Qisheng Lei, Michael Becerra, Bradley Schumacher

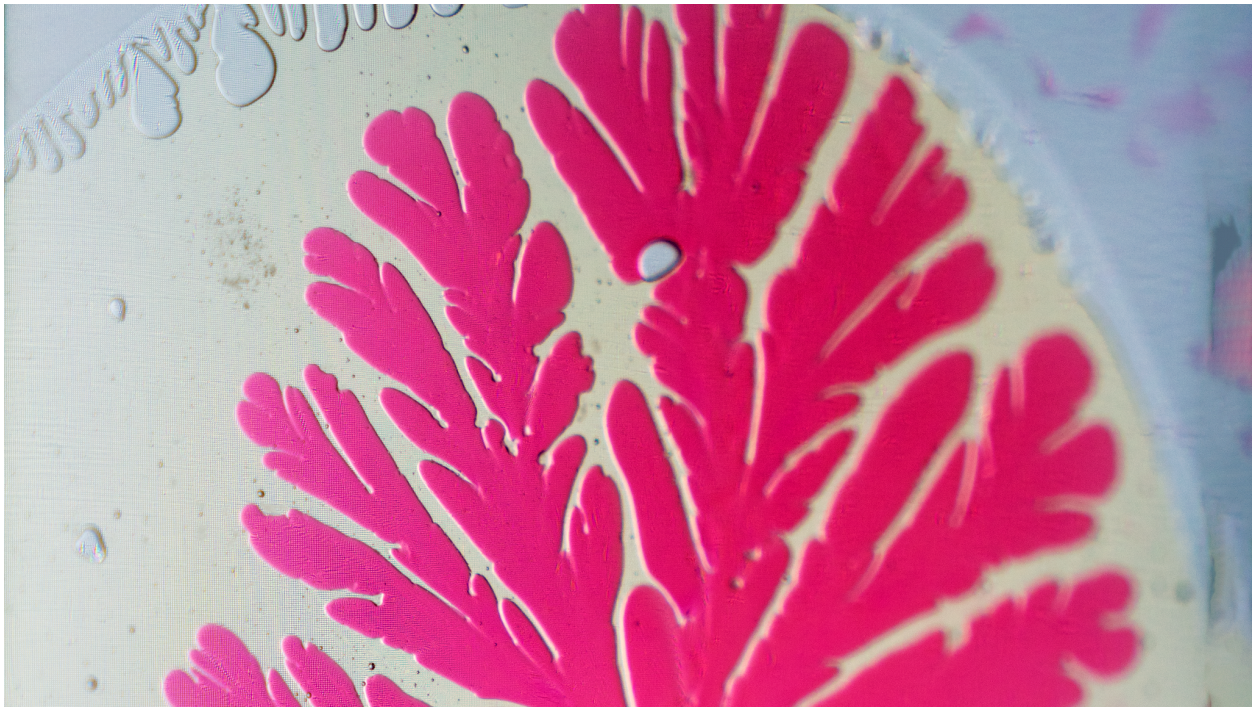
MCEN 5151 - Flow Vis

Prof. Jean Hertzberg

Team First

6 October 2023

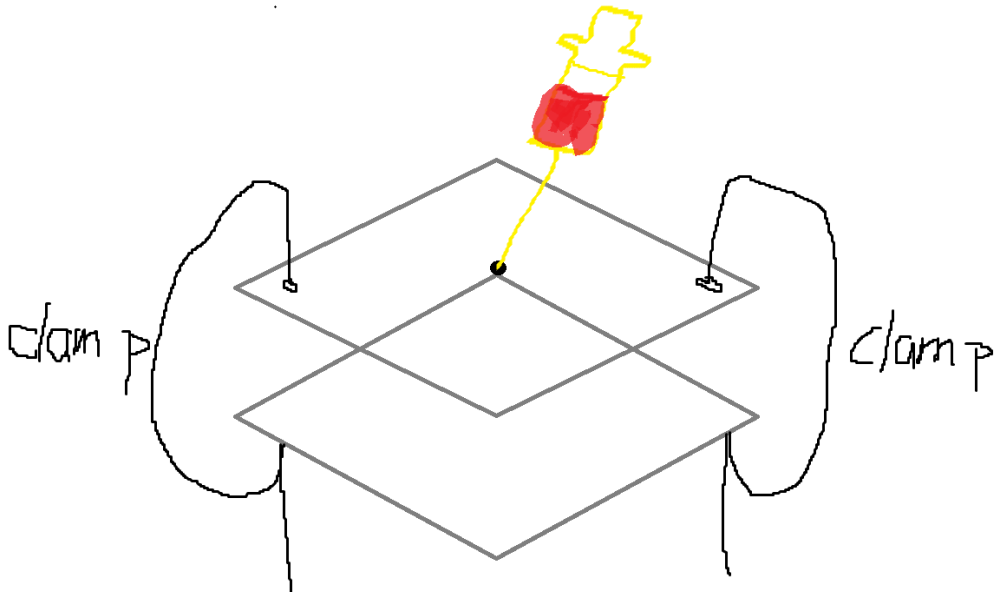
Team First Report



The image shows part of the Saffman-Taylor instability, the pattern of less viscous fluid pushing on the more viscous fluid. This is the team first assignment, as a team, we decided to demonstrate the Saffman-Taylor instability. This phenomena happens when two different viscosity fluids are pushing on each other and will create this pattern. The intention of the image was to capture the beautiful and interesting pattern with Saffman-Taylor instability in colors in order to easily demonstrate the phenomena. We used canola oil at first as the more viscous fluid being pushed, however the results are not as easy to capture. We switched to honey as the

viscous fluid after and captured an image with that. The less viscous fluid is water with food coloring. My teammates Michael Becerra and Bradly Schumacher helped with the entire process from setup to taking the video and pictures.

We used two pieces of acrylic plastic sheet. One is flat and smooth, the other one has a small hole in the middle of the sheet. After putting honey in the flat and smooth sheet of acrylic, then we clamped them together using clamps. We used a syringe to push the dyed water through the hole in the middle of the other side of acrylic plastic, then we can see the Saffman-Taylor instability, the picture below shows this setup.



The flow has a low Reynolds number, laminar flow, we ignore the gravity effects because the distance between two plates are very small[1]. The pressure applied from the small hole on the top plate pushing the fluids between two plates. When we remove the syringe, the fluid is coming out of the small hole on top because the pressure is not applied anymore. The Reynolds number can be calculated with some reasonable assumptions: The velocity can be roughly estimated from video Michael recorded to be roughly 0.04m/s. Length to be 0.1m and the dynamic

viscosity of honey is 10,000 cP, the density of honey is 1420 kg/m^3. The reynolds's number can be calculated as following:

$$Re = \frac{UD}{\mu/\rho} = \frac{0.04 * 0.1}{10000/1420} = 5.68\,E-4$$

As we can see Reynolds number is small which fits our assumptions and the Safeman-Taylor instability we observed[2].

Two fluids include water with food coloring as the pink/red less viscous fluid we used, the honey which shows yellow is the more viscous fluid we used. The acrylic plastics are easily obtainable from craft stores, a drill is required with a small bit to drill the hole on top of the acrylic. We used coat hanger clamps to clamp two sheets of acrylic together. For lighting, we used an iPad with a full white background and full brightness underneath both sheets of acrylic to provide enough lighting that is close and stable for the picture. There is no flash used on camera and no other lighting besides ambient lighting from ITLL. With the setup images drawn from above, the experiment was able to be repeated, however, the speed when pushing down the syringe is a variable factor and has an impact on the final image, but they should be similar to each other.

When taking the picture, I am trying to focus on fully showing the phenomena, however, there are some distracting factors like syringe and hands and excessive fluid coming out of the hole on top. iPad from underneath provided a clear lighting solution to show the image I was trying to capture. Camera is over the glass and slightly offset. Below are the settings:

- Size of field of view: 39.59 Degree
- Distance from object to lens: 0.2m
- Focal length: 60mm
- Type of camera: Full frame mirrorless digital camera. Sony A7R ii.

- Original pixels: 1952x4472
- Final image pixels: 4472x2515
- Exposure Specs: f/4; 1/160sec; ISO 640

Image before being edited:

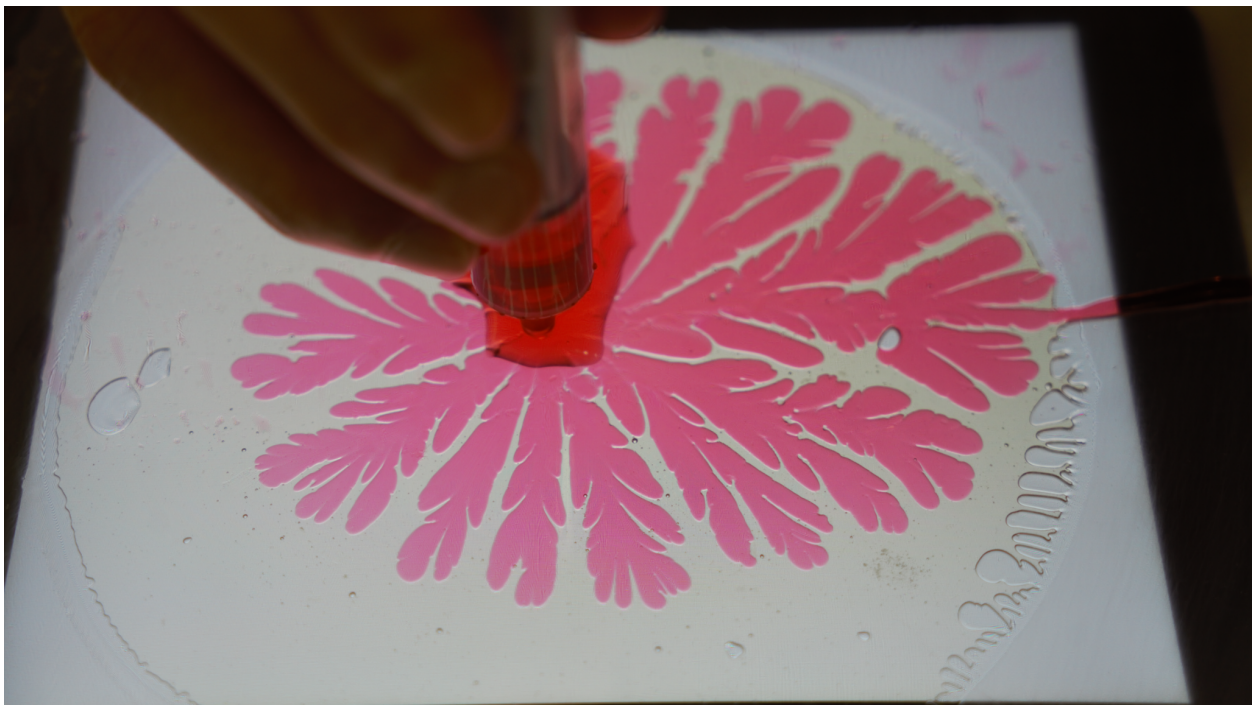


Image processing involves cropping, and adjustments to brightness, exposure, saturation. Simple adjustments to make the contrast better and flow easier to see.

The image reveals the finger-like pattern saffman-taylor instability shows. I like the beautiful pattern for simple fluid phenomena. Out of focus on the right side of the picture, there is also a slight color change on the tip of the dyed water. The air bubble creates something different, either like it or hate it. The fluid physics are shown well and my intent is fulfilled. I think there is less ability to take a full picture with distracting elements like a syringe or hands with some higher technological equipment. I should have focused more just on one section of the flow in a full frame without needing to crop.

References

[1]H. Thome, M. Rabaud, V. Hakim, and Y. Couder, “The Saffman-Taylor instability: From the linear to the circular geometry,” Phys. Fluids 1, 224-240(1989).

[2]P. Tabeling, G. Zocchi and A. Libchaber, “An experiment study of the Saffman-Taylor instability,” Cambridge University Press (2006)