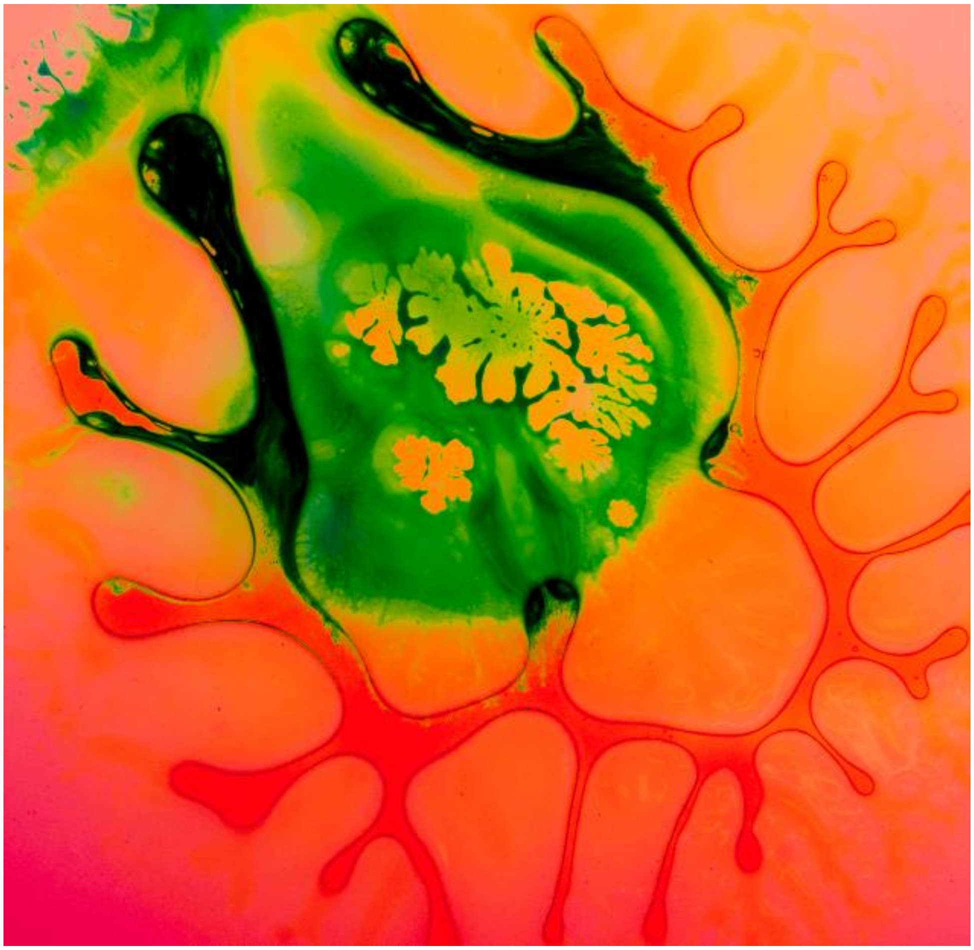
Flow Visualization: The Physics and Art of Fluid Flow

MCEN 5151



Alyssa Berg

With help from Anthony Johnson, Jeff Bryne, and Aaron Coady

4/5/12

Viscous Fingering

Purpose

The purpose of this picture was to capture an image or viscous fingering. I really wanted a picture that was really bright and colorful that would attract the audience's attention. Originally I really wanted to capture an image that was really bright and a backlight was used to make it glow in the dark. I took plenty of these pictures although might favorite was this simple yet vibrant picture of corn syrup with food dye.

Apparatus

This picture was taken using a tablespoon of Kroger brand corn syrup and greaan Kroger brand food dye. The corn syrup was initially poured onto an opaque sheet of acrylic that was a half inch thick. Then a few drops of the food dye were added. After the dye was added, a clear piece of acrylic that was also a half inch thick was pressed on top of the syrup and dye. The picture was taken immediately after removing at was directly the clear sheet of acrylic. The removing of this sheet of acrylic caused it to create even more viscous fingering along the edge of the syrup rather than just the viscous fingering with the green food dye. The light source for the picture was from a set of work lights that were placed directly under the opaque acrylic. Figure 1 demonstrates this set up. In this picture the frame of view is approximately two inches by three inches.

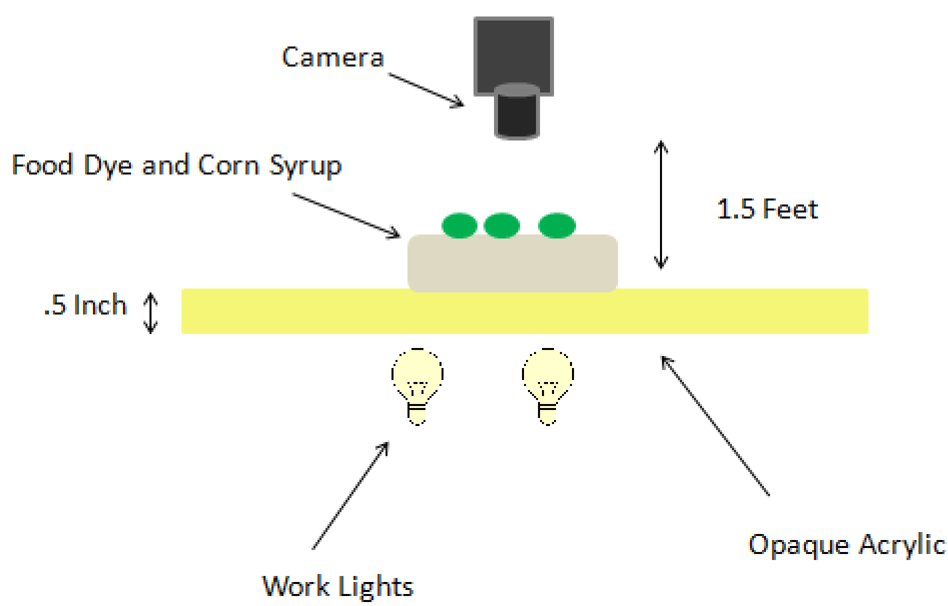


Figure 1: Apparatus

Physics behind the Picture

The goal of this picture was capture an image of viscous fingering. This phenomenon is the formation of patterns in an unstable interface between two fluids. It occurs when a less viscous fluid is injected and it displaces a more viscous fluid [1]. For theses fluids, the viscosity of corn syrup was between 2,000 and 3,000 centipoises and the viscosity of the food dye was obviously lower since the phenomenon occurred [2]. This type of phenomenon can also be referred to as Saffman-Taylor instability. This most commonly occurs in Hele-Shaw geometry and the Darcy Equation can most effectively describe the physics [3]. This law describes an equation that describes the flow of a fluid through a porous medium. The equation incorporates the permeability, area, pressure drop, viscosity, and the length of the pressure drop [1]. Something that also affects the stability on the edges of the fingers is surface tension. Surface tension is defined as the force along a line of unit length, where the force is parallel to the surface but it remains perpendicular to the line [4]. In the corn syrup, the molecules are pulled in every direction creating a zero force. However on the surface the molecules are not pulled equally on all sides and they are pulled inwards [4]. This creates internal pressure and forces the liquid to contract to minimal surface area. Overall, the main forces that were seen in this picture were surface tension, and different shear forces from the different viscosity. However in this experiment, Reynolds number and Grashof number were zero initially since neither one of the fluids were moving and didn't significantly relate to this experiment.

Picture Details

When taking this picture my camera was set to specific settings to capture the physics I wanted. For this picture I used a Sony alpa-230 DSLR camera. The distance from the camera to the object was approximately a foot and half and the field of view was two inches by three inches, it is also 3875 by 2592 pixels. The ISO was 100, the exposure was 1/125 sec at f/11 and the focal length was 55mm. This photo had minimal editing done to it compared to my previous photos. From the original image I first cropped the picture, and then I added tints of red and orange as well as slightly increasing the contrast. By performing these simple changes in Photoshop I was able to make the picture appear a little brighter and make it seem more colorful. The original picture can be seen in Figure 2 and the picture after my editing can be seen in Figure 3.

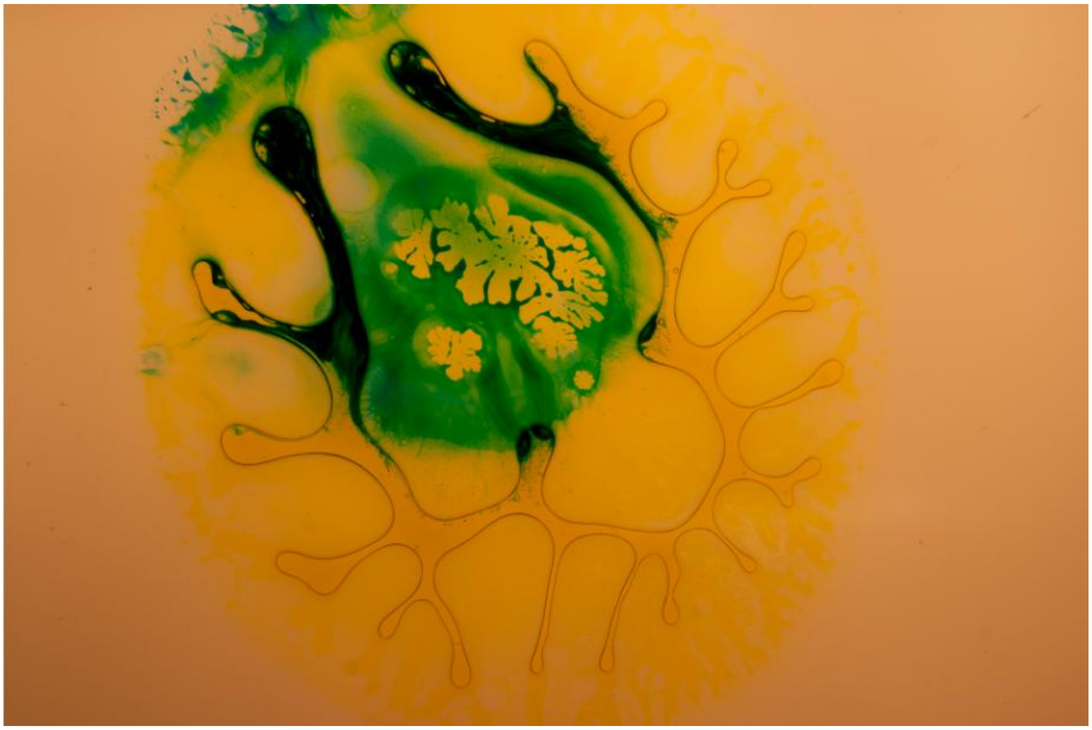


Figure 2: Original Picture

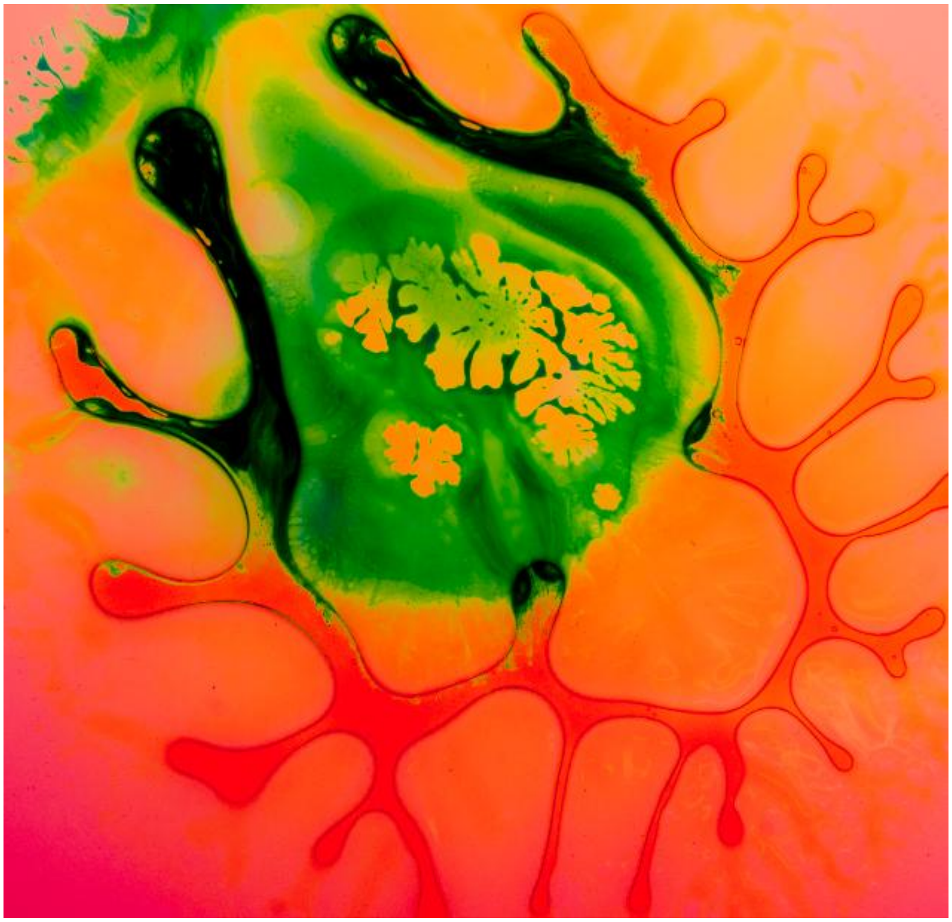


Figure 3: Final Picture

Conclusion

This picture was intended to reveal the artistic view of viscous fingering. I think this image really captures the beauty of the phenomenon and I am very happy with the picture. I also think that is does a nice job of capturing the image flows, in that you are able to see two distinct examples of viscous fingering in one picture. Overall I did fulfill my initial intent; however, I really would have liked to have a little bit of a clearer picture as well as have a picture that incorporated a black light since I really like those types of pictures. I am happy with this picture though, since it is clearly demonstrates the phenomenon occurring as well as being a beautiful picture.

References

[1] "Viscous Fingering." *Wikipedia*. Wikimedia Foundation, 17 Mar. 2012. Web. 05 Apr. 2012. <http://en.wikipedia.org/wiki/Viscous_fingering>.

[2] *Viscosity Chart*. Web. 4 Apr. 2012. <http://www.research-equipment.com/viscosity%20chart.html>.

[3] Tabeling, P., G. Zocchi, and A. Libchaber. "An Experimental Study of the Saffman-Taylor Instability." *Journal of Fluid Mechanics* 177.-1 (1987): 67. Print.

[4] Kyte, J. (2003). "The Basis of the Hydrophobic Effect". *Biophysical Chemistry* **100** (1–3): 193–203.