Team project 1

Saffman-Taylor Instability in a Hele-Shaw Cell

Flow Visualization

Ray (Hsin-Jui) Wu

October 25, 2007

Prof. Hertzberg and Prof. Sweetman

The purpose of this image of the team project is to present Saffman-Taylor instability in a Hele-Shaw Cell with oil and food coloring in water. A Hele-Shaw cell consists of two flat plates that are parallel to each other and are separated by a small distance (see Figure 1). This is a two dimensional flow field because the length scale of the X and Y directions are larger than the length scale in the Z direction. At least one of the plates is transparent so that the fluid movement in the two dimensions of the X-Y plane can be observed, such as the behavior of an interface between two miscible fluids, and the interface between two immiscible fluids.

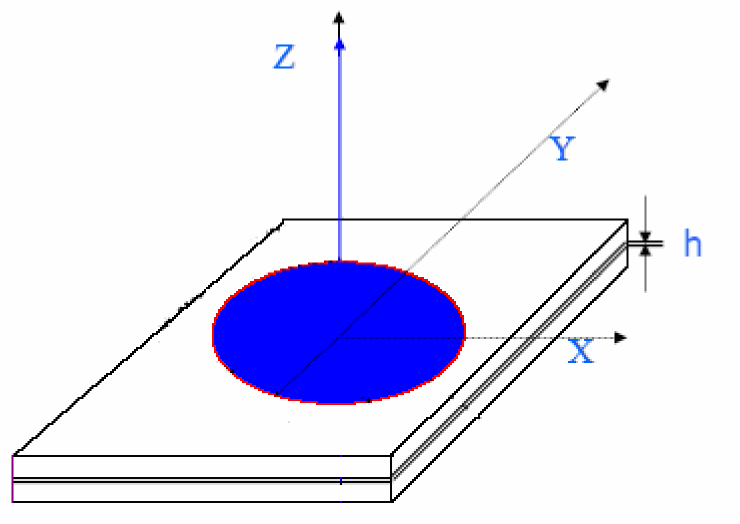

Figure1. Schematic of the Hele-Shaw Cell

In the Hele-Shaw cell, lower viscosity flow drives the higher viscosity flows causing fingering instabilities on the interface between the two flows. This phenomenon is the so-called Saffman-Taylor Instability. The lower viscosity flow was food coloring mixed with water and then injected into higher viscosity flow corn oil by syringe. Air is also injected to induce Saffman-Taylor instability. We have to increase the speed of the pushing syringe because this speed is a driving force in inducing the lower viscosity flow to push outside the higher viscosity flow. This could be related with fingering instability on the interface of these two flows. If we inject the lower viscosity flow too slowly, the Saffman-Taylor instability is not observed.

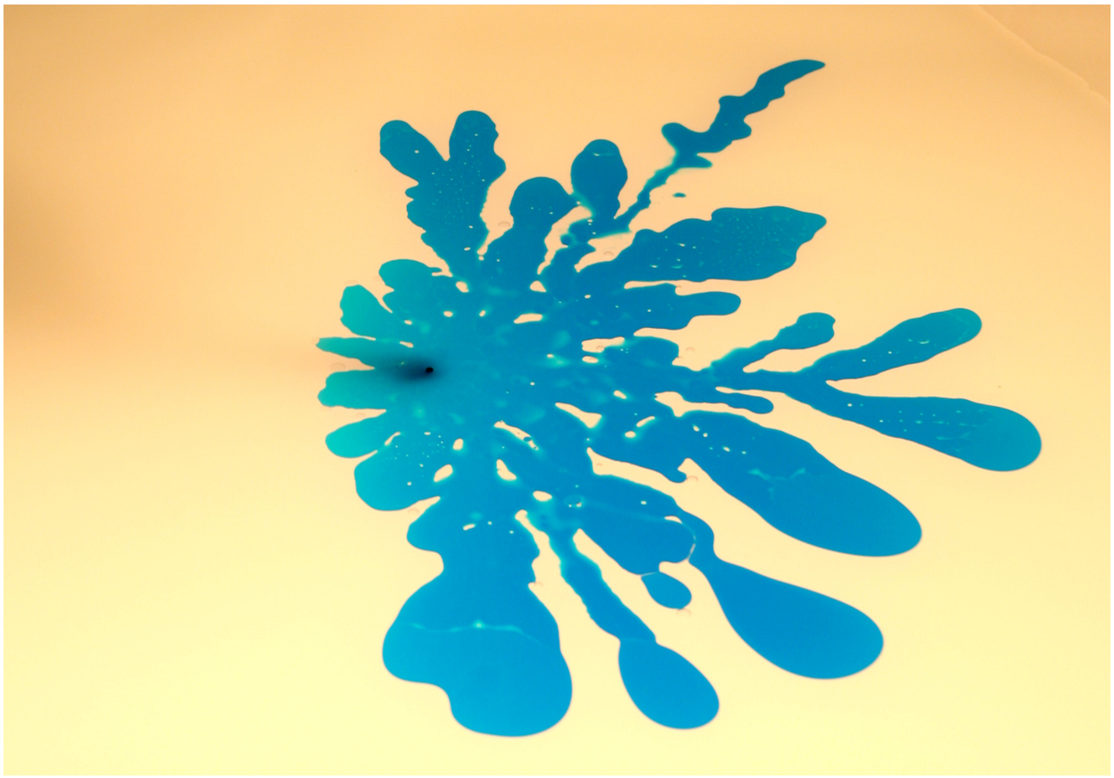

Figure 2

This behavior is present for just a few seconds, so that we have to set up tripod first, use manual focus to control precisely, capture quickly as many pictures as we can, and prevent the vibration of the camera. The fingers are moving and growing by time steps so that I took a series of continuous pictures. Although the tripod is not high enough, I have tried to capture the top view as closely I could. I picked one picture to be my final image (Figure 2) that I adjusted by Photoshop in order to increase the contrast. This allows the specific presentation of the interface of the two different viscosity flows and the finger pattern of the Saffman-Taylor instability. The photo technique for this image is listed below.

Camera information

Mark: Canon
Model: Canon EOS DIGITAL REBEL XTI
Lens: Sigma 18-200mm with OS
Shutter speed: 1/20 sec
F-Stop: f/6.3
ISO: 200
Focal length: 51.0mm
Pixel Dimension: X: 2000; Y: 1393
Flash: No

Conclusion

This image successfully presents the fingering pattern of the Saffman-Taylor instability in a Hele-Shaw cell. For our team delta, we used two different flows to inject to the oil such as red food coloring, blue food coloring, and the air. After finishing this experiment, I think that the Hele-Shaw cell is very useful for observing fluid phenomena on a two dimensional scale. There is much recent research related to experiments using the Hele-Shaw cell such as spin-coating, and the Coriolis force. Overall, I am happy to capture these pictures of a Hele-Shaw cell experiment, set up equipments with teammates together, and present the beautiful image of the fingering pattern of the Saffman-Taylor instability with food coloring and oil.

References

1. Wu, H-J, Tsai, C.-H., Chen, C.-Y., Wen, C.-Y., "Labyrinthine Fingering Instabilities on Magnetic Fluids". *The 27th (ROC) National Conference on Applied and Theoretical Mechanics*, 2003.
2. Chen, C.-Y., Wu, H-J, "Numerical Simulations of Interfacial Instabilities on a Rotating Miscible Magnetic Droplet with Effects of Korteweg Stresses", *Bulletin of APS*, 49, 10, Nov. 21-23, 2004.
3. http://www.iop.org/EJ/article/0295-5075/2/6/005/epl_2_6_005.pdf?request-id=iLIFtLmG3BGCv9_N2wi7Kg
4. http://www.colorado.edu/MCEN/flowvis/course/SaffmanUser.pdf