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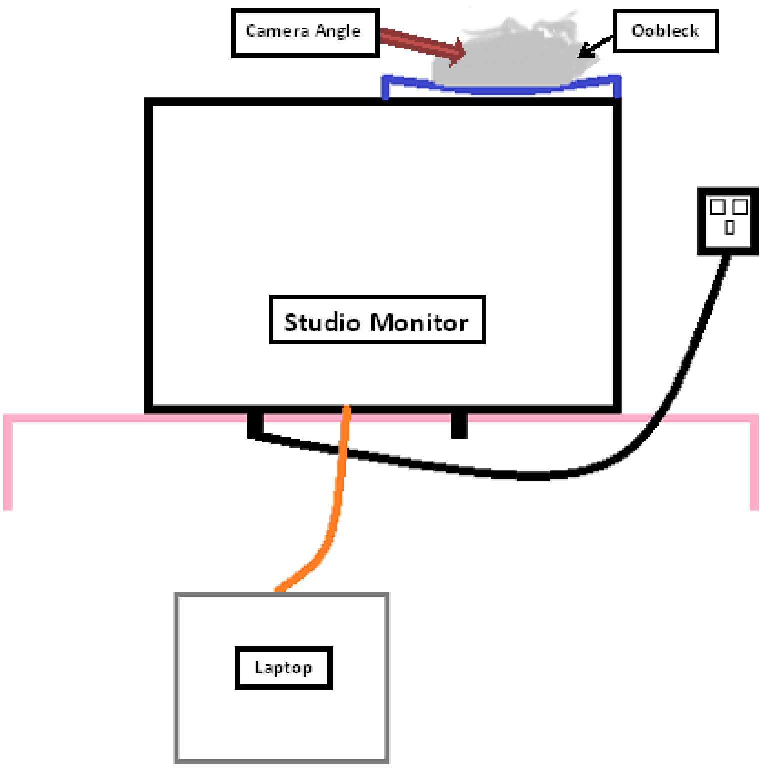
Get Wet Assignment

For this flow visualization image, I chose to excite oobleck (cornstarch and water) with sound emitted from a studio monitor (M-Audio BX8a). Oobleck is a non-Newtonian, "shear-thickening" fluid, which means that it behaves differently to common, "every day" fluids, like water. Instead of flowing and conforming to the shape of its container irrespective of external conditions, non-Newtonian fluids behave more like solids when stressed like fluids under normal conditions. The physics behind this phenomenon will be discussed further later on in the report. At first, I wanted to show the oobleck moving under constant sound output, but ultimately, I decided to make the oobleck 'dance' by hitting it with pulses of sound. This was mainly an artistic decision, but I also believe that this method resulted in a unique visualization.

The visualization schematic is shown below. The camera angle is approximated for two dimensions, but in an overhead view, it would ideally be rotated 90 degrees counterclockwise ("into the page" in the view seen in figure 1).




Figure

The monitor was set up with the cone facing upward. A small foam structure (in pink) was constructed to support it and stand off the volume knob and power cable from the floor. Then, a protective plastic sheet was taped over the speaker cone, and approximately half a cup of oobleck (120 mL) was poured onto the speaker. Then, the monitor was connected to a laptop, which was running sound synthesis software. Using the software, a two oscillator synth was created (a sawtooth wave layered with a sine wave), and a notch filter was utilized to increase the intensity of the synth at 30 hz to +6 dB. This notch filter value was chosen by trial/error and bisection to a find a frequency that maximized the movement of oobleck. Then, in order to send pulses through the monitor onto the oobleck instead of a constant standing wave, a cutoff filter was applied with low-frequency oscillation (1 hz). After completing the synth, the volume knob was raised, food dyes were added, and photos of the 'dancing' oobleck were taken.

A Reynolds or Grashof number would be very difficult to estimate for this flow because of the fluid's shear thickening nature.[1] For Newtonian fluids, viscosity remains constant, but for non-Newtonian fluids like oobleck, viscosity is a function of shear rate. Equation 1 below is used to describe the relationship between shear stress and shear rate for any fluid.

(1)

Tau is the shear stress,  is shear rate, and k and n are experimentally determined constants. For Newtonian fluids, n is approximately 1, but for non-Newtonian fluids, n is greater than 1.[2] These relationships are depicted in figure 2.

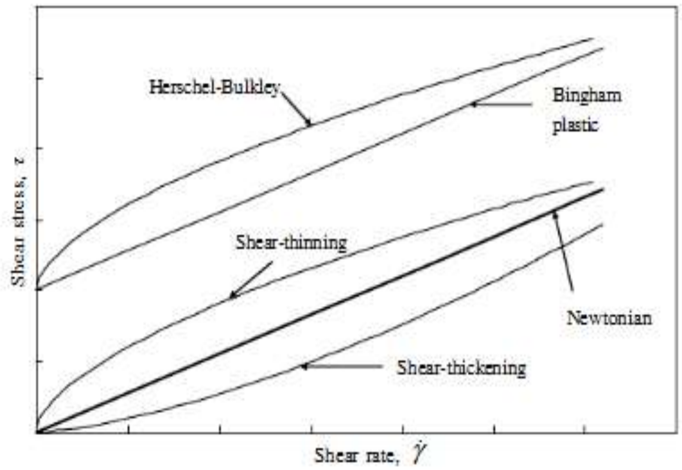



**Figure – Shear stress vs. shear rate for various fluids[2]**

In the context of this particular setup, this means that when the sound pulse hit the oobleck, it physically lifted off the speaker cone like a bouncing stone, then flowed back down like water. After a few pulses, the oobleck became unevenly distributed on the cone, so creases began to form. This resulted in parts of it 'flapping' upwards like stingray wings by a few inches. Despite this flapping, the vast majority of oobleck stayed within the confines of the cone.

The main visualization was the oobleck moving and contorting on the speaker. However, it was not the only one. Though it was not originally intended to be a noteworthy visualization technique, the food dye ended up played a significant role. It moved towards the creases with each pulse, and formed extremely distinct line patterns. These lines changed with time, and provided further insight into the movement of the oobleck. This also made the resulting photo much more interesting and artistic in terms of color depth and detail.

The camera used was a Canon PowerShot SX130 IS. The specifications for the photograph were f/8, 1/250 exposure time, ISO-400 and 5mm focal length. The camera was brought extremely close to the oobleck (about 5 inches) and macro mode was used. The small aperture (f/8) was chosen because of the relative proximity of the oobleck, the quick shutter speed was chosen to limit the blurring of the rapidly vibrating oobleck, and the ISO was chosen

1 J. Harris, "A note on the generalized Reynolds number in non-Newtonian flow." Queen's College, August 1963.

2 M. Eesa, "CFD Studies of Complex Fluid Flows in Pipes." University of Birmingham, March 2009.

to strike a balance between adequate lighting and limiting noise. Even though a fluorescent tube light was held directly over the speaker, and a nearby door was opened to let in a minimal amount of sunlight, significant post-processing was required to offset the darkness of the photograph; contrast in particular needed to be increased. Additionally, the photo was rotated counterclockwise 90 degrees in order to offset side of the distracting background elements, like the plastic sheet and back wall. The before and after can be seen below in figure 3.

**Figure – Before (left) and after (right)**

Also, the final photograph ended up having a resolution of 2706 x 3114 pixels (after rotation and cropping) to capture a field of view of about 4 inches by 3 inches.

Overall, this visualization was a success. I was able to get the oobleck to behave the way I wanted, and achieved artistic details that I was hoping to include. However, I would have liked to have had a brighter light source. It would have allowed me to make the shutter speed even quicker (to further reduce blurriness), turn down the ISO, and layoff of the heavy post processing. I would really like to make this image again in the future. I have a very solid procedure now, and I believe that I could capture something even more interesting and artistic if I had the opportunity.