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Group Project 2 Report – Work Independently

Objective

The primary objective of this project is to capture Saffman-Taylor instability using a Hele-Shaw cell. Saffman-Taylor instability is an important phenomenon to understand because by examining Saffman-Taylor instability, one can understand the flow of substances in porous media. The following paragraph provides a brief introduction on Saffman-Taylor instability before going into the experimental details section.

Saffman-Taylor instability is analogous to Rayleigh-Taylor instability. These types of instability occur between two types of fluids with different densities and viscosity. When a less viscous and a less dense fluid is being pushed into a highly viscous and dense fluid, under gravitational and viscous effect, this injection will cause the surface of the fluid to be unstable, this unstable behavior is also known as disturbances (1). Depending on the degree of disturbances, the instability can grow and create the fingering effect. As such, Saffman-Taylor instability arises when the interfaces of two liquids are being disturbed.

Flow Apparatus

Figure 1: Hele-Shaw Apparatus

Figure 1 shows the Hele-Shaw apparatus that was used in this project. Hand soap was used as a heavily viscous fluid whereas the dye-water was used as a less viscous fluid. A syringe plus needle was used to inject the dye-water into the porous medium where hand soap was located. Originally, I followed the Hele-Shaw's instruction by placing the viscous fluid on the plastic then covering the viscous fluid with a piece of glass on top prior to injecting the less viscous fluid into the porous part. However, I could not capture the Saffman-Taylor instability at all when this guideline was followed because the dye-water started to mix with the hand soap right away. I believe the primary reason for this issue was that the viscous fluid was not completely sandwiched between the two surfaces; therefore, Saffman-Taylor instability could not form.

To increase the Saffman-Taylor instability effect, first I injected the hand soap fluid in, and then the dye-water was next. By doing it this way, I was able to produce Saffman-Taylor instability. To create the flowery Saffman-Taylor instability shape with blue border, I had to inject three different types of fluids. The first fluid was a mixture of soap and blue-dye water, the second fluid was the purple handsoap, and lastly, the red-dye water. In terms of light effect, I used normal fluorescent lightbulbs with 60 W and placed them under the apparatus. By doing it this way, the capture of Saffman-Taylor instability was enhanced.

Discussion

After using the whole bottle of hand soap and spending approximately 6 hours on this project, I was able to capture several images that show Saffman-Taylor instability. I think that the chosen picture has a minimal amount of noises. These noises are mostly due to the bubble formation. These bubbles cause the fingering layer not to be continuous. To avoid bubble formation, I think that I will make sure there will be no air bubble in the syringe next time because this can introduce bubbles into the highly viscous layer.

During the formation of Saffman-Taylor instability, I noticed that the fingering shape became stable after a short time, meaning that the less viscous fluid did not recede and fall back into the hole. The primary reason for this steady state behavior is due to the low velocity of the moving fluid (2). Another feature that I observed was that the Saffman-Taylor instability shape was extremely uniform, not fragmented in anyway. This behavior can be explained via shear rate. Complex fluids with different shear rates will have different Saffman-Taylor instability effect. For example, complex fluids characterized by a moderate shear thinning rate are known to have a viscous fingering shape whereas complex fluids with high shear thinning rate have a fracture-like pattern (3). Based on this description, I believe that the moving fluid was experiencing a moderate shear thinning rate because the fingering shape was uniform.

Visualization Technique

A desk lamp with fluorescent lightbulb of 60 W was placed under the equipment in order to enhance the visibility of Saffman-Taylor instability. Lights from ceiling were turned off to minimize the reflection when capturing the image. The field of view of the image was 6 in. by 6 in. This study was done indoor and it was taken at 9:08:56 PM on March 28th of 2010.

Photographic Technique

A Canon camera with PowerShot SD 1200 IS was used to capture the image. The camera-subject distance was approximately 1 ft. The captured image has the following camera information.

Table 1: Camera Data

Shutter Speed	1/80 sec
F-Stop	f/3.2
Aperture Value	f/3.2
Max Aperture Value	f/3.1
ISO Speed Ratings	80
Focal Length	8.295 mm
Flash	None

Dimension	3648x2736
Resolution	180

Conclusion

Overall, I believe that my image does clearly show Saffman-Taylor instability. I am very satisfied with my image because it is very clear, no motion blurs, and it demonstrates the fluid the phenomenon that I was trying to study. This image also resembles other things such as amoeba and flowers. However, there are some distracting elements in the image such as air bubbles. I will try to eliminate these in the next experiment. In the future experiment, I will vary the viscosity ratio of the two fluids to see how this will affect the fingering appearance. In addition, I will also use non-Newtonian fluids to study the interested phenomena.

Works Cited

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3. *Saffman-taylor instability and pattern formation in diffusion-limited aggregation.* **Sarkar, Subir K.** 5, 1985, Physical Review A, Vol. 32, pp. 3114-3116.

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