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Flow Visualization
Team Project #3
4/25/11

Team Project #3 – Dish Soap & Glass

The image taken for the third team assignment shows interesting shapes created by placing dish soap between two panes of glass. The panes of glass were then slowly pulled apart to create the "veins" of dish soap. I didn't start the project with the soap idea. First, I tried to take a still image of an egg breaking in a fish tank. I assumed it would be relatively easy to capture the moment of impact by placing the camera in 10 frame burst mode. However, after a few hours of failed attempts, I decided it was actually difficult to capture the exact millisecond when the break occurs. Figure 1 shows some of my failed attempts; obviously, the pictures were very close to the correct timing. I basically stumble on the glass pane idea, although in-class discussions helped point me in the right direction.

Figure 2 shows a diagram of the experimental setup for final image. The camera was placed directly above the panes of glass, which were on top of a white background to provide good contrast for the red dyed soap. The panes of glass were approximately 10in long and 3in wide.

Figure 1: Egg Smashing Attempts

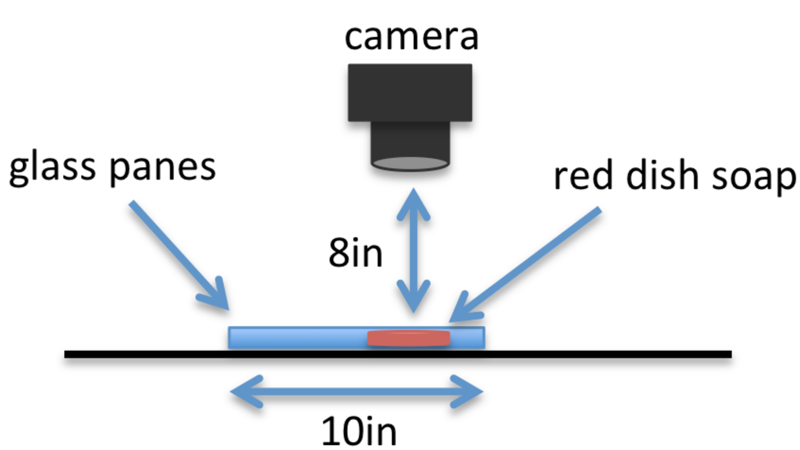

Figure 2: Flow Visualization Setup

Figure 3 shows the actual experimental setup. The camera was placed on a tripod boom to hold it directly over the panes of glass. Additional lights were used because ambient light was not sufficient. Figure 3 also shows the white background used to produce a cleaner image. The panes of glass had to be carefully placed on the background to avoid reflections from the lights.

Figure 3: Experimental Setup

The unique fingers created in the soap were the result of the Saffman-Taylor instability. The branched patterns are called viscous fingers[1], and were the result of the air pushing the more viscous soap between the two panes of glass. The air velocity was the result of the void created when the two panes were pulled apart. The higher pressure air was forced towards the lower pressure void between the two panes. A significant amount of research has been conducted to understand the Saffman-Taylor instability using Hele-Shaw cells. A Hele-Shaw cell consists of two transparent plates typically separated by 0.5mm. Then the space between the two plates is filled with a high viscosity fluid and a low viscosity fluid is injected to create the instability[1]. My experiment differed slightly in that soap was the high viscosity fluid and air was low viscosity “fluid”, and the air velocity inwards initiated the instability.

Figure 4 shows the Saffman-Taylor instability in a Hele-Shaw cell with oil and air[2]. Reference 2 found that the number of fingers excited between the air and oil increased as the square root of the velocity of the interface. This concept can be applied to my image to explain the large number of fingers. When pulling the two panes of glass apart, the low pressure void held them together with a significant amount of force. When I finally overcame the force, the gap between the panes would increase quickly, pulling air in with significant velocity, leading to the large number of fingers.

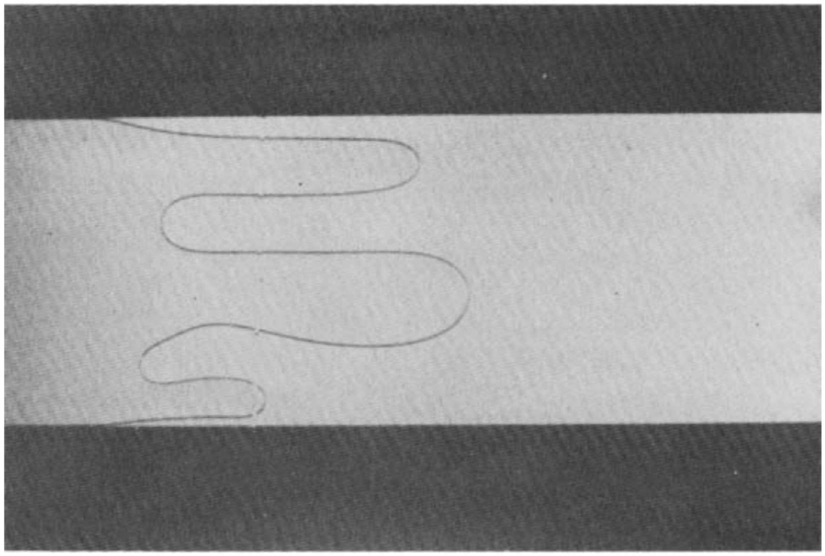

Figure 4: Saffman Taylor Instability of oil and air in a Hele-Shaw cell[2]

Reference 2 explains how the interface velocity affects the number of fingers that appear, but Figure 4 does not look very similar to the viscous fingers in my image. Figure 5 shows fractal viscous fingering between water and a non-newtonian fluid in a Hele-Shaw cell[1]. Of course, the dish soap I used was not a non-newtonian fluid, and my image looks more like a mix between Figure 4 and Figure 5. Therefore, I believe my image is best described by the oil and air interaction shown in Figure 4, but I created a significantly larger interface velocity when I pulled the two panes of glass apart.

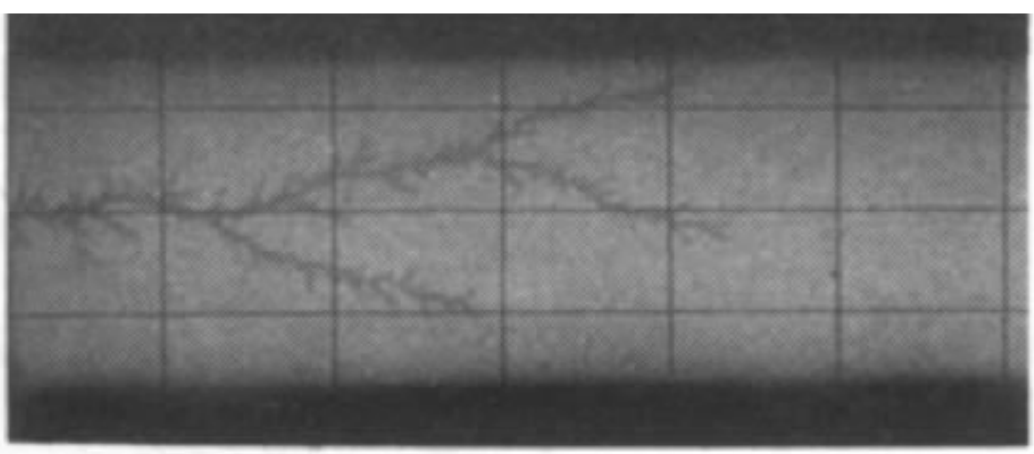

Figure 5: Fractal viscous fingering[1]

To produce the final image, I mixed 3 TBS of yellow Dawn dish soap with 5 drops of red food coloring. Then, I placed a drop of soap (about ½ tsp) on the center of a glass pane. Next, I placed a second piece of glass on top of the first, smashing the soap into a thin round circle. Finally, I slowly separated the two panes of glass and took pictures during the entire separation process to resolve different shapes in the soap. When I reached a point with an interesting pattern, maybe one millimeters of separation between the two panes, I took the final image I submitted for this assignment.

The original image field of view was approximately 6in in width and 4in in height, and the distance from the camera lens was ~8in. A Canon T2i digital camera with a 17-85mm focal length lens was used to take the picture. The camera was in burst mode, taking 10 images continuously at 3.7 frames/second.

Camera:	Canon T2i DSLR
Focal Length:	85mm
ISO:	ISO 640
Shutter Speed:	1/125 s
Aperture:	*f*/5.6
Original Pixel Size:	5184 x 3456
Final Pixel Size:	2279 x 2308

Aperture 3 was used to modify the original image. The original image was significantly cropped to emphasize the unique features in the soap "fingers" and eliminate the edges of the glass panes. The original was a bit dark, so the brightness was increased. Then, the contrast was slightly increased to compensate for the increase in brightness. The ambient lighting gave the original image a somewhat yellowish quality. To replace the yellowish tint with a whiter look, I adjusted the white balance and tuned the black, gray, white levels. Finally, the corners of the image were cleaned up in Photoshop using the clone tool.

Overall, I think my final image is excellent. I had several quality images that I could have submitted, but in the end I decided to use an image with a wider field of view to include as many fingers as possible.

References

[1] Nittmann, Johann, Gérard Daccord, and H. Eugene Stanley. "Fractal Growth Viscous Fingers: Quantitative Characterization of a Fluid Instability Phenomenon." *Nature* 314.6007 (1985): 141-44. Print.

[2] Tabeling, P., G. Zocchi, and A. Libchaber. "An Experimental Study of the Saffman-Taylor Instability." *Journal of Fluid Mechanics* 177 (1987): 67-82. Print.