Flow Visualization Group Report #2

MCEN 4151

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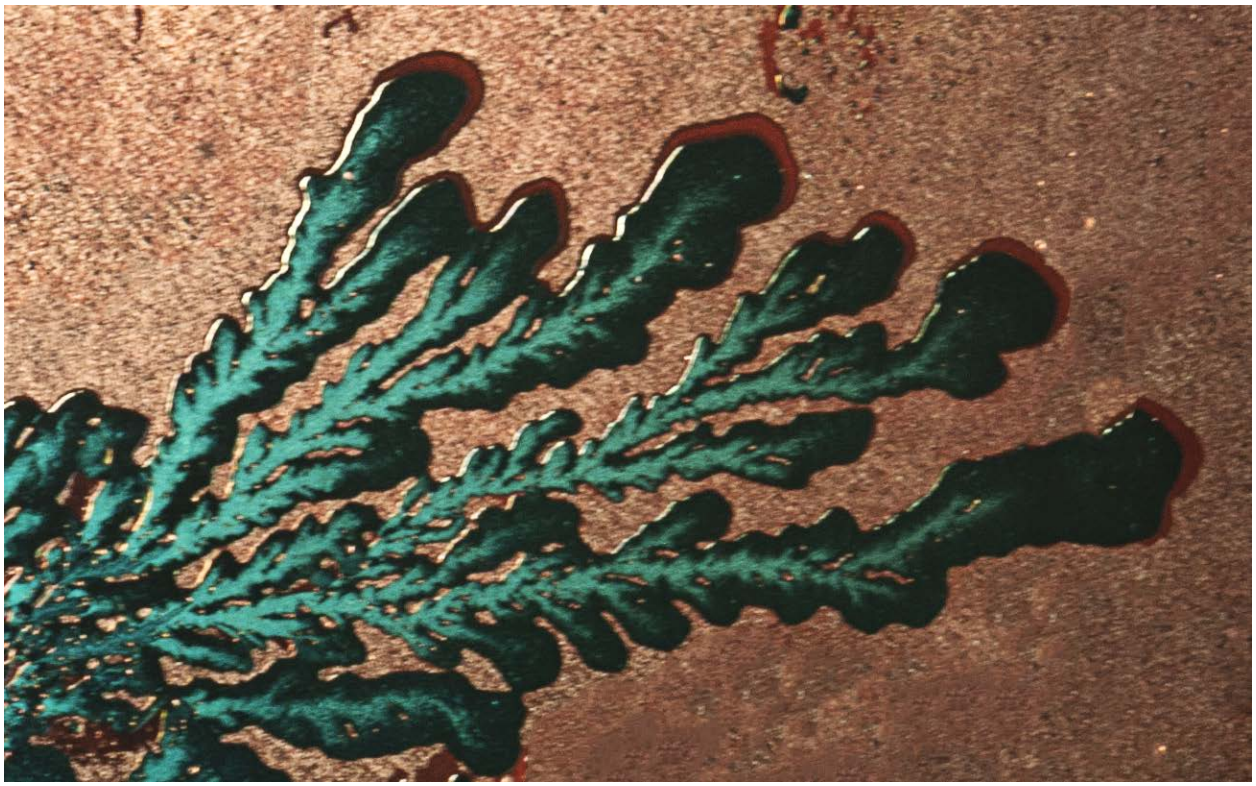

This is the third flow visualization submittal for the MCEN 4151 class. The image was taken individually, however a group was assigned to help with the brainstorming ideas for the photo, the setup, and the lighting of the image. The phenomenon that was intended to be observed was the Hele-Shaw flow fingering between two pieces of glass. Team members that helped to make this photo possible include; Coulter Pohlman, Hans Loewenheath, James Shefchik, and Spencer Aguilar.

The apparatus that was used to capture the phenomenon was already available in the light and vibrations room of the ITLL. The setup consists of a hollow frame on which two sheets of glass rest on top of. Since the frame had an empty center the lighting was set up to come from below with the camera mounted above the glass. The full apparatus can be seen in Figure 1.

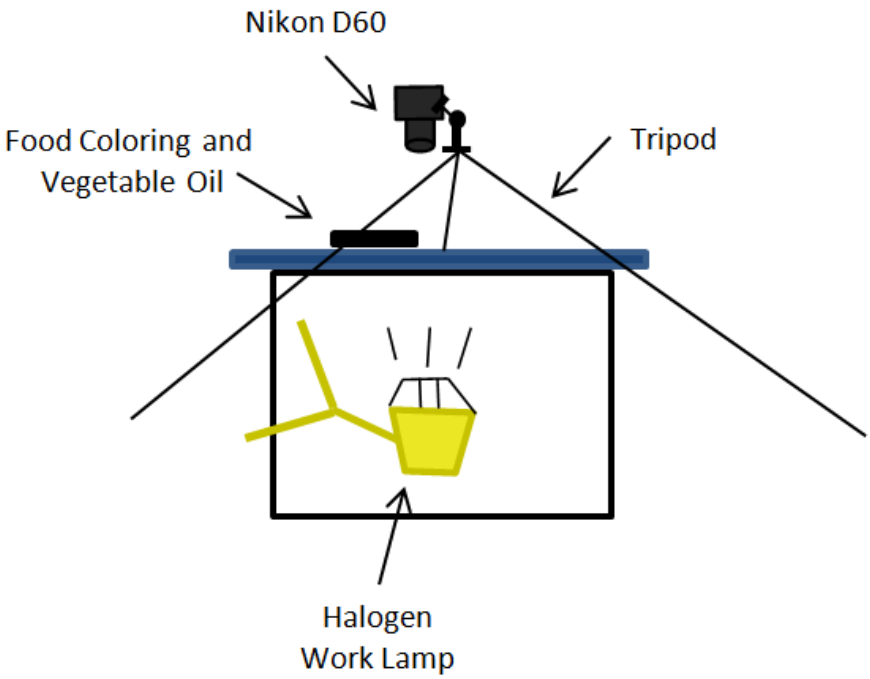

Figure 1. Photo Apparatus

In the Hele-Shaw flow describes the flow of a fluid between two infinitesimally close flat plates. Similar to other boundary layer theory, the flow between the two plates has a parabolic velocity profile. The velocity is dependent on the pressure gradient across the fluid, the separation between the two plates and the viscosity of the fluid as seen in Equation 1.

$$\boldsymbol{u} = p\,\frac{z^2 - H^2}{2\mu} \tag{1}$$

By estimating the distance between the two plates as 1mm, the viscosity of the food coloring assumed to be that of water at 0.001 N*s/m^2, and finally a pressure gradient of 5 Pa, yields that velocity of the fluid was travelling at approximately 1.8 mm/s. This velocity worked out well for the purpose of the photo since the flow was moving slow enough to easily capture.

Using the velocity found above, the Reynolds number of the flow is able to be found. Using the Reynolds number equation seen in Equation 2 the Reynolds number is found.

$$Re = \frac{\rho u D_H}{\mu} \tag{2}$$

Using Equation 2 it was found that the Reynolds number for the flow is roughly 0.02, very small compared to other flows.

The visualization technique that was used was food coloring and vegetable oil so that the different viscosities would stay separate. This solution was made in a small cup and roughly 4 tablespoons of vegetable oil was mixed with a teaspoon of food coloring. The lighting that was used to capture the final image was a halogen work lamp placed directly below the glass to light up the fluid. The distance from the glass to the lamp was about a foot.

The fingering that occurred was on a very small scale which is why a macro lens was used. The field of view of the original image is about 1 inch by 2 inches while the lens was 6 inches off of the glass. A Micro-Nikkor 105mm macro lens was used with an f stop of 5.6. A Nikon D60 DSLR was used to capture the image. The original pixel dimensions are 3900x2916 and final dimensions of 1000x 819 pixels. The shutter speed was set to 1/6 of a second with an ISO setting of 100 to reduce the noise. In Photoshop the image was altered using only cropping and adding contrast. Below in Figure 2 a before and after can be seen of the image that was taken.

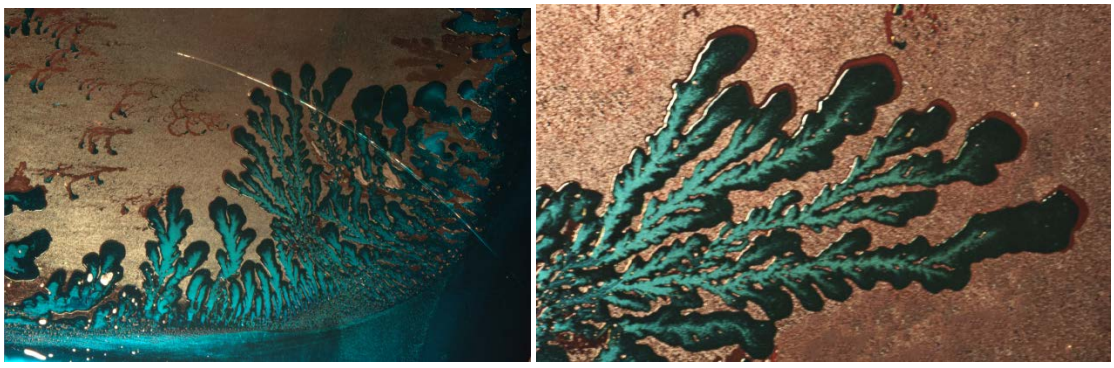

Figure 2. Before (Left) and After (Right)

The image reveals the fingering effect of the Hele-Shaw flow and the distribution of the food coloring as seen as the darker areas in the photo. After all was said and done I like the original image that I took more than the final photo that was submitted. This is because I cropped the image so much that it got grainy and was not very clear any longer. I feel that I fulfilled my intent of the image and captured the fingering that I wanted to see. Developing this idea further various fluids could be used as well as different injection methods. Something that could be improved on is the lighting that was used so that more of the details would be revealed. Overall, I am satisfied with the final photo.