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Flow Vis IV1
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Table Salt - A Solid or Liquid?

This was the first project that I completed for Flow Visualization Fall 2022, and was an individual project that I completed in my own house. The video shows table salt being poured from the container onto a clear glass table, and my finger pushing the salt around. My aim with this project was to push the definition of a fluid, so I thought that sand could be a good example because it is a solid crystalline structure at a smaller scale. I did not have any sand on hand, but I could achieve the same thing with table salt, which I had in my kitchen. I did struggle quite a lot trying to find the right balance between reflections and enough lighting/showing glass scratching for my video camera, but eventually I found a combination of next room lighting, overhead lighting, computer backlighting, and side lighting from a headlamp that seemed reasonable.

As the salt was poured onto the glass flat table, there were only a few forces at play on each salt particle. Gravity, Normal, and Surface Frictional Forces were the most prominent, while air resistance (also frictional) played a small role. It is computationally very expensive to model this entire system because of the quantity of the particles, but also their individual geometries are a major point in predicting where the particles may land. Even the most advanced supercomputer would get bogged down with these calculations. Each particle is crystalline and is odd-shaped, so the Normal Forces can point in every direction. This happens at the moment at (and right before) the particles leave the nozzle of the container, causing a set trajectory towards the glass table. The trajectory is acted upon by gravity and air resistance, as well as contact with other salt particles and their aerodynamics. When the salt hits the table, it's orientation will dictate the normal force and rebound direction, and internal and surface friction will dictate the amount of force absorbed by the particle and by the glass table. When the particles start to pile up, the Normal Forces change, and different physics are observed as the pile achieves a "jammed" state, or a state where the particles interlock with each other and get stuck. A jammed state could happen with marbles trying to exit a funnel, but all of them moving through at once will get them stuck. The most fluidic way to observe salt is when it's moving, like when sand is moving through an hourglass (Chakraborty et al, 2017).

The salt was poured onto the top of a glass dining room table, and video recorded from below. I wanted to record from below in order to have the viewer experience salt being poured on them, which was fun, although I feel like recording from up top would give a better 3D representation of what happens when the salt starts to pile up on itself. Due to the lighting, the thinner parts of the salt mounds were brighter than the rest, which helped with the 3D visualization. I used Kroger Iodized Salt, purchased from King Soopers. The table surface was wiped on both sides with rubbing alcohol and a paper towel in preparation for the pour. The thermostat was set to 72 degrees fahrenheit, and humidity was 40% outside, with our attic vent fan at max speed. For the lighting, 4 elements were used. The living room ceiling fan light (4x Great Eagle 14W 60Hz 125mA 14W 2700K 1500lm bulbs), 15 feet away, was set to full brightness, the overhead (4 feet above glass table) dining lamp (3x the same bulbs as the living room) with orange stained glass shielding was set to between ¼ and ⅓ brightness, and my

Lenovo Legion laptop's screen was set to full brightness 2700k white 12 inches away, in parallel with the light coming from the living room light. Finally, my Black Diamond Spot headlamp's main beam was set to full brightness (aux beam off) and placed perpendicular to the light from the laptop and living room, shining right to left in the video frame, and was placed approximately 8 inches from the rightmost spot where the salt was poured. The video was filmed during a dark night, so no light came in through the windows.

My DSLR Canon is not able to take high quality videos, so I used the digital camera built into my iPhone XS instead, which was able to record with good quality at 1080p/60fps (1920 x 1080 pixels). It has optical image stabilization, which was not used as the camera was totally stationary, and was converted to mp4 from H.264 format. The 6 element lens is a wide-angle f/1.8 aperature, and has a hybrid IR filter. The camera was placed 10 inches below the surface of the glass table, and tilted approximately 10 degrees away from the computer and living room lights to reduce reflections. I used calipers to measure the field of view in my particular setup, which was 9.4 inches across and about 4.4 inches vertically.

The image shows both the fluidic and solid states that salt can take. One salt particle acts as a solid, and will bounce off of the table surface and other salt particles. But as a system, they act organically as a fluidic group, like molecules within a stream of water for example. This is most evident by watching the salt particles around the periphery of the mound right after they are poured out of the container, especially when the flow of the pour is reduced. Because they are outliers, they bounce directly off of the table and scatter further than when the flow is fast. The more salt particles, the easier it is to visualize the salt as a fluid, and when the flow is restricted or the particles fall outside of the main area, the easier it is to visualize the salt as a collection of solid particles. I like that the video can show the duality of the state of salt, but as mentioned above, I think the 3D nature of the salt pile could be visualized better from the top of the table. I would be able to use a less complicated lighting system, especially if I poured the salt onto a less reflective surface. Perhaps the salt could be lit from below the surface of the glass table too, which would light up the edges of the salt mound more than the center, but might not be necessary or possible with a less reflective table surface. I also feel like pouring the salt was significantly more interesting than my finger moving the salt mound in a S pattern, so I wish I had highlighted that more. I do feel like I succeeded in showing that the salt can act as a fluid or solid depending on flow rate and visualization technique. I wonder what would happen if I shook the salt for a very long time and repeated the experiment, would the eroded particles react with each other in a more fluidic way? What other "particle-fluids" can demonstrate this effect, and at what point does the particle size approach something so small that it is socially accepted as a fluid?

Reference:

Bulbul Chakraborty, Kabir Ramola, Stefano Martiniani, K. Julian Schrenk, and Daan Frenkel. "The Physics of Sand". BrandeisNOW Nature Physics, University of Cambridge. (June 2017).