Cymatic Visualization of Oobleck on Shake Table

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Image/ Video 3

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Figure 1: Still from IV 3 Video Submission Showing Oobleck at 10 Hz

For this third Image/ Video submission, students were set out into teams once again in order to further explore various types of fluid flow. My team was interested in the properties of the non-Newtownian fluid known as oobleck, which is a shear-thickening fluid formed from a mixture of cornstarch and water. It was decided that we would subject a body of oobleck to vibration from shake table within the ITLL on campus in order to see what patterns would be formed. Initially, we had planned to capture this oobleck while it was subjected to strong vibration such that it would jump in the air, however this did not end up being the case. I instead decided to create a video submission of the oobleck as it was subjected to various vertical vibrations. Figure 1 depicts a still from the video. This was made possible with the help of my teammate Bryce Dickson, who assisted in the experimental setup of the table as well as the control of the shake table from the main computer (shown in Figure 2). My other teammates, William Watkins and John Whiteman assisted as well and helped with material acquisition.

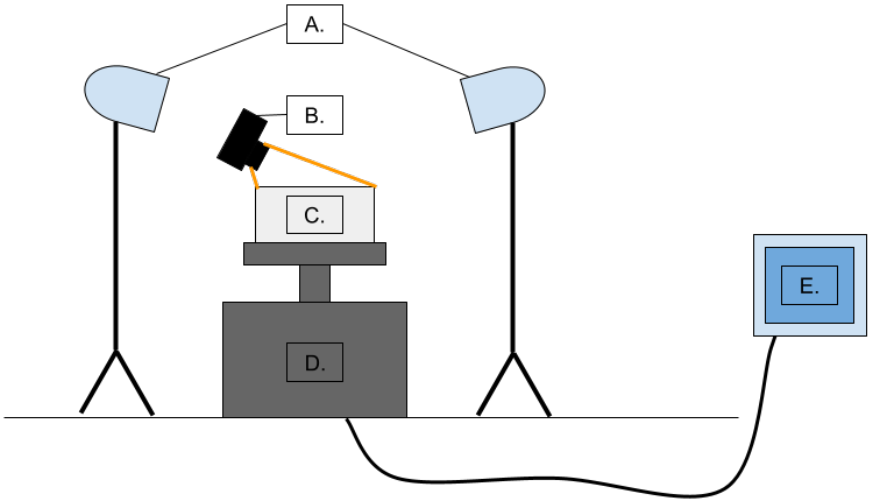

Figure 2: Experimental Setup for Figure 1

Figure 2 shows the experimental setup used to take Figure 1. The elements labeled are described in Table 1:

Table 1: Figure 2 Items and Descriptions

Item	Description
A	LED Lights on Tripod
B	Handheld Nikon D3400
C	Tupperware Containing Oobleck
D	Shake Table
E	Shake Table Control Software

Cymatics is a term describing the study of sound made visible through fluid flow, such as with vibration. This visualization is a derivative of cymatics, as different patterns in the oobleck appeared based on the differing input frequencies. Oobleck, however, is different from water, as it is a non-Newtonian fluid, meaning that it does not exhibit the standard properties of a fluid as described by Newton's Laws of Physics. In this particular case the fluid is 'shear-thickening', meaning that the consistency thickens when experiencing a shear force or disturbance. In the case of the visualization, this means that the fluid will experience inconsistent densities throughout the container as a vibration force is applied, since the fluid experiences different forces in varying locations. Lima (2020) describes this effect as a "snowplow", in which particles inelastically compress into one another. These differences create interference patterns, which allow for resonance across newly created standing nodes as energy is continually added to the system.

Since the oobleck is a non-Newtonian fluid, calculations modeling the system are difficult to achieve and outside the scope of this course. However, the system can be modeled as water to understand the physics behind the generated waves. The equation that governs the velocity is as follows:

$$v = \lambda * f \tag{1}$$

Where v is the velocity of a wave, f is the frequency of the wave and lambda is the wavelength.

Typically, standing waves are the kind that are measured with this equation, since it would allow them to propagate without interference (Kim et al, 2012). However, we can estimate the wave velocity given the

information in the IV video. Given the frequency applied from the shake table of 10 Hz, we can analyze the initial wavelength from the first frame of the video to be approximately 1 inch. Using Equation 1, the wave velocity is approximately 10 in/s.

An example of a single standing wave is best depicted in research from Kim et al. below:

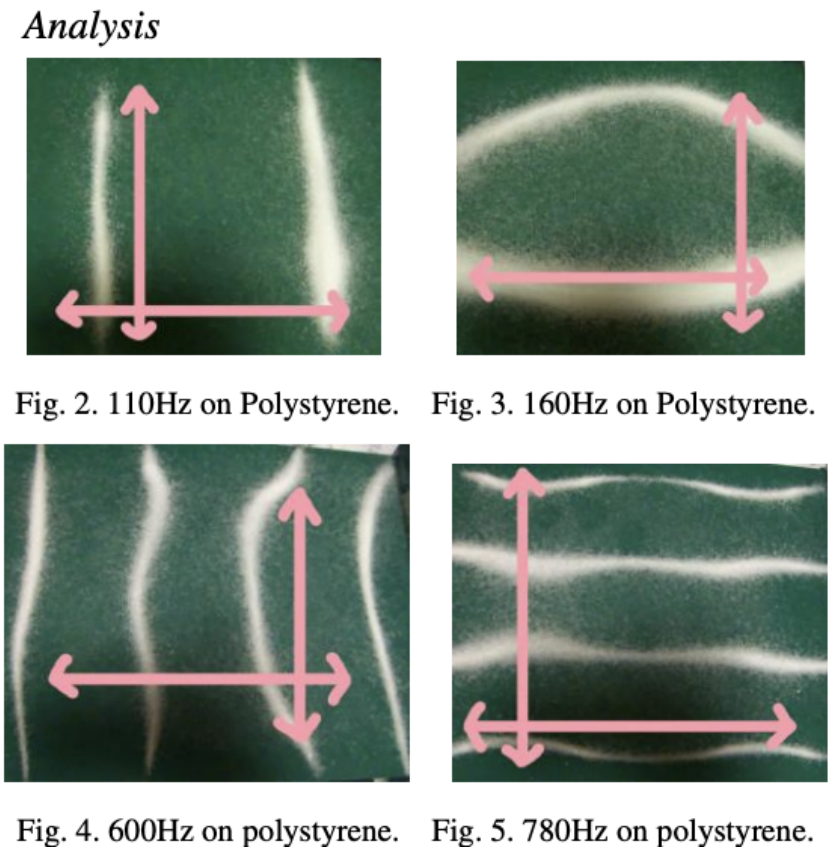

Figure 3: Kim et al (2012) Cymatics Vizualization of Standing Waves at Different Frequencies

Figure 3 shows the effects of different frequencies on particles of polystyrene. This depicts a clear way of measuring the wavelength of the particles!

The goal of this assignment was to visualize the effects of vibration on oobleck using a shake table capable of generating different frequencies. To create the mixture, a ratio of 2 cups of generic corn starch to 1 cup of water was used, which created a more fluid-like result. The procedure that followed was to tape the underside of the Tupperware containing the oobleck to the metal plate on the shake table, and then to program differing vibrational frequencies to be run on the table. Various photos and videos were then taken while the test ran. I simultaneously held an iPhone 13 to record video at 240fps, along with a Nikon D3400 to take stills. Bryce also added various colors of dye to improve the visibility of the fluid as it was shaken. The only light used in the scenario were two SAVAGE brand 35W 5500K LED bulbs with a white light setting producing 2130 lumens; no built-in camera flash was utilized.

The submitted video was taken with an iPhone 13 Mini camera, using the built-in 12MP camera. The photo was taken with a focal length of 26mm at aperture f/1.6. The frame rate was 240 fps, so that it could be slowed down 4x to a smooth 60 fps for playback. The goal of the framing of the image was to capture the most action of the oobleck as it was excited in the Tupperware. The FOV of the image spans a region of 12x24 inches (at 3840 x 2160 pixels), and the subject was approximately 24 inches away from the lens.

Since the submission was a video, I was more focused on the clip selection than the editing of the video. I decided to compile several clips that featured the oobleck undergoing a sine sweep from 10-60 Hz. The field of view was planned to be enough to capture the entire Tupperware to see the interference patterns that were presented. I also added a custom piece of music to the background that I felt fit with the visualization presented.

In conclusion, this video highlights the behavior of a fluid as it undergoes constant vibration from a shake table. I am pretty happy with the way that it turned out, as the oobleck made some pretty neat patterns that was cool to capture on video. While I feel successful in fulfilling my intent, I believe that with further experimentation I could have achieved further standing nodes, or perhaps with increased concentration of the corn starch in the container. I would keep the same camera settings, but attempt to change the frame such that less of the testing environment was in view.

References

Kim, Sojin, and You Jin Oh. \Experimental Study of Cymatics." You Jin Oh and Sojin Kim, Aug. 2012, https://d1wqtxts1xzle7.cloudfront.net/58374136/404-E3006-with-cover-page-v2.pdf?Expires=1668224372&Signature=GZZdJP3TxeV5CDsWMHAtxW~~Ed0XrfSqoG4TDkTI7h2wQ3J072YAf~kAGsPlpGWJJKN3sngqgWsYolqI3Nid8RrH44MBrvmwY2aLvp9dbhydJUpF7QvIX2yuEcAiacfcetKsm4p9JJvdvvKQJqfg9BAp1rXBaqOFrvkqDkDUdgQe2YePinL6Ln96WAx8f9hzwQxv2dQmrdXlgbGGQYB-pSK4DrpaXnHcJBjl5ttJYLaZfF12533TP7G-T1bN9P7wSlisSJ7QjDGpSX8SFfLp56tlN6ZN7iAIbygtHu3hiuKjErAV-cNs4w-cZECNJzfVUggpUfagpo0uNdNsNQdH-Q__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

Lima, E A, et al. \Studying the Oobleck with Video-Analysis." IOP Science, 2020, https://iopscience.iop.org/article/10.1088/1361-6552/ab921a/meta?casa_token=PE8V8uLtZfkAAAAA:ANSQiEsPbXNdzI1rPR79OT0awcBlsH4YrnBr1slBy6c70aR1fOs-fSm0kLPyXGelBi0Ykusbcv02ybonVBI.