Sinking of Ice

By: Travis Smith

CU Boulder

MCEN 4151 Flow Visualization

Collaborators: Cooper Lay, Sam Nicastro

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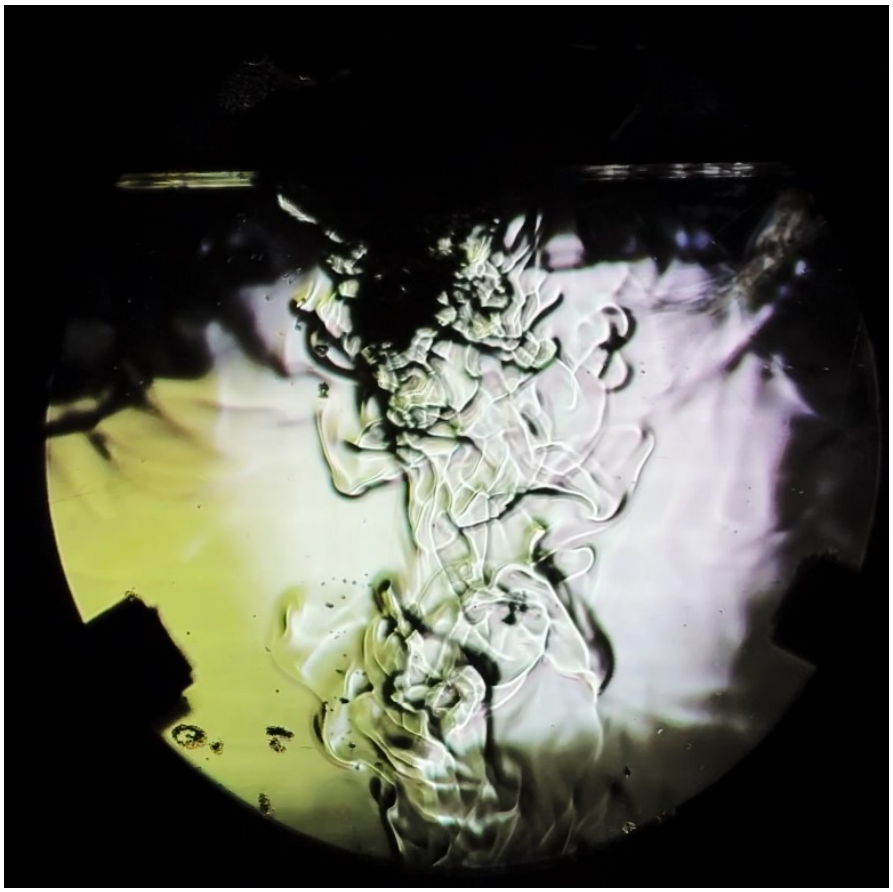

Figure 1: Schlieren imaging of an ice cube melting in a tank of warm water.
https://youtu.be/5zENpSs4zF0?si=oaUIdvmjiqvq-j8k

Introduction

This image was taken for the third team project in the Flow Visualization course. The intent of this image was to visualize the change in density of water at different temperatures and to see the cold water sinking to the bottom of the tank. I would also like to thank Cooper Lay and Sam Nicastro for their help setting up the experiment.

Procedure

For this setup, a z-type Schlieren imaging setup was used, Figure 2. Schlieren imaging is a way of visualizing changes in index of refraction between fluids, or in variations of a fluids like temperature gradients. It does that by first collimating a light source into completely parallel light, letting the changes in index of refraction scatter some of the light, and then focusing the light back down to a point so the camera can see it. Because of this, gradients in temperature difference that are close to parallel with the light shows as shadows in the camera. A knife edge is placed in front of the camera just outside of the focused light beam to help block out any of the defected light.

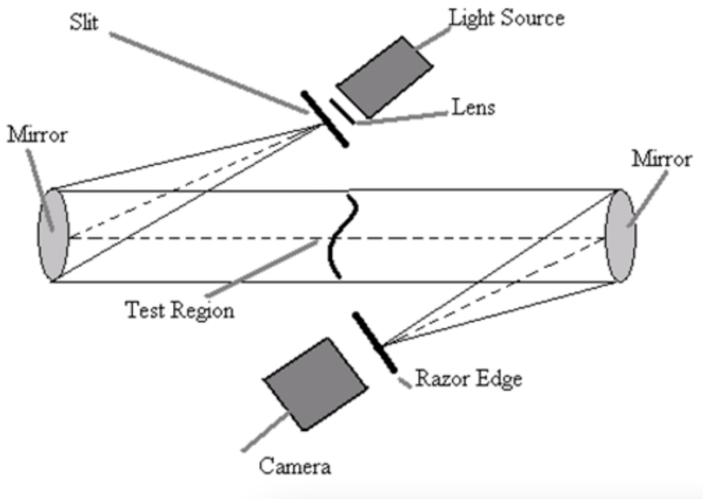

Figure 2: A drawing of a z-type Schlieren imaging setup [1].

In my experiment I placed a 5-gallon tank of warm water, about 100°F, in the test region and floated an ice cube until it fully melted. The ice cube was about 3 inches long, 1 inch tall, and ½ an inch wide. The test region for this experiment was about 4 inches in diameter, as can be seen in Figure 3.

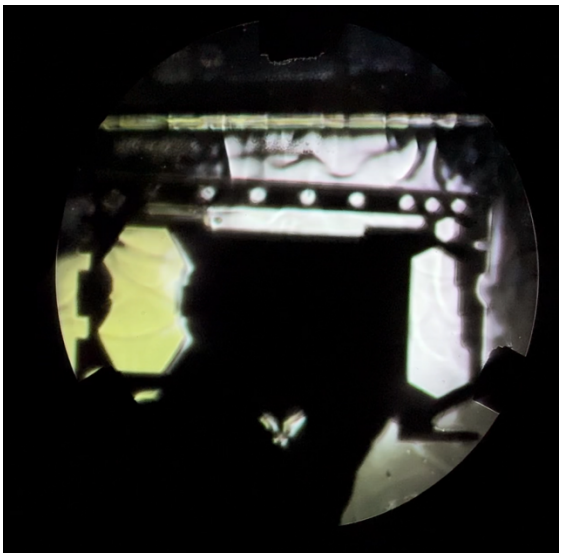

Figure 3: A 3-inch-long tool is being held in the test region of the Schlieren setup indicating that the test region is about 4 inches in diameter.

For Schlieren imaging it is important to use a small light source, and here I used an LED flashlight. For recoding I used an iPhone 16 Pro 2x lens (58mm) with the 5x digital zoom. I used my phone because it was much easier to position the camera in the focal point of the light than the DSLR camera that I had. This video was recorded in 4k, 3840 x 2160 pixels, at 60 fps. This video was then cropped to 1508 x 1408 pixels. A screenshot of the original image can be seen in Figure 4. In the final video, the contrast was increased for more definition in the waves, and the saturation in the midtones was increased to bring out the yellow on the left hand side of the frame.

Figure 4: A screenshot of the unedited and uncropped video.

Discussion

The density of water at 32°F is 62.421 lb/ft^3 and the density of water at 100°F is 61.996 lb/ft3 [2]. Because the density of the cold water is greater than that of warm water, the cold water sinks to the bottom of the tank. Also, the molecules of the warm water are more excited than those the cold water, so they are more likely to diffuse into the cold water than the other way around. It can also be seen that the area of the cold water, shown by the ripples in the video, decreases the lower in the tank it goes. This is because the temperature of the water is equalizing as the heat has more time to transfer.

I am really happy with how the result of the experiment. It was always my intent to try and visualize the melting of ice and I think that is clearly seen here. I think that the physics are well demonstrated, even though Schlieren imaging is a qualitative technique. I believe the banding that is seen in the video is the result of the LED light and the shutter speed of the camera. This is something that I would like to resolve in the future. Also, my hair can be seen in frame during a portion of the video. This wasn't realized until after the setup was disassembled and that was a bit disappointing. Finally, I would like to clean the mirrors next time, however, first surface mirrors are extremely difficult to clean without damaging them.

Work Cited

[1] https://www.researchgate.net/figure/Schematic-of-the-z-type-Schlieren-set-up-used-to-visualize-the-flow-field-of-the_fig2_317595995

[2] Editor Engineeringtoolbox. (2003, January 25). *Water - Density, Specific Weight and Thermal Expansion Coefficients*. Engineeringtoolbox.com. https://www.engineeringtoolbox.com/water-density-specific-weight-d_595.html?vA=32&units=F#