Sand jets

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1 Purpose of the investigation

When a heavy sphere is dropped onto a bed of loose, fine sand, a remarkable phenomenon occurs: a large, focused jet of sand shoots upwards. Although similar looking jets are observed on impact in fluid systems, they are held together by surface tension. Surprisingly, the granular jet exists in the absence of both surface tension and cohesion. My aim was to explain the behavior of the sand and describe the phenomena quantitatively.

2 Method of the investigation

For my research I used a cylindrical container (0.5m high, 0.4m weight), filled with sand. After dropping the steel ball, we can observe the following series of visible events: first, the ball vanishes in the sand and a crown-like splash is created. Then, after a while, a jet shoots out of the sand at the position of impact. Finally, a granular eruption is seen at the position of impact, resembling a volcano.

The first thing I was able to measure quantitatively, was the dependence between depth penetration and the kinetic energy of the ball. For the experiment, I have used 2 steel balls with different diameters.

Scientists have already measured the behavior of the sand and a ball under the surface. They used composite x-ray imaging to show changes in local packing fraction after a metal sphere impacts a granular bed surface.

3 Results of the experiment

As I written before, I have measured the dependence between depth penetration and the kinetic energy of the ball. The following diagram illustrates the results:

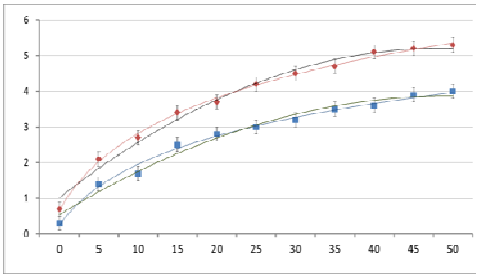

Fig. 1 Depth penetration versus the height drop of the ball. The red dots denotes the results obtained for the ball which diameter was 1.2 [cm]. In the second experiment (blue dots) I have used 0.8 [cm] wide ball. Sand bed was 20cm deep. The axis x shows the height of a drop and the axis y denotes the depth of the penetration. All values are given in centimeters.

I was also able to vary the packing density of the sand in the container. Next diagram shows how depth penetration depend on the drop height of the ball and the packing density of the sand.

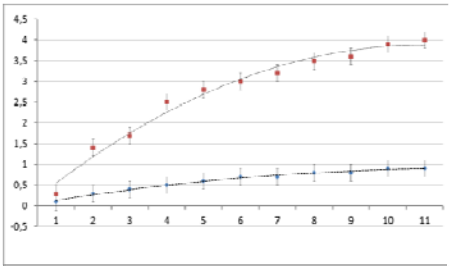

Fig. 2 Depth penetration versus the packing density of the sand. The volume of the denser sand (blue dots) equaled 0.7 of the volume of loose sand (red dots).

When the sand jet is falling down, we can observe the clusters and droplets formation. While the upper part of the jet is still going upwards, in the lower parts occur inelastic particle-particle collisions. This leads to density inhomogeneities in the jet.

4 Conclusions

This experiment shows that loose sand beds can sometimes behave like a fluid, although there is no surface tension. Jet height depends on many factors, eg. the initial height of the sphere, sphere diameter, compression of a sand bed and an ambient pressure.

References

[1] John R. Royer, Eric I. Corwin, Bryan Conyers, Andrew Flior, Mark L. Rivers, Peter J. Eng, and Heinrich M. Jaeger, “Birth and growth of a granular jet”, Phys. Rev. E 78, 011305 (2008)

[2] John R. Royer, Eric I. Corwin, Andrew Flior, Maria-Luisa Cordero, Mark L. Rivers, Peter J. Eng and Heinrich M. Jaeger, "Formation of granular jets observed by high-speed X-ray radiography", Nature Physics 1, 164 – 167 (1 December 2005).