Duncan Lowery - 9/26/2018
FILM 4200-001 - Get Wet Visualization Report

The video I made was intended for the first project in the Flow Visualization course. It was shot one evening in my dining room on the surface of a glass-topped table. Initially, my plan was to non-uniformly dye a viscous fluid, using my camera to document how the fluid would spread out when another flat piece of glass was placed on top, noting how much the area of the fluid increased, and how the dyed and undyed sections of the fluid mixed. The trajectory of my project shifted after performing my first test, during which I witnessed a beautifully complex 'viscous fingering' effect as I separated the two glass panes. I later discovered that this phenomenon is a result of the Saffman-Taylor instability.

To prepare for the fluid flow, I first removed everything from the table in my dining room. I cleaned the surface and underside of the glass top with glass cleaner and a sponge, along with the entirety of the second glass plane, which I extracted from a picture frame. The scene was lit from overhead with four 6.5-watt LED bulbs. An additional 10-watt LED bulb was placed two feet from the reaction, eight inches above the surface of the table. All bulbs had a "frosted finish" to diffuse light, and their color temperature was 2700K. I began shooting once the Sun had set.

To create the viscous fingering reaction, I poured between one and three tablespoons of viscous fluid onto the surface of the table from six inches high. I then placed the second piece of glass on top, allowing its weight to spread out the fluid. After waiting a few seconds for the edges of the spreading fluid to slow, I then lifted the top piece of glass from one side. The ‘fingers’ propagated from the edge lifted up, toward the opposite edge still in contact with the table. Occasionally I removed the fluid and replaced it, but between these occurrences I simply set the glass pane back on top of the reacted fluid, which yielded smaller, more complex fingers. The apparatus I used is a crude version of a Hele-Shaw cell, a visualizing device featuring two parallel smooth planes, the distance between them approaching zero asymptotically. In my example, this distance is determined by the thickest part of the fluid, and decreases as the fluid becomes more uniform when the top glass pane is applied. When lifting the glass from the fluid, the entire pane flexed in the direction of upward force supplied by my hand. In both my method and a traditionally-designed Hele-Shaw cell, a less viscous fluid is forced into a more viscous fluid (Reference 3). Because the interface between these two fluids is unstable, a deflection occurs, forming a sinusoidal pattern known as ‘viscous fingering’ (References 1 & 2). In my example, the less viscous fluid was the air in the room, and the more viscous fluid was the mixture I created with dish soap, soy sauce, and cornstarch.

To be more specific, I combined six tablespoons of dish soap (Great Value brand) with one tablespoon of soy sauce (Kikkoman brand (reduced sodium)), and one-half teaspoon of cornstarch (ARGO brand). I decided to use dish soap as the base of my fluid because it was already uniformly viscous from the bottle. I included the soy sauce in hopes of increasing contrast between the fluid and the white piece of paper I taped to the underside of the table to act as a backdrop. The cornstarch was added to compensate for the overall decrease in the fluid’s viscosity after the addition of the soy sauce.

In order to keep the background consistent, the field of view was always less than 11 inches wide, the width of the piece of paper used as the backdrop. Because of the amount of fluid I used, the reaction itself was close to 10 inches wide at the start of shooting, but as I repeated tests with the same mass of fluid, the total span of the fluid increased when the top piece of glass was applied, but did not decrease when it was removed. As a result, the edges of the reaction are outside of the field of view in some of my shots. During filming, I used two lenses to capture my images. One was a Panasonic Lumix 14mm-45mm variable lens. I shot at f5.6, and at the minimum focal distance of one foot. The other lens was an 80mm-200mm variable lens from Albinair. I shot at f8, at the minimum focal distance of 4.5 feet. Both lenses were extended to maximum telephoto. My camera is a Blackmagic Pocket Cinema Camera, a digital mirrorless camera with an image sensor of 16mm by 9mm. Its maximum capture resolution is 1920px by 1080px. I shot at the camera's native ISO, which is 800. The rolling shutter was set to 180 degrees, meaning that the sensor was exposed to light for one-half of the duration of each frame. Because I shot at 24 frames per second, my effective shutter speed was 1/48 of a second. All of my video was taken as a lossless, compressed RAW image sequence in CinemaDNG format. To make my footage watchable and visually pleasing, I used a software called DaVinci Resolve 15 to first interpret the RAW image sequence as a 24 frame-per-second video, then adjusted the lift and gain of each clip to fill the dynamic range of my monitor. I had to do this because the camera shoots a flat or 'log' image for the sake of preserving high dynamic range. These images look unsaturated and have low contrast until they are color corrected. Because I shot with a white balance of 3200K, and the color temperature of my lighting was 2700K, all of the footage came out looking too warm. Luckily, I was able to fix this issue easily within DaVinci Resolve without losing any information in my video, because the CinemaDNG format is not encoded with a specific white balance, ISO or color space. This means I can choose and adjust these variables within the software as if I had shot the footage with any combination of these settings.

While I thought my video captured clearly the formation of viscous fingering patterns as a result of the Saffman-Taylor instability, and the processed final images suited my aesthetic sense, I will change two things about my execution going forward: firstly, I will use food dye in the rest of my visualizations, because their saturation and vibrancy makes the visualization clearer, as I have learned from looking at my fellow classmates' projects, and because more vibrant colors make for a more visually-striking image. Secondly, I will use more light in my future visualizations. The depth of field in my images was too shallow for the majority of the fluid in frame to be in sharp focus. Increasing the amount of light in my scene will allow me to close my aperture further while maintaining good exposure. A smaller aperture gives greater depth of field in the image. I am also interested in repeating the experiment with a traditionally-constructed Hele-Shaw cell, both because I think a round, symmetric flow will be easier to capture fully within my frame, and because backlighting the fluids will give them more vibrancy.

References:

1. Kondic, Ljubinko, Michael J. Shelley, and Peter Palffy-Muhoray. "Non-Newtonian Hele-Shaw Flow and the Saffman-Taylor Instability." *Physical Review Letters* 80, no. 7 (1998): 1433-436. doi:10.1103/physrevlett.80.1433.

2. Mod-01 Lec-40 Viscous Fingering: Darcy's law. Lecture by Prof. S. Pushpavanam. YouTube. December 15, 2014. Accessed October 01, 2018. https://www.youtube.com/watch?v=cmIR7bO70Fo.

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3. Saffman Taylor Instabilities- Viscous Fingering. Video by Lena. YouTube. April 07, 2016. Accessed September 28, 2018. https://www.youtube.com/watch?v=FqC7VGTGh4U.

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