Get Wet
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Introduction

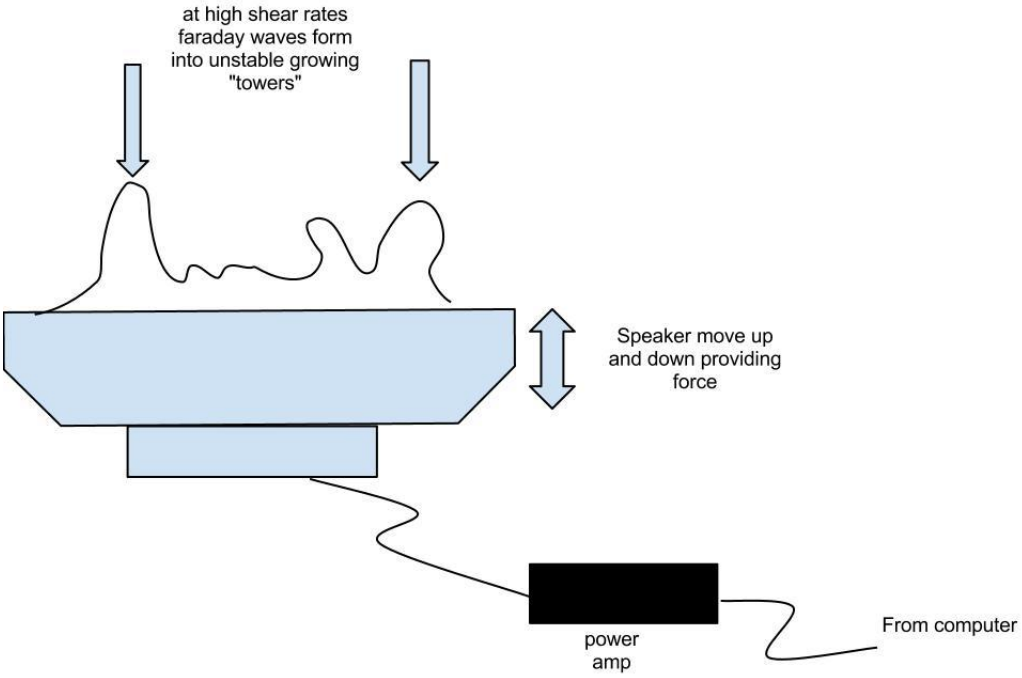
In the process of exploring various flow visualization images online and through the class discussion I became particularly intrigued by the behavior of non-Newtonian fluid (such as a mixture of cornstarch and water referred to as oobleck) which has properties of both a liquid and a solid. My interest in music technology further compelled me to explore physical responses to audio rate vibrations. My goal was to reproduce the extending tendrals and dancing blob-like creatures formed by the oobleck mixture under stress from a vibrating speaker and to compile and interesting composition displaying these behaviors. It was also an exploration of UV reactive liquid which was mixed into the oobleck to see if it could help visualize features of the flow when viewed under a black light. The end result was a video and some still images at the end of the video. It was satisfying to reproduce some of the displays I've seen along these lines and see them first hand. I hoped to create a compelling video displaying the intriguing nature of this flow. It was partially successful in this regard but I would have liked to make a more professional looking final output and capture some more interesting behaviors.

Context of flow

For this experiment I created a non-Newtonian fluid by mixing cornstarch and water. The mixture was poured into an old subwoofer speaker turned upside down to reveal the 12 inch cone. The speaker was driven by a small 25W stereo "T-amp" to provide power. The signal to the amplifier came from the audio programming language Max MSP which was used to drive a low frequency sine wave into the speaker. Through experimentation for the mixture and depth of the mixture in the speaker cone I found the most interesting activity occurring in very low frequencies between 22 and 30 Hz. Vibrating liquids with a steady frequency creates standing waves on the surface.

Under the right conditions the peaks of these waves when perturbed will cause the outgrowths. The unstable nature of the mixture and chaos caused by the high speed vibrations cause the mixture to grow tendrils which become unstable under their own weight and fall, while this impact may cause other growths to begin to form. A study done at the University of Texas confirms this and describes this chaotic state I was most interested in as follows: "The protuberance eventually falls, nucleating a new hole, and
the growth of a finger is repeated. After many repetitions the entire surface writhes with fingers and holes yielding the spatially and temporally erratic state"[1]. In the case that the mixture has released from the speaker base and becomes airborne it takes on other properties that seems to resemble that of suspended liquids which are held together by surface tension. This material is also called a dilatant which means the viscosity increases with the rate of shear strain[2]. A study at Cornell explains "they showed that fluids became thicker or more viscous when particles were driven past one another too quickly for the fluid between them to drain or get out of the way."[3]

Approximating that the speaker cone at its center is moving up and down around 1/2", completing a cycle in 1/30th of a second it can be calculated that the vibration is approximately:
(1/2 in. / 12 (in/ft) / 5280 (ft/mi)) / (0.5 * 1/30 s / (3600 s / hr))
7.8914e-6 mi / 4.630 e-6 hr6 ~= 1.7 mph (perhaps not the most useful unit of measure)
This seems to be rather slow, however the acceleration related to the changes in direction keep the mixture under force. The speed of the flow itself is much harder to estimate since it greatly depends on the actual state of the material at the time.



Scenario

I mixed approximately two cups of cornstarch with one cup of water until it was reasonably homogenous (because of the unique behavior this is more difficult than I expected). As one stirs the mixture the pressure from mixing causes the mixture to stiffen and become like a chalky solid. Once the force is removed the mixture relaxes back into a liquid form. After it was placed in the speaker the mixture was adjusted by adding cornstarch or water based on experimental observation. I added approximately 1/2 Tbs of T-900[4] a UV tracer. In a darkened basement (at night) a lamp was placed near the speaker to provide low ambient light, additionally a 2' black light was employed to provide a secondary light source and to excite the UV tracer. Both lights were approximately 2'-3' from the speaker although the blacklight was moved around during filming to try and achieve different effects. At times only the blacklight was used to illuminate the oobleck.

Capturing the flow

A camcorder on a tripod was placed between 12 and 18 inches from the activity, mostly from a slight angle above, but some side views more in plane with the speaker and some from more directly above. A Sony DCR-40 was used The Sony camcorder was unable to lock its focus which made it difficult to get clear images since in the low light it was consistently adjusting focus. The camcorder a Sony “DCR-42“ digital HDD camera had its optical 20x zoom maxed out, recorded at 30fps. The camera does not support recording to uncompressed video and unfortunately I found it lacking in its image quality. Especially when viewed on a large screen as in class, the noise especially in the dark areas became apparent. The video compilation was created using iMovie without using any effects except a minimal use of cropping to clear some clutter from the background. The still images shown at the end of the video were captured with a fixed 50mm lense with the following parameters:

F-stop: f/1.8
ISO: 1600
shutter speed : 1/200th s
no flash

Only under blacklight:
F-stop: f/2.0
ISO: 800
Shutter Speed: 1/50th s
no flash

Summary

The video and stills captured capture a wide variety of the unique behavior displayed by non-Newtonian fluids under stress. I was happy to see the results of this experiment live and frankly could have stared at it for hours (I guess I did). The flow of the mixture is very organic and fluid, while the randomness causes for infinite intrigue as it is constantly morphing into a new form which is what compelled me to want to recreate this in the first places. In the future I would like to find a better way to vibrate the mixture. For one the speaker did not like being submerged in the mixture for so long and the center of the cone actually softened to the point that it peeled off. I’ve since seen other videos in which people use a plastic dish glued into the speaker or line it with a plastic bag. However I think these could affect the aesthetic of the image. A dish would have allowed better control over the depth of the mixture. Since the speaker cone is, well a cone with a dome in the middle the depth of the mixture was irregular. I believe different depths will contribute significantly to the types of behavior observed. Further to this, trying a wider variety of tone frequencies and complexities (more harmonically rich sounds) would be another interesting aspect to explore. In particular I would like to know if I could find a wider variety of behaviors and find ways to consistently reproduce these. Additionally as suggested in the feedback, use of dyes could likely significantly contribute to the visualization of this flow by providing additional contrast. Another point on aesthetics; I could have done a better job of controlling the background and should have had a black backdrop so as to not distract from the

main act. In the end I was able to reproduce the unique behavior of the non-Newtonian fluid known as oobleck and feel my work contributes a unique approach and imaging results.

1. http://arxiv.org/pdf/nlin/0311026.pdf

2. http://en.wikipedia.org/wiki/Dilatant

3. http://www.news.cornell.edu/stories/Sept11/ShearRates.html

4. http://www.blacklightworld.com/Security%20Tracer%20Commercial.htm