Second Group Project

Flow Visualization: The Art and Physics of Fluid Flow

Hans Loewenheath

4/4/13

The associated image was taken for the second group project during the Spring 2013 semester of the Flow Visualization class. The image intends to capture the Hele-Shaw cell of a fluid between two plates separated by a small distance. In the media shack in the ITLL, the team used a table specifically created to capture the Hele-Shaw cell. Helpful teammates included: Thomas Polhman, James Shefchik, Grant Boerhave and Spencer Aguilar.

The apparatus used to create the Hele-Shaw cell is stored in the Media Shack of the ITLL. This apparatus, as seen in figure 1, consists of a table that holds two transparent plates on top of each other. The bottom plate is stationary. The top plate can be manipulated using screws on each corner in order to adjust the height of each corner. This allows the top plate to have varying heights between the corners. To set up the experiment, a mixture of olive oil and food coloring is mixed and then drawn into a syringe. The syringe then drops a small amount of the mixture onto the bottom plate. Then the top plate is placed on top of the fluid and bottom plate so that the least amount of bubbles are created. Using the screws at each corner of the top plate, the height of the top plate can be varied until the desired visual effect is achieved. Sometimes it can be beneficial to manually shift the top plate to help the fluid achieve the associated fingering effect.

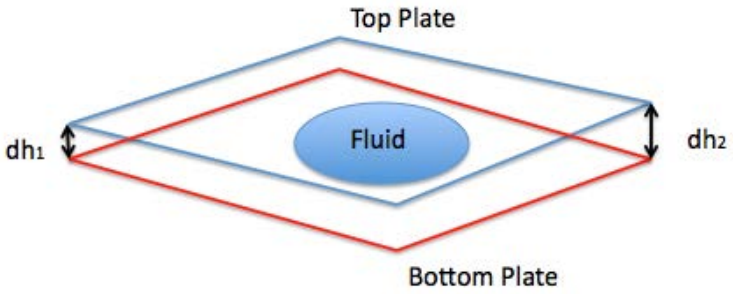

Figure 1: Hele Shaw apparatus

Once the visual effect is achieved, the fluid can be assumed to be stationary. While stationary, it may take up to 5 minutes before the fluid takes a less desirable shape by losing its finger definition. This fingering effect of a Hele-Shaw cell is formed by

the Saffman-Taylor instability at the fluid-fluid interface[i]. The differing viscosities between the olive oil and water based food coloring create the fluid-fluid interface necessary to achieve the desired fingering.

In capturing the Hele-Shaw cell, visualization techniques included red construction paper for a background, backlighting, and food coloring as the liquid for a solid contrast with the red background. The red construction paper was provided by Spencer Aguilar and taped to the back of the bottom layer of glass, which was below the associated fluid. The backlighting consisted of two 50W tungsten-filament work lights placed below the Hele-Shaw cell table. The associated fluid consisted of about half olive oil and half blue food coloring. This allowed for the best visualization technique.

The associated image has a field of view of about 3 inches. The fluid is about 12 inches from the macro lens of the camera, which was directly above the fluid. The Nikon macro lens used has a set focal length of 105mm and a maximum aperture of f-2.8. The DSLR camera captured an image with a width of 3872 pixels and a height of 2592 pixels. The camera used was a Nikon D60, belonging to Grant Boerhave. The exposure specifications were: aperture of f-5.6, shutter speed of 1/20 of a second and an ISO of 400. Using Photoshop, the image was manipulated using curves, levels and the sharpening filter.

Image before Photoshop editing

The image feels as though it wants to be a painting from the modernist era with splotches created by Jackson Pollack. The image reveals how fluids can behave in a manner that is entirely unexpected and utterly beautiful. I enjoy the contrast in the image as well as its two-dimensionality. The image does lack some information that a three-dimensional model might provide, such as how the boundary layer changes in height throughout the fluid. These changes are most likely too small to be captured by a macro lens with this field of view. The physics of the fluid are shown quite well as most of the fingers are well displayed and defined. Something I would like to demonstrate in the future would be how multiple fluids of similar viscosities might mix in the same situation. Instead of just demonstrating the single food coloring, I would like to see how 3 or 4 food colorings would mix as the fluid tries to maintain surface tension.

---

[i] Fontana, J. V., Lira, S. A., & Miranda, J. A. (2013). Radial viscous fingering in yield stress fluids: Onset of pattern formation. *Physical Review E: Statistical, Nonlinear & Soft Matter Physics*, *87*(1-B), 1-10. doi:10.1103/PhysRevE.87.013016