Theme Park

Sandglass

Imagine you're in a sauna. You're gradually starting to sweat. You perspire more and more until finally the sweat cascades down your body like a waterfall. It becomes hard for you to breath, your eyes fixate on a sandglass, and the sand inside just doesn't move fast enough. Suddenly it occurs to you that as the sand on top becomes depleted, the grains of sand are falling slower and slower and slower...

In fact, this is only your imagination. The rate at which the sand falls is steady and does not slow down. There is, however, a mystery behind how fast sand falls in a sandglass.

Dr. Yoshihiro Taguchi, Associate Professor of Physics at Tokyo Chuo University, explained:

When many grains are collected together and considered as a single entity such as sand, the grains are called granules. Granules exhibit different characteristics from that of solids or liquids.

Let's consider the case of water. The more volume you have, the more water pressure results. With granules, however, volume and pressure are not proportional to one another. A good illustration of this is a tunnel. A mountain is made up of an accumulation of rocks, soil, sand and other elements, which, in a general sense, could be viewed as granules. If the volume of granules were proportional to pressure, at the foot of the mountain would be a tremendous amount of pressure that would collapse the tunnel. The energy in granules, however, not only acts downward, it also disperses itself laterally.

Now let's imagine designing two sandglasses, one using water and the other using granules. The drain speeds for water and granules would be quite different. This is because water pressure is proportional to volume, which would cause the drain speed to decrease as the volume was depleted. In contrast, no matter how many granules remain in the upper section of a sandglass, the overall drain speed is constant except for a small fluctuation factor. This is why a sandglass utilizes sand as opposed to water.

Granule movement is so mysterious that designing a simple sandglass can still be a challenge. For example, the diameter of the narrow section of the sandglass, the orifice, must be at least six times that of the particles to allow them to flow properly. It's also important to make sure the diameter of each grain is roughly the same size and to thoroughly wash the sand to preclude extra friction between particles.

Recently, it was shown that within a steady flow of granules, there is a slight fluctuation (of period 1/f). It would be interesting if someone were to make a sandglass based on this unique phenomenon. For example, if you were to install a sensor near the orifice that translated speed changes into sound, each time you flipped the sandglass you would be able to enjoy a different sound. This is because the sand flow exhibits a periodic fluctuation that is slightly different each time you flip the sandglass.

In this day and age, much of our society has become static and predictable. Machines have to be predictable and so, in general, precision has become very important. I also tend to think, though, that human nature is more attracted to things that are not predictable than those that are predictable.

In a society where digital and quartz watches have replaced old-fashioned clocks, sandglasses have not yet disappeared. The phenomenon of the flow of sand through an orifice is still a powerful mystery we have yet to fully understand.

Dr. Yoshihiro Taguchi's Home Page:
http://www.granular.com/tag/index-j.html

The seven wonders of hoppers*

1. The pressure against the interior wall of a hopper remains constant no matter how many grains are inside. The wall pressure 3 cm above the base of the hopper, for example, is independent of the amount or height of grains contained in the hopper.
2. If a large number of grains are poured into the hopper and then you open the exit orifice, pressure on the orifice walls will increase dramatically.
3. Orifice wall pressure and the speed of grains exiting the orifice both exhibit a periodic fluctuation.
4. The speed at which grains exit the orifice is equal to 2.5-3.0 times the orifice diameter.
5. The average exit speed of grains is independent of how many grains remain in the hopper.
6. Sometimes connecting a tube to the mouth of the orifice will increase the exit speed of grains.
7. When the orifice diameter is less than 6 times the grain diameter, the orifice will become clogged.

* A hopper is a standardized container used in granule research that is shaped in the center like the upper half of a sandglass. Similarly, a sandglass can be considered to be a practical application of the hopper shape.