77
20	90
25	106
30	125
35	142

Table 3: Vertical position with time for 15 mm intruder

Time (seconds)	Vertical position (mm)

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Vbbripress.org

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0	8
5	24
10	46
15	94
20	130
25	138
30	140
35	142

Table 4: Vertical position with time for 19 mm intruder

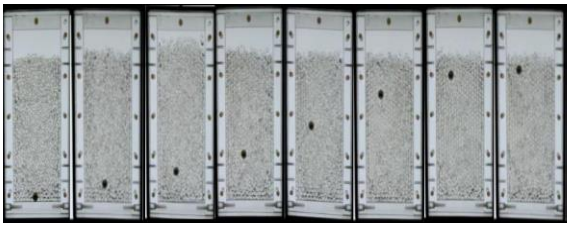
Time (seconds)	**Vertical position (mm)**
0	10
5	43
10	78
15	123
20	155

The second aim of the experiment is to find the effect of changing frequency on the settling (rise) time and speed for 12.68 mm sphere to reach the surface of the granular bed. To achieve this aim, the following readings were recorded from experiment:

Table 5: Rise velocity versus frequency for 12.68 mm intruder

Frequency (Hz)	**rise velocity (mm/sec)**
6	0.1
7	0.4
8	3.9
9	8.5
10	10.4
11	9.8
12	10.5

Fig.2 shows different shots of the intruder during its rise in the granular bed because of vibration.



(1) (2) (3) (4) (5) (6) (7) (8)

Fig.2: Rising of intruder through granular bed because of vibration

IV. Results and discussion

A. Rise velocity of 8.5 mm

The rise in vertical position of the intruder is plotted in Fig. 3 at different times, to estimate the speed as a function of time; the displacement function will be derived with respect to time as follows:

$$S = \frac{dy}{dt} = \frac{d}{dt}(3.14\,t\; + 12.682)$$

$$S = 3.14\; mm/s$$

Where; “S” is speed (mm/s) and “t” is time in mm.

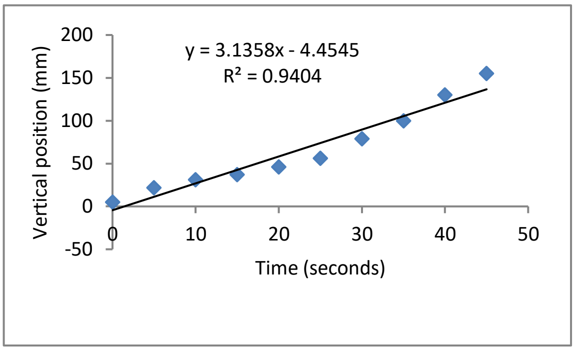


Fig.3: Vertical position with time for 8.5 mm intruder

It can be noted that the relationship between the vertical displacement and time is linear as shown in Fig.3.

B. Rise velocity of 12.68, 15, and 19 mm

The rising velocities for 12.68, 15, and 19 mm intruders are calculated using the same method as for

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the 8.5 mm intruder. The rise in vertical position is plotted against time in Fig.4, 5, and 6 for 12.68, 15, and 19 mm intruders, respectively. For the 12.68 mm intruder, the displacement function will be as follows:

$$S = \frac{dy}{dt} = \frac{d}{dt}(3.80\,t\ +\ 12.083)$$

$$S = 3.8\,mm/s$$

While the displacement function for the 15 mm intruder will be as follows:

$$S = \frac{dy}{dt} = \frac{d}{dt}(5.06\,t\ +\ 7)$$

$$S = 5.06\,mm/s$$

And for the 19 mm intruder:

$$S = \frac{dy}{dt} = \frac{d}{dt}(7.4\,t\ +\ 7.8)$$

$$S = 7.4\,mm/s$$

From the calculated velocities, it can be noticed that the rising velocity is increasing with the particle size

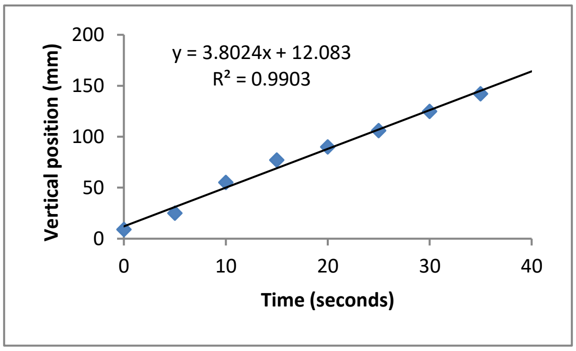

Fig.4: Vertical position with time for 12.68 mm intruder

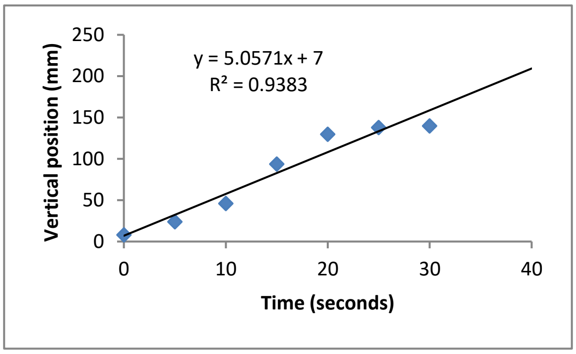

Fig.5: Vertical position with time for 15 mm intruder

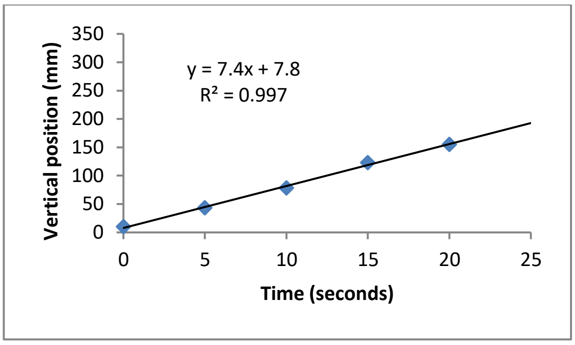

Fig.6: Vertical position with time for 19 mm intruder

It can be noted that the relationship between the vertical displacement and time is linear as shown in Fig.4,5, and 6.

C. Rise velocity at different intruder size.

The summary based on previous data analysis can be seen in Table 6.

Table 6: Rise velocity versus intruder diameter

D (mm)	8.5	12.68	15	19
S (mm/s)	3.14	3.8	5.1	7.4

The regression of data in table 6 was made using Excel to determine a relationship between diameter of intruder and the rise speed

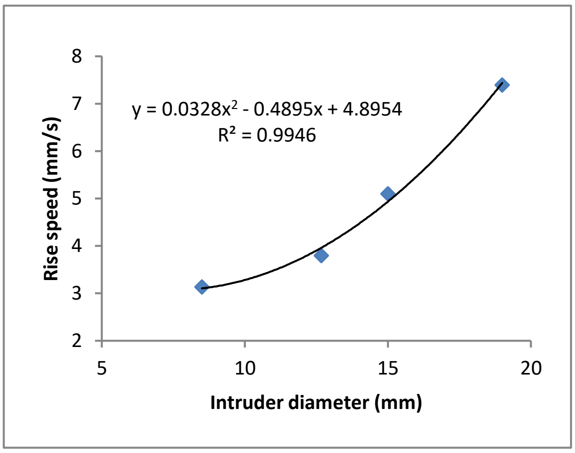

Fig.7: Relationship of rise speed in mm/s versus intruder diameter in mm

As shown in Fig.7, the rise speed is proportional with intruder diameter where the function is parabolic with the following expression:

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$S = 0.0328\, D^2 - 0.4895\, D + 4.8954$

Where D is the diameter of intruder in mm and S is the rise speed in mm/s.

D. Rise velocity at different frequency for 12.68 mm intruder

Based on Data in Table 5, the relationship of rise speed versus frequency was represented in Fig.8.

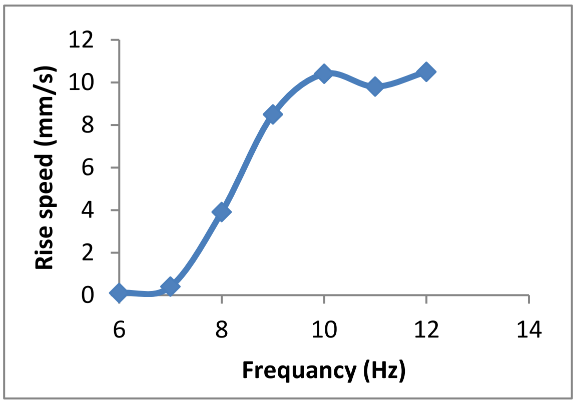

Fig.7: Relationship of rise speed in mm/s versus frequency in Hertz

It can be noted that the rise speed increases as the frequency of the shaking machine increases. This behavior is agreed with literature review data.

V.Conclusion

Segregation can be defined as a counterintuitive phenomenon where the separation of dry granular particles occurred during shaking depending on the size of materials where the large particles rise to the surface and the fine materials descend to the bottom of the flow channel or bed. Granular segregation occurs both in natural flows such as landslides, and in industrial processing where it can cause severe problems. There are many material processing techniques in environmental, chemical and pharmaceutical applications depend on this phenomenon.

This project aims to study the effect of changing the size of intruder spheres on the rise speed of the large sphere in the acrylic small particles. In the other hand, the effect of increasing the shaking frequency on the rise speed was investigated. A set of experiments were accomplished to obtain reasonable data for granular segregation and the parameters that play major roles in increasing the rising speed.

The first part of experiment depends on testing 4 different intruders using 8Hz frequency where each intruder (sphere) has its unique diameter. The vertical displacements data were recorded with time to find the segregation speed (rise speed). It was found that the vertical displacement increases as the diameter of intruder increases. Based on displacement – time data, the rise speed was determined analytically for each experiment. Finally, it was found that the rise speed is proportional with intruder diameter where the function is parabolic with the following expression:

$S = 0.0328\, D^2 - 0.4895\, D + 4.8954$

Where D is the diameter of intruder in mm and S is the rise speed in mm/s.

The second aim of the experiment is to find the effect of changing frequency on the settling (rise) time and speed for 12.68 mm sphere to reach the surface of the granular bed. It was found that the rise speed increases as the frequency of the shaking machine increases. This behavior is agreed with literature review data.

VI.References

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Advantage Materials Letters (AML)

First draft received MAR 2020
Accepted August 2020
PJN.6202008
SNY: 000020200828
ONLINE VERSION

Vol.40, No, 1 Aug 2020
Vbbripress.org

www.Vbbripress.org

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