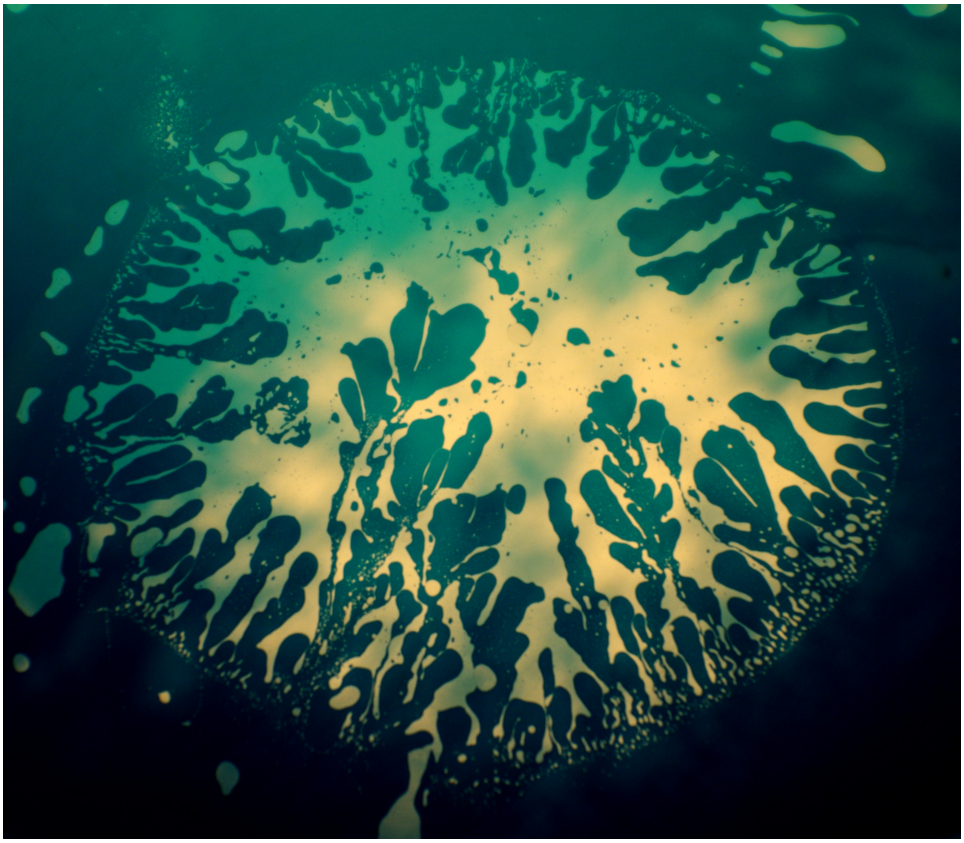
MCEN 5151: FLOW VISUALIZATION
WITH DR. JEAN HERTZBERG



Micro Sprawl

Group Image 2

James Shefchik
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Introduction

The intent of this image is to show the complex structures that form in the contest of viscosity and surface tension between olive oil and food coloring. This image was created with the assistance of teammates Hans Loewenheath and Spencer Aguilar.

Conditions

This image was captured on March 15th at 11:49 a.m., in the Integrated Teaching & Learning Program and Laboratory (ITLL) in the Engineering School at Colorado University at Boulder. We were able to use the vibrations laboratory, which is equipped to be a dark room. We were able to control the lighting in this dark room. Only white light was used, produced by a 500W Halogen work lamp. White paper was taped on the bottom of a Hele-Shaw cell, blue dye was dropped on top of a drop of olive oil in between the two plates of glass comprising the Hele-Shaw cell. The upper plate was raised, causing a separation of plates, inducing capillarity movement toward the areas of narrower cell separation. This capillarity movement revealed the different viscous and surface tension forces of the two distinct fluids. This photograph was captured from directly above the structure captured. Figure 1 shows a mock up of the arrangement for the photograph.

Figure 1. Abstract of Setup

Physics

The fluid phenomenon is known as "fingering", which occurs when a less viscous fluid (the blue dye) penetrates, or displaces, the more vicious fluid (the olive oil). Of course, all olive oil batches will have slightly different properties, one estimate for the viscosity of olive oil is 91.5 Centistokes[1]. Approximating the food coloring to have the viscosity of water, we expect it to be about 1.0 Centistokes.

In a larger scale, density could also play a role in the dynamic interaction, but in such a limited space the surface tension force overcomes the buoyancy force due to the density difference. The non-toxic liquid dye should have a similar density to salt water, or about 1.025 kilograms per liter, where the olive oil's density is only about 0.91 kilograms per liter. This difference in density will encourage the olive oil to float on the surface of the dye, but each fluid wants to wet the glass and, due to surface tension, wants to stay together. These forces balance out in a very interesting way, causing the curious structures of this image. Water has an innate surface tension around 73 dynes per square centimeter[2] and olive oil is near 33 dynes per square centimeter. But, between the interface of the two, the surface tension is around 16 dynes per square centimeter[3].

To calculate the buoyancy force, we must discover the potential food coloring displacement by the olive oil. As our fluid was pressed between two pieces of glass, the depth of the fluid is minimal, say on the order of a piece of paper, or about 0.1 millimeters, which would allow 1/10,000 kilogram of force per square meter, or 9.8 dynes per square meter, or 0.00098

dynes per square centimeter, which is certainly negligible next to the 16 dynes per square centimeter of surface tension. Meaning, it is safe to assume that there will only be dye or olive oil at any place between the glass. As the glass was lifted, the pressure caused the coloring to penetrate and displace the oil.

The Image

Taken with a Pentax K-5, the original JPEG image was edited with the GIMP editing program, the artist used the PNG images to export the file data. Unfortunately, the PNG format does not keep the EXIF data.

The field of view is 3/4 inch by 3/4 inch, or about the size of my thumb nail. In addition to the Pentax lens, the artist also used a 2x macro screw-on attachment, which was about 6 inches from the glass.

Table 2: Camera and Original Image Data

Camera:	Pentax K-5
Lens:	SMC Pentax-DA L 55-300 mm
Focal Length:	55 mm
F-stop:	f/7.1
Exposure:	1/100 sec.
ISO Speed:	ISO-400

Width:	4928 pixels
Height:	3264 pixels
Horizontal resolution:	300 dpi
Vertical Resolution:	300 dpi
Bit Depth:	24
Color Representation:	sRGB

The photograph color was enhanced in GIMP using the color curves modulation, to obscure the background and to sharpen the contrast. It was cropped nearly square to focus on the interesting round subject.

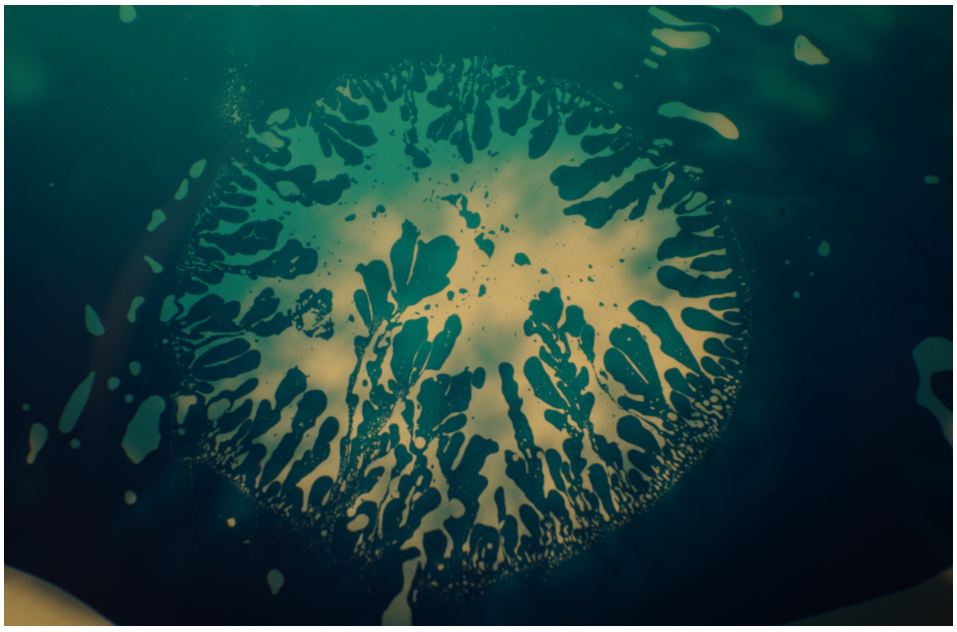

Figure 3. Untouched image

Conclusion

I am quite pleased with this image. It effectively exposes the hydraulic displacement by a free pneumatic stream. The focus is right at the crest of the well, the colors reveal the surface structures. After hours searching the internet, I could find nothing similar or that added to understand this phenomenon. Further exploration could better reveal the surface and body force interaction. An attempt could be made to quantify the air velocity.

References

1. Fluid Data table, Solutions by Design, Engineers Edge, <http://www.engineersedge.com/fluid_flow/fluid_data.htm>
2. Fluid Data table, Chemistry 520 Lecture Notes, University of Washington, <http://depts.washington.edu/chemcrs/bulkdisk/chem520B_aut10/notes_Week%206%20lecture%203.pdf>
3. Than, P, et al, "Measurement of Interfacial Tension between Immiscible Liquids with the Spinning Rod Tensiometer", P. Than et al., Department of Aerospace Engineering and Mechanics, University of Minnesota, 1986. <http://www.aem.umn.edu/people/faculty/joseph/archive/docs0/88_1.pdf >