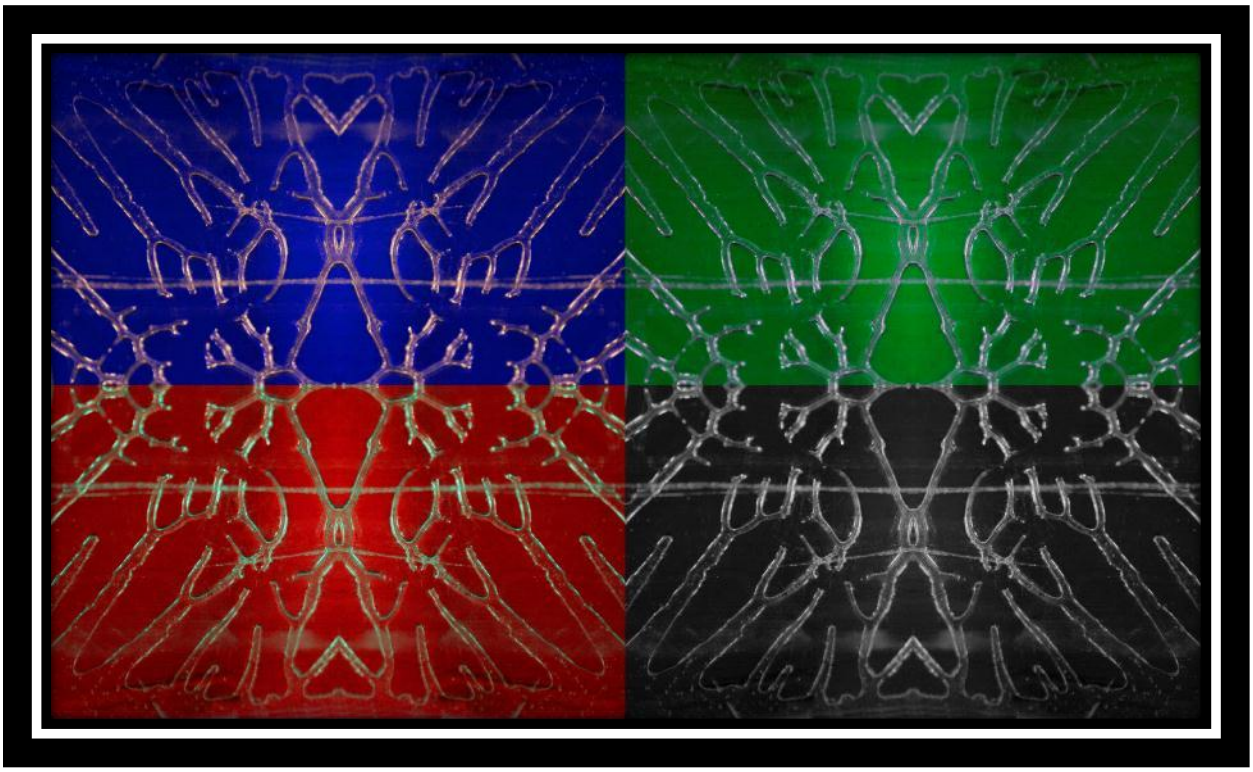
Flow Visualization
MCEN 5151

Spring | **2012**

Scotty Hamilton



Group members:
Hayley Schneider, Jeremy Baugh, Gregory Lundeen, Nicholas Shearon

University of Colorado at Boulder

Introduction:

Viscous fingering is a unique effect that takes place when a fluid is between two plates that are separating apart. This phenomenon is called the Taylor-Saffman instability and provides a beautiful canvas to take a photo of.[1] Initially the intended photo was to be a Kaye effect, another interesting fluid phenomenon where shampoo is poured onto an angled surface and creates a jumping effect. While cleaning up the shampoo, the team noticed the viscous fingering occurring between the plates and snapped some photos.

Image:

This image was taken on March 11th 2012 in the Durning Laboratory at the University of Colorado at Boulder. This image required a team effort and a lot of experimenting with different reactions. This setup is commonly known as a Hele-Shaw cell.[3] The initial setup can be viewed in (Figure 1)

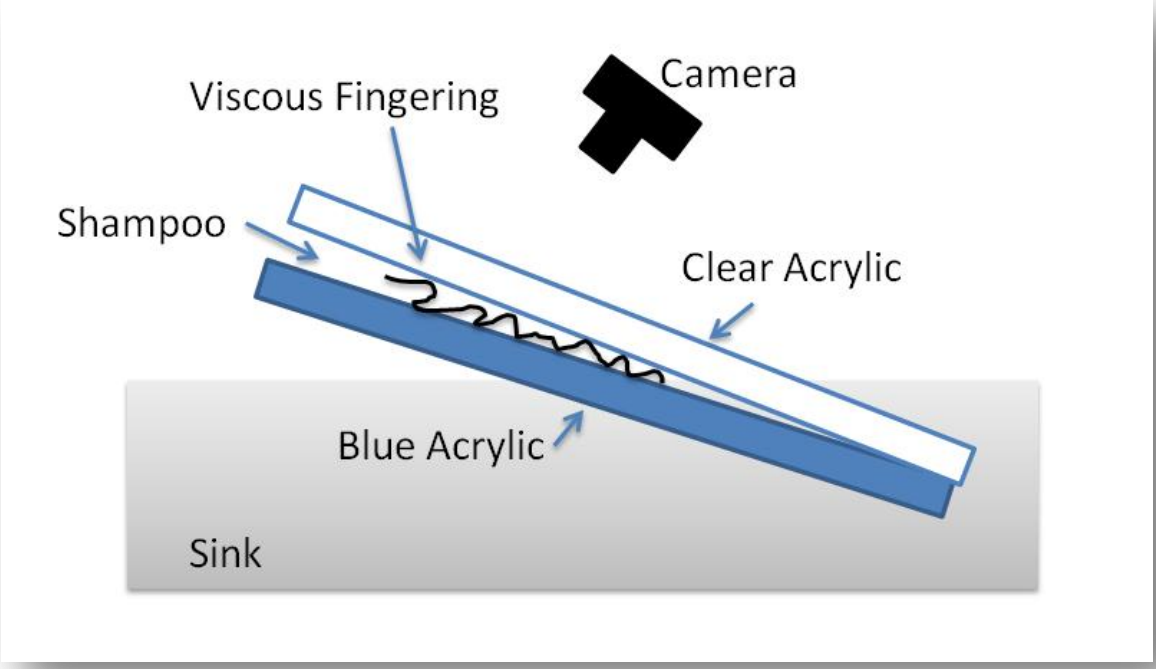


Figure 1 Setup for Viscous Fingering

The figure shows the two acrylic plates separating and the location of the shampoo in-between the plates. The light source was a large halogen light next to the camera.

Physics of Phenomenon:

The Hele-Shaw Cell was first used back in 1898 to capture fluid between two plates.1 Sir Geoffrey Taylor released the first journal on the effects of having a two-phase flow between two plates in 1956.1 The two phases in this image are the shampoo and air. They collide as the plates open and air is allowed into the shampoo volume. The abstract patterns are created by the surface tension the shampoo has on the boundary layers of the Plexiglas.[3] Since the Plexiglas was lifted from one corner, it is noticed that the gap between the plates increases in time and space. This allows the fingering to spread across the plates depending on the gap in the plates. The gap ranged from approximately 1mm to a max of 3mm. See figures 2 and 3 to examine the boundary layers caused by the Plexiglas separation.

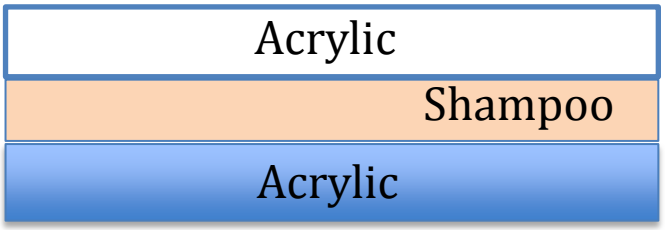


Figure 2 Side view of layers

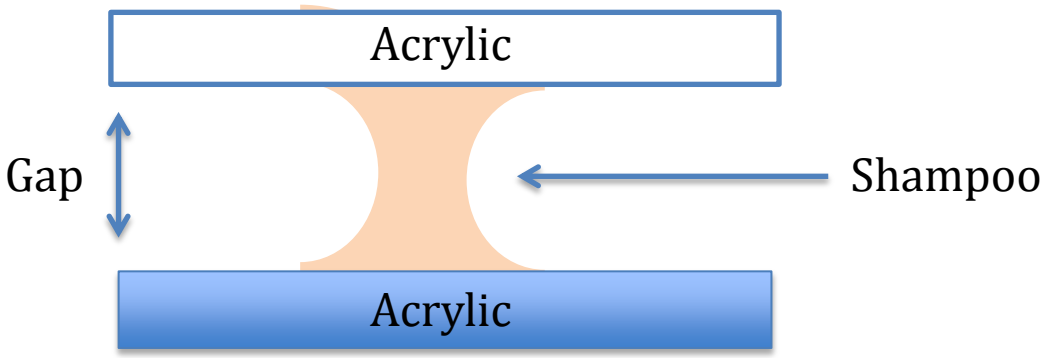


Figure 3 Layers with gap between plates

In general, the surface tension between the plates and the surfactant causes them to stick together as the plates are pulled apart. Gaps are created around the shampoo giving it a fingering look when looked at from above.

Photographic Technique:
The following is a list of the camera settings used to take the photo.

- Size of the field of view: 3 x 6 inches
- Distance from object to lens: 12 inches
- Lens focal length: 49mm
- Type of camera: 6.3 megapixel Canon EOS Digital Rebel
  Original (3072 x 2048)
  Edited (5068 x 2934)
- Exposure Specs: Aperture: f/5.6
  Shutter Speed: 1/640 ISO 800

Figure 4 Orginal Image

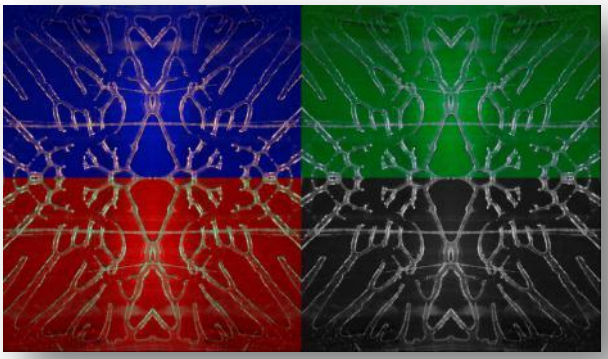


Figure 5 Processed Image

The original and processed image can be seen above. The processed image was cropped around some of the fingers then mirrored horizontally to create one of the squares seen in the processed image. Different hues were added to change the color of each corner image. At first only one corner was going to be used, but all the colors looked so good together that a composite image of all the photos was made. The top section and the bottom section are mirrored off each other.

Commentary:

The fingering brings an ominous dark response to this image. Almost like the webbing of a spider. It is interesting to look into the image and find unique shapes within the fingering. The photo also has an Andy Warhol effect with the many different colors.

References:

1. Saffman, P.G. "Vicous Fingering in Hele-Shaw Cells." *Journal of Fluid Mechanics* 173 (1986): 73-94. Web. 20 Mar. 2012. <http://authors.library.caltech.edu/10133/1/SAFjfm86.pdf>.

2. Pomeau, Yves. Hakim, Vincent . Dombre, Thierry. Combescot, Roland. "Shape Selection of Saffman-Taylor Fingers." *The Physical Review Letters 56* (1986): 2036-2039. Web 20 Mar. 2012

3. Wlodarski, Krzysztof. Tian, Fei-Ran. Shelley, Michael. "Hele-Shaw flow and pattern formation in a time dependent gap." *Nonlinearity 10* (1997): 1471-1495. Web 20 Mar. 2012