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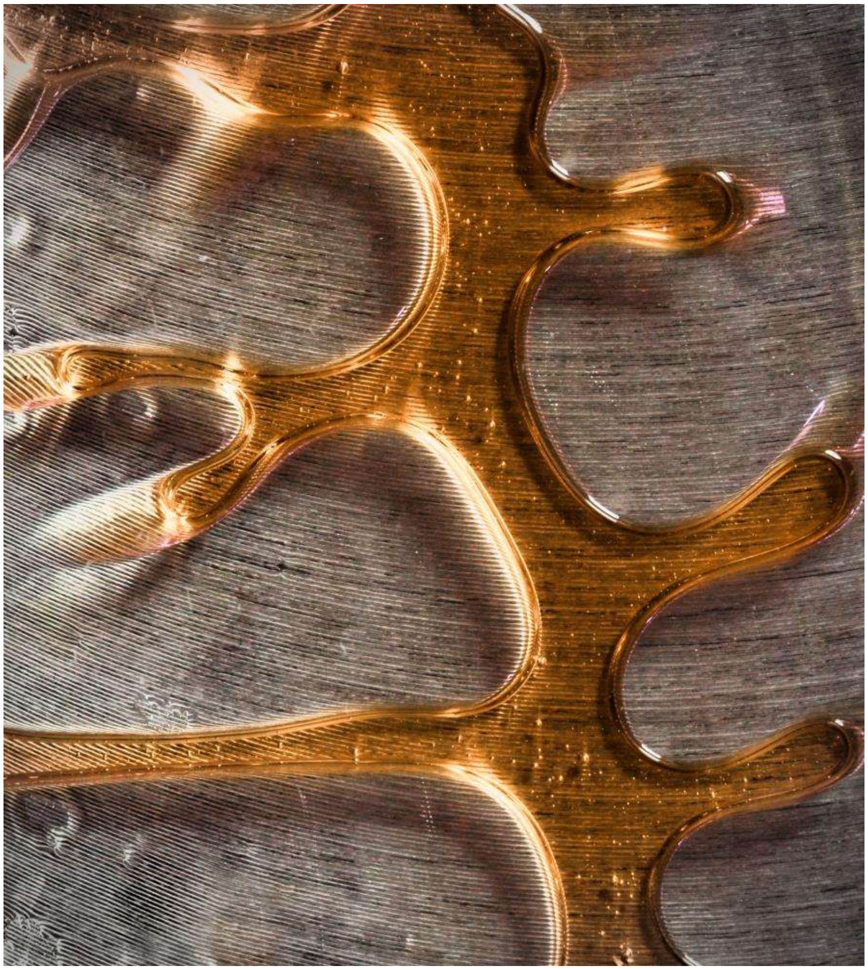
MCEN 5151

10/4/2023

Team First Report



Credit to Jess Holmes for moving the glass sheet up and down to create the fluid phenomena.

For this assignment our group used a Hele-Shaw cell to create Saffman-Taylor instabilities using air and corn syrup. The Hele-Shaw cells typically consist of two glass plates which sandwich a highly viscous fluid with a small opening in which a less viscous fluid is injected. We initially tried this setup, but the images I took weren't sharp and didn't have an interesting background. I grabbed a piece of aluminum scrap that was in the ITLL machine shop that was faced with a fly cutter and placed a small amount of corn syrup on the aluminum and laid the tempered glass on top. One of my group members, Jess, then moved the glass plate up and down which created the Saffman-Taylor instability using the air as the less viscous fluid. The instability generated with this setup is slightly different from a traditional Hele-Shaw cell because the less viscous fluid was introduced from the outside of the more viscous fluid, instead of being injected in the center. This just results in the instability forming the other direction and the fingers point outward instead of inward.

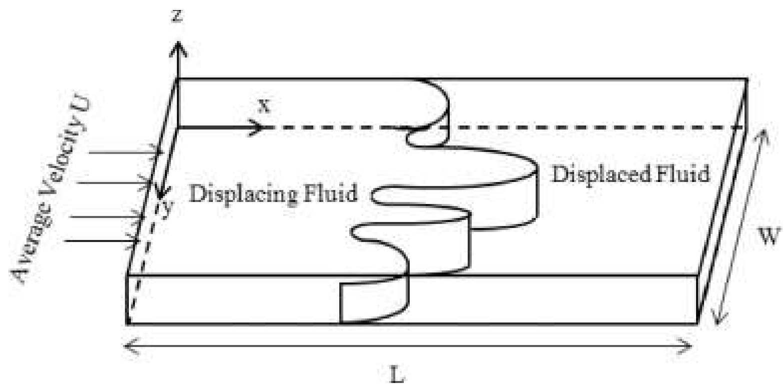



**Figure 1.**

The liquid interface between high and lower viscosity fluids creates finger formations as fluids are forced together.

In a perfect environment, as one fluid is pressed into the other, either from the center or from the circumference, the shape would remain the same. In other words, in a typical Hele-Shaw cell, as the less viscous fluid is injected into the more viscous fluid, a mathematical model would suggest that the fluids maintain the same shape and the inner fluid would grow as a circle. But in a physical setup, there are instabilities as the name suggests, which are very slight deformities on the surface or in the fluid cause changes in the curvature of the fluid boundary which forms the fingers we see (Figure 1.). The viscous fluid tends to advance faster in front of a curvature in the flow direction as the fluid volume to be pushed is smaller. We can calculate the Reynolds number of the corn syrup in the cell as it will give us some information about the fluid interaction. The equation for the Reynolds number is given as $R = \frac{u \cdot L \cdot \rho}{\mu}$, where $u$ is the velocity of the fluid, ρ is the density, $L$ is the characteristic length, and μ is the dynamic viscosity. Solving for R using, $u = 2\frac{cm}{s}$, $\rho = 1.38\frac{g}{cm^3}$, $\mu = 12000\frac{g}{cm \cdot s}$, and $L = .1\ cm$ we find that $R = 2.3 \cdot 10^{-5}$. Since this is much less than 1, we can conclude that the viscous forces are the dominate internal forces, so the fluid exhibits creep. Since the fluids we used are incompressible, as the glass was lifted, it lowered the pressure between the plates which forced the air in and induced the phenomena.

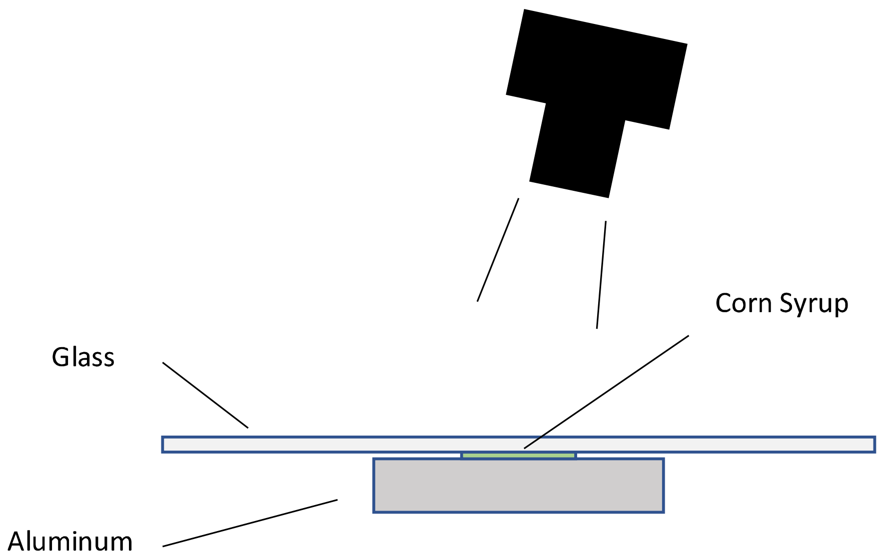



**Figure 2.**

Camera and experimental setup. The glass plate was raised and lowered by hand, and the camera was handheld.

Corn syrup is naturally yellow, but we added green food coloring to the syrup to create more contrast between the background so it would pop out more in the image. We placed the aluminum on the floor and manually raised and lowered the glass plate to create the fingers in the syrup that we were trying to image. Fortunately, the corn syrup was viscous enough where we could hold the glass at a certain height and the fingers wouldn't move which made photographing the phenomenon easier. All of the lighting came from the lighting in the room, and due to the striations in the aluminum, it would light up differently based on the angle we were photographing. I chose to take my picture so there wasn't too much glare or reflecting light as I felt it took away from the fluid dynamics which I was trying I capture.

I used a 90mm macro lens without a tripod because the area I was photographing was too dynamic to use a longer macro lens fixed in a tripod. By handholding the camera, I could photograph the region which had the most interesting finger formations and focus quickly in on it. As mentioned earlier, the aluminum background was very dynamic based on the angle the camera and lights made with it. Once I rotated the aluminum on the ground into a position which looked the best and reflected just the right amount of light, I found a camera position which showed the texture of the aluminum without directly reflecting light into the camera. Since I was using a 90mm lens, the end of the lens was about 1 foot away from the Hele-Shaw cell. The field of view was a little bit wider than it should have been because I had to crop the image down to focus on the region I was interested in which reduced the resolution on the image. Below are the camera settings which I used to take the image.

| | |
|---|---|
| Camera | Nikon D800 |
| ISO | 1250 |

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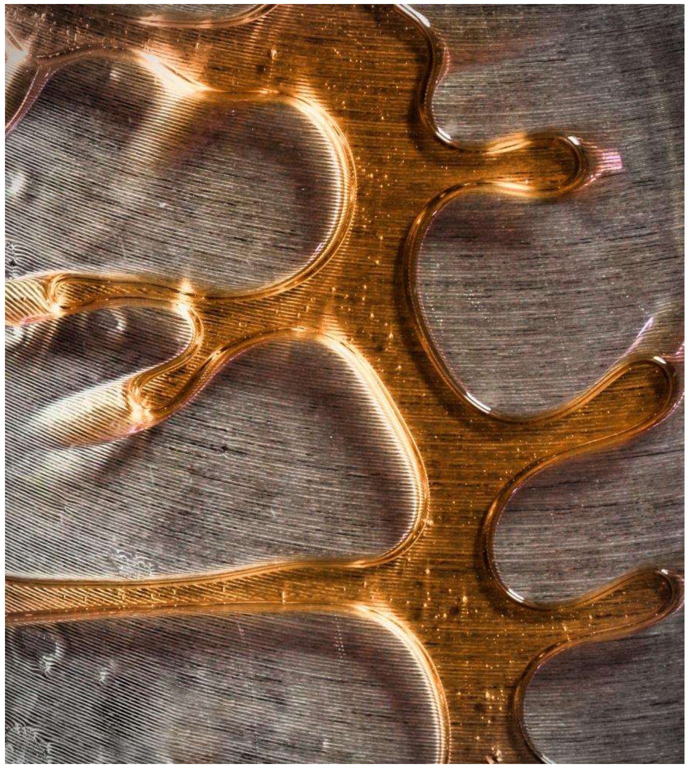
| F-stop | f/8 |
| Shutter Speed | 1/250 s |
| Focal Length | 90mm |

The original image had a resolution of 7378 x 4924, and the final cropped size is 2238 x 2503. In addition to cropping the image, I changed the color hue, so the green turned back to the yellow that the corn syrup originally was because I thought it was brighter and would grab the viewers' attention better. I also slightly rotated the image clockwise to align the fingers with the horizontal and vertical axis. The field of view of the original image was about 4 inches wide. The aluminum scrap that we used was 2.5 inches wide at its widest. A side-by-side of the original image and the post processed image can be seen in the figure below.

**Figure 3.**

Unedited image (7378 x 4924)



Post Processed Image (2238 x 2503)

For the Get Wet project, I knew immediately when I took the picture that it was going to be the image that I submitted and presented, but for this project, I took a bunch of pictures and had to go back and choose one that I thought would look best. Because of this, I am not as happy with the final image because the composition and resolution weren't exactly what I was going for, but it was close enough. I really want all my work in this class to be something I am proud of and am happy to show to people, and I felt the get wet project accomplished that, but this project not so much. The physics in the image are clear and the technical elements of the photograph are fine, but the artistic elements that add beauty and complexity are missing. I had to edit the image a lot from the original which I don't find ideal because it makes it more unnatural, and the whole point of this class is to capture the natural beauty of fluid flow. If our group were to remake the Saffman-Taylor instability, we would make our own Hele-Shaw cell with an acrylic back plate or a high-resolution screen so we could change the color and back light the fluids without seeing individual pixels. Making a Saffman-Taylor instability in the typical fashion by injecting fluid into the middle is easy to make, but more difficult to photograph well as we found.

Sources:

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