Experimental Research on the Angle of Repose for Granulated Materials

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1. Introduction

Granular materials consist of many macroscopic (>10 μm) particles which can be poured in a cone-like shape. The angle of repose is the minimum value of α at which one granule starts sliding down on the inclined plane. After reaching this angle, the particles start to slide down the slope like an avalanche. To determine the critical values of α for different materials and circumstances I must take into consideration the so-called force chains because these force chains determine the angle α [2]. Looking at the pile it can be seen that the angle of repose α is not the only angle, there are three different angles. The interface friction angle (δ), the angle of repose (α) and the granular frictional angle (β) [3].

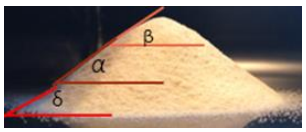

Figure 1 – Sliding wedge used for the spreading type of slope stability analysis

The main acting forces which determine the angle of repose in a system for particle *i* can be calculated by the following equation:

$$\sum \vec{F}_i = m_i \vec{g} + \sum_{j=1}^{n} \vec{F}_{ij,\text{friction}} + \sum \vec{F}_{ij,\text{normal}} + \sum \vec{F}_{i\,\text{cohesion}}$$

2. Research Methods

In my experiments I controlled the shape and speed of the pouring. In my research I used simple kitchen granular material, as ground poppy seeds, chia seeds, sesame seeds and flour. Two different experimental setups were investigated. In the first experiment the particles were poured between two glass plates. [1]. In the second one the particles were poured on a free plane ground. The effect of the plates on the angle of repose can be seen on the *Figure 2*. The effect of the shape of particles on the pile formation was studied by digital microscopy. The dependence of the size of particles and the humidity were also investigated.

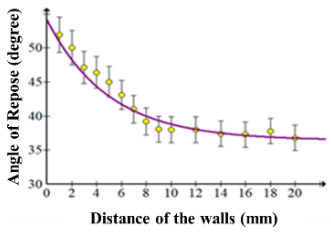

Figure 2 – Angle of repose of semolina depending on the distance of the walls

3. Results

According to my measurement, the most relevant parameters for the angle of repose were the properties of the surface, the shape, the size of the particles and the humidity of the materials. The results for the size can be seen in *Table 1*.

For increasing the effect of the size, I made experiments with flour ground in three different sizes, thus I could assume that their coefficient of friction is the same. In the case of other factors besides the size are invariable, the smaller the size, the larger the angle becomes (*Table 1*). To explain this phenomenon, I should take in to account in the Van der Waals forces.

Table 1 – Angle of repose of the different flour particles

Material	Width of the particle	Length of the particle	Angle of repose
Semolina	741 μm	1239 μm	33–26°
Pastry flour	262 μm	471 μm	38–41°
White flour	2.39 μm	2.82 μm	42–46°

From my experiments it became visible, the more asymmetric the particles are, the smaller the angle is. The explanation of this phenomena is based the potential energies of the particles. During measuring the angle of repose for plain white flour, I noticed that the flour formed lumps, because of its humidity. I reduced the humidity of the flour by heating of the material. The difference in the angles between the flours investigated in the mentioned two conditions was nearly five degrees.

4. Conclusion

I gave an extensive view about the phenomenon with measurements and with investigating most of the relevant parameters as well as I could optimize the angle of repose.

5. References

[1] H.J. Hermann: On the shape of the sandpile, available online at http://www.comphys.ethz.ch/hans/p/224.pdf*

[2] I Zuriguel, T Mullin: The role of particle shape on the stress distribution in a sandpile available online at http://rspa.royalsocietypublishing.org/content/royprsa/464/2089/99.full.pdf*

[3] Liu, Zhichao: Measuring the angle of repose of granular systems using hollow cylinders available at http://d-scholarship.pitt.edu/6401/*

(*Available at 02.03.2018)