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Flow Visualization
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Team Image 2 Report

For the second team assignment in Flow Visualization: A Course in the Physics and Art of Fluid Flow, I worked with two of my team members to photograph the behavior of a non-Newtonian fluid. Non-Newtonian fluids are interesting because their flow properties differ in some way from the more familiar Newtonian fluids such as water. To create a non-Newtonian fluid we made a mixture of approximately 1 part water and 2 parts corn starch. This mixture is commonly called oobleck and is one of the most common examples of a non-Newtonian fluid because it is both easy to make and has interesting flow properties. Oobleck is a shear thickening fluid, meaning its viscosity increases with the rate of shear acting on the fluid. My teammates and I had seen interesting videos of the behavior of oobleck when a small amount of the fluid is placed on a speaker. The oscillating speaker increases the rate of shear experienced by the oobleck which causes small fingerlings or towers of oobleck to rise out of the fluid. Our goal was to photograph this phenomenon.[1]

The flow apparatus used was simply the speaker itself. We borrowed a small computer speaker and took the actual speaker out of the speaker housing and oriented it horizontally. To ensure the oobleck wouldn't damage it we wrapped the speaker entirely in plastic wrap. The speaker was approximately three inches in diameter. We found that a frequency of about 40 Hz was ideal in order to get the best fingering. We wanted to experiment with much higher frequencies but it seemed like the higher frequencies put a lot of stress on the speaker and we didn't want to damage it. A simple drawing of our apparatus setup can be seen below in Figure 1.

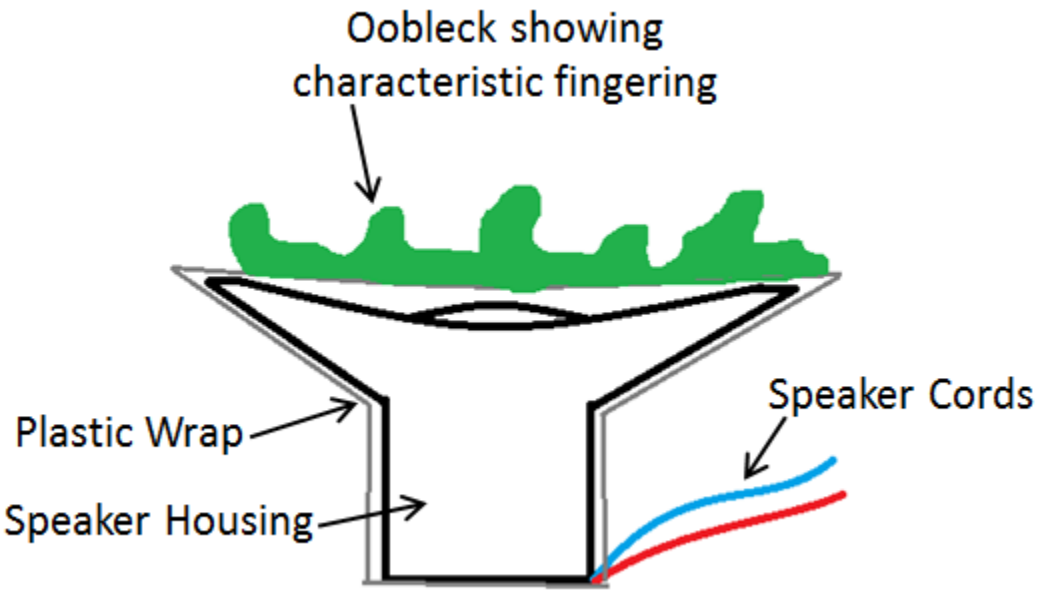

Figure 1

As discussed in the first paragraph oobleck is a shear thickening fluid, meaning its viscosity increases with the rate of shear acting on the fluid. We see the characteristic finger of oobleck because the vibrating speaker greatly increases the rate of shear of the fluid causing its viscosity to increase. A more viscous fluid can better hold its shape allowing the fingers to propagate and grow as long as the speaker is vibrating. The more important question then becomes: What causes oobleck to be a shear thickening fluid? It has to do with the fact that the long corn starch molecules suspend in the water. At low rates of shear, water can easily fill the small gaps between the corn starch molecules where it acts as a sort of lubricant and allows the mixture to flow easily. At higher rates of shear the water cannot as easily fill the gaps between the corn starch molecules and friction between the molecules greatly increases causing the viscosity of the fluid to increase. A diagram of this can be seen below in Figure 2.[2]

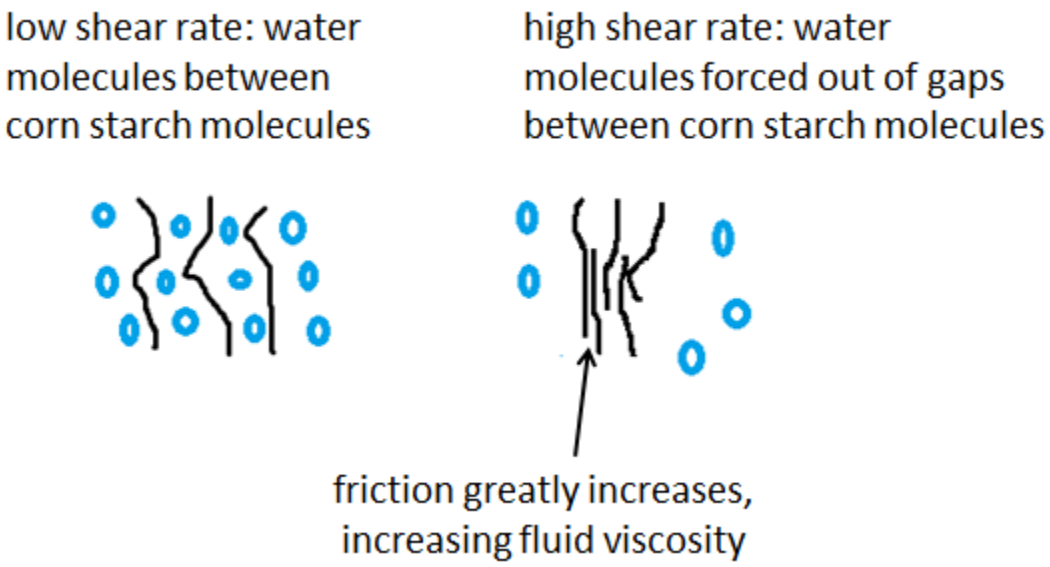

Figure 2

I was hoping to find some concrete equations to describe oobleck behavior but it seems that the behavior of oobleck and non-Newtonian fluids in general is not fully understood0.

To better visualize the oobleck's behavior we dyed it with food coloring. At first we just photographed the oobleck with no food coloring at all. We found that because undyed oobleck is a pale off-white color it is difficult to see any detail in the photographs. We then tried dying the oobleck a solid color. This allowed us to see slightly more detail but we still found that any solid color obscured detail. Finally, we decided to place a few drops of food coloring on the oobleck before the speaker was turned on and let the vibration of the speaker and fingering of the oobleck mix the food coloring. This allowed us to see much more detail in the photographs. To light the oobleck we borrowed a set of painter's lights from Mike Elliot in the ITLL and placed them about two feet from the speaker. I wish we had had slightly more light but painter's lights get very hot and we didn't want the heat from the lights affecting the oobleck in any way.

The size of the field of view in the final image is about 4 inches wide by 4 inches tall. The distance from the speaker to the camera lens was approximately 6 inches. The lens focal length was 55.0 mm. The image was captured using a Canon EOS Digital Rebel XTi camera with an EF-S18-55mm f/3.5-5.6 lens. The original image was 3888 pixels wide and 2592 pixels tall. I cropped the original image to remove some distracting features at the top and bottom of

the photograph leaving the final image 3888 pixels wide and 1713 pixels tall. The aperture of the lens was f/5.6. I wish we could have used a smaller aperture to get better depth of field. However, we didn't have enough light to use a smaller aperture. The shutter speed was 1/400 of a second. We needed a high shutter speed to ensure we didn't have blur in our photographs. It would seem to me that because the speaker was vibrating at only 40 times a second a shutter speed of 1/400 of a second would have been more than enough. However, we did try slower shutter speeds to capture more light but it seemed that any shutter speed less than 1/400 of a second would result in image blur. The ISO was set to 400. The original image can be seen below in Figure 3 and the final image can be seen in Figure 4. Not a lot of post-processing was done on the image. As you can see the biggest thing I did was reverse the colors of the image in Photoshop. I did this because I think it just makes for a much more interesting and even slightly mysterious image. I especially like the vibrant orange streaks in the left side of the final image; they seem to make the image "pop" a lot more. I also used the auto-contrast feature and vibrance tool in Photoshop to further refine the image.

Figure 3: Original Image

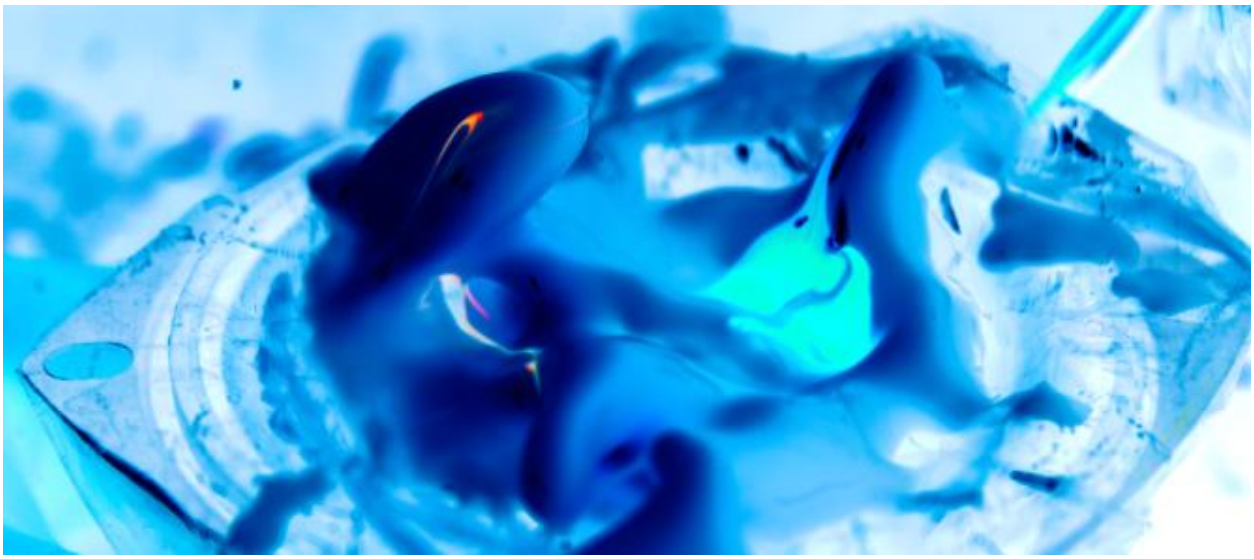

Figure 4: Final Image

The image reveals the interesting shear-thickening properties of oobleck. I like the mysterious feel of the final image and how it almost looks alive in some way. When you see oobleck on a speaker it certainly looks like it could be alive and I think the final image captures that. The fluid physics are shown fairly well. I do wish we had had more light because I feel like more details may have been revealed. It would also have allowed us to bring more of the image into sharp focus because we could have decreased the aperture size. I also wish I had a more detailed explanation of why oobleck is a shear thickening fluid. I feel our original intent was fulfilled but if I was to try this again I would have found a better source of light; perhaps an off-camera flash. I would also like to try this with a much large speaker and a larger quantity of oobleck. Overall, the image turned out pretty much how I envisioned it. I especially like the effect that reversing the colors using Photshop produces.

Works Cited

[1] "Non-Newtonian Fluid." *Wikipedia, the Free Encyclopedia*. Wikimedia Foundation, Inc., 03 Apr. 2011. Web. 08 Apr. 2011. <http://en.wikipedia.org/wiki/Non-Newtonian_fluid>.

[2] "Dilatant." *Wikipedia, the Free Encyclopedia*. Wikimedia Foundation, Inc., 10 Mar. 2011. Web. 08 Apr. 2011. <http://en.wikipedia.org/wiki/Shear_thickening>.