Red Coral

Group Assignment #3 Report

MCEN 4151 – Flow Visualization

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Group 7

Introduction

For the final of three group assignments in Flow Visualization my group and I decided to explore the flow apparatuses available to use within the media shack of the ITLL. We selected to use the Hele-Shaw Cell built in part by Jean Hertzberg and her teaching assistant, Jesse Capecelatro. The purpose of the Hele-Shaw Cell is to visualize the Saffman-Taylor Instability which is what my team and I sought to find. My team and I saw many images created using mechanisms like this and wanted to explore how different effects can be created using different fluids.

Figure 1: Final image

Saffman-Taylor Instability

When a less dense fluid is accelerated towards one of greater density, there is an instability between the interface of the two fluids which forms fingering known as Rayleigh-Taylor instability. I explored this effect in my Get Wet assignment and found that the fingering instabilities are formed by a reaction between the two fluids which exert surface forces on each other in an attempt to reduce their combined potential energy. Any agitations between the interfaces result in greater perturbation which is dependent on the viscosity of the two fluids, resulting in Rayleigh-Taylor fingers.

The Saffman-Taylor instability is analogous to that of Rayleigh-Taylor, but in an over-damped case (Ashmore). The uniform fluid contact between all fluids and the two parallel plates adds surface tension to the system resulting in a different effect than seen in Rayleigh-Taylor instabilities. The instability is formed through the use of a Hele-Shaw Cell in this case (Figure 2). It is made of two parallel flat plates which are separated by a very small gap. At the middle of the lower plate there is a small hole in which the fluid can be injected using a syringe. As stated previously, a less viscous fluid should be used to displace a more viscous fluid already in place between the plates and centered on the hole. My team and I used dyed water to displace honey which formed the Saffman-Taylor instabilities shown in Figure 1.

Figure 2: Saffman-Taylor Instability Machine (Hertzberg)

Visualization Technique

Because the apparatus was already built and used extensively, my team and I had very few problems figuring out how to use it. The most difficult part was cleaning up each mess as we experimented with many different fluids common in the kitchen. We wanted to use only fluids that could be washed down the drain such as soapy water, honey, vegetable oil, syrup, food coloring and air. After each experiment the fixture was cleaned thoroughly and new fluids were used until we were happy with the images taken. It was important to clean the surfaces carefully as to eliminate any residual unwanted fluids or colors that would contribute to irregularities in the resultant image.

As stated previously, the image shown in Figure 1 is water colored with red food coloring displacing honey. A 10mL syringe was filled with water and 50 drops of red food coloring. About ¼ cup of honey was placed in the middle of the bottom plate and sandwiched between it and the glass. The red water was then injected slowly and held at different intervals so that images could be taken. As such, the whole process required two people, one to inject the dye and the other to take several pictures. Grant Meaux took the majority of the pictures while Shane Weigel and I injected the fluid. The process was very static and many images could be taken of, essentially, the same subject.

The fluid flow was lit from below the apparatus by two 500W light bulbs found within the media shack. They were positioned as to eliminate any shadows as well as provide uniform lighting upon the subject area. Other image specifications and camera setting can be seen below.

- Field of view: 5X6 inch
- Distance from object to lens: 1 foot
- Camera: Canon EOS Rebel T1i
- Focal length: 33.0mm
- Image dimensions: each original – 4752x3168 pixels, final – 4752x3168 pixels
- Exposure specifications: 1/160 sec shutter speed, f/8.0, 100 ISO

- Post-processing: color contrast – curves, cloaning image irregularities
    - original image seen below in Figure 3

Figure 3: Original image

Conclusion

The Hele-Shaw cell built for student use within this course was very easy to use and produces amazing images. My team and I weren't sure what to expect concerning the difficulty of its application and what sort of fluids could be used. However, each experiment provided interesting images and it was difficult to select just one. My desires for this image were met as you can easily see the Saffman-Taylor fingers formed by this flow. The image is quite beautiful and clean with no distractions. The only thing I would like to change about the image is the ring of honey seen towards the end of each fluid flow. It is a bit distracting and difficult to tell what is going on there. However, it also shows a very interesting effect as the flow is much less distinct and more dispersed.

The best part about the image, I believe is the detail that can be seen when looking at the picture close up. You can see parallel lines of fluid flow marking the course and direction as it displaces the honey. It is interesting to see how it flows around small bubbles and converges at the ends. It was fun and interesting using the Hele-Shaw Cell and I hope I have more time in the future to try more experiments. It would really be interesting to see how the shape of the Saffman-Taylor fingers change when the relative viscosities of the two fluids are changed as well. Maybe in the future a student will decided to do just that.

References

Ashmore, Jacqueline. The Penetration of a Fluid into a Porous Medium or Hele-Shaw Cell Containing a more Viscous Fluid. February 2000. 3 May 2011 <http://www.seas.harvard.edu/brenner/taylor/handouts/saffman_taylor/saffman_taylor.html>.

Hertzberg, Jean. Saffman-Taylor Instability Machine - User's Manual. 3 May 2011 <http://www.colorado.edu/MCEN/flowvis/course/SaffmanUser.pdf>.