MCEN 4151

Flow Visualization

Report - IV 4: Air Foil in Flume Tank

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MCEN 4151: Flow Visualization

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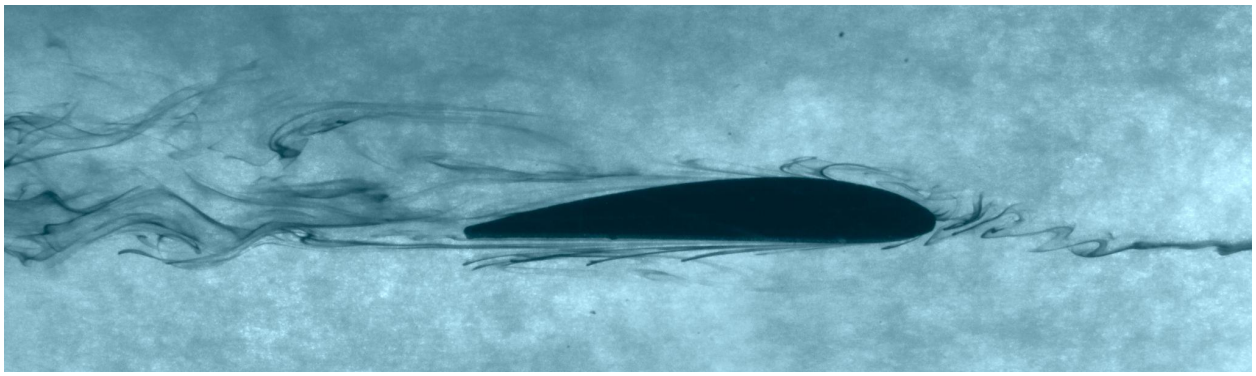

1 - Introduction

For this week of Flow Visualization, our group decided to experiment with the flume tank. We wanted to capture how fluid streams interact with bluff bodies. For my particular image I used a 3D printed airfoil, with blue food coloring dye injected in the flow of water. This was a pretty tedious experiment because to get a good flow and image of the phenomena you need a steady laminar flow, steady hands to inject the dye, and a thin syringe needle. Out of all the photos I had gotten I saw that this one provided the most realistic streamline around an airfoil and some noticeable features in the stream. In this photo the dye didn't insert itself as a solid stream of dye, instead it was a little choppy and swirly. There are two waves that are created after the airfoil which I thought were really interesting the way they are adjacent to each other.

2 - Experimental Setup

Our set up consisted of the 3D printed bluff body, food coloring dyes, and the flume tank. The airfoil was attached to the wall of the flume tank with double sided tape. The tape held surprisingly well with how strong the current was and how much resistance the airfoil experienced. The dye was injected into the tank via a syringe which was at an angle of about 20 degrees from the direction of flow. The length and width of the airfoil was 3x0.75in and was 3D printed by Kendall Shepard. The flow rate was measured at 10 Liters in 36.4 seconds which yields a volumetric flow rate of $2.75 \times 10^{-4} \frac{m^3}{s}$.

3 - Flow Phenomena

What's being depicted in this image is laminar flow being disturbed by a bluff body. While the bluff body takes the shape of an airfoil and should have a smooth flow of dye around

it, that's not what was shown. I have reason to believe that the somewhat rough surface of the 3D printed airfoil induced a small amount of friction on the water flowing by. Since an airfoil is one of the most aerodynamic objects, normal laminar flow around it would look smooth and collected. Laminar flow around an airfoil looks like:

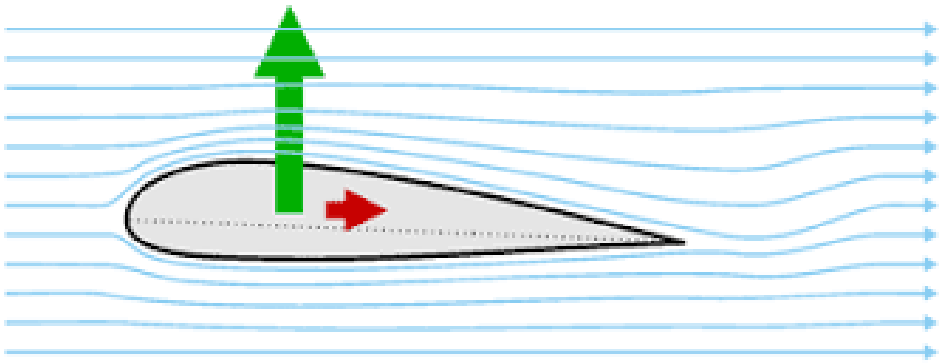

Figure 1: Flow around an airfoil

In the image above, the green arrow represents the lift force and the red arrow represents the drag force. As seen above the flow is very smooth, almost consistent with my image. At the thickest part of the airfoil, the surface creates a high pressure area where the object separates the water. Behind the object is a low pressure area where the water flows in a slanted direction downward. This high to low pressure creates turbulence in the water which is seen in *Figure 1* at the tail of the airfoil.

$$Flow\ Velocity\ = \frac{Volumetric\ flow}{Cross\ Sectional\ Area} = \frac{0.000275 m^3 s^{-1}}{0.048m \times 0.076m} = 0.075 \frac{m}{s}$$

$$\text{Reynold Number: } Re\ = \frac{V_{flow} \times L}{v} = \frac{0.075 \frac{m}{s} \times 0.064m}{0.00000105 \frac{m^2}{s}} = 4570$$

The Reynolds number is above 2000 which indicates that the flow is turbulent, my initial assumption was that this was laminar flow because of how slow and smoothly the water flowed. It makes sense seeing that the dye looks so chopped and spread out after it hits the airfoil. The low pressure area of the airfoil created small vortexes in the flow following the tail which creates those wave like shapes seen in the presented image.

4 - Visualization Technique

Working with the flume tank was challenging in some cases, for instance the flow of the tank was hard to toggle with. Props would have to be used to slow the flow so that there would be a high enough water level to have the airfoil off of the ground. It was also very challenging to get a smooth ejection of coloring dye to flow through the tank, the problem was that the syringe would sputter the dye and our hands weren't that stable. We used different colors of dyes in the water, we used red, green, and blue. What felt appropriate was the blue dye because it gave a very dark color and blended with the water very well. Red looked like a shark attack and green looked like swampy sewage water. We also tested different bodies such as cylinders and cubes, but the airfoil was the most interesting to see.

5 - Photographic Technique

To capture the turbulent flow of the dynamic fluid meant that we needed to capture a moment where the dye is sharp and clean and clearly demonstrates the flow of the water. I used an exposure time of 1/400 which is pretty fast but not too fast where the lighting would be off. I believe the settings I used were adequate but I think maybe zooming in and having better focus would've helped. Below are the camera and image specs:

Image Specs

Camera	Canon EOS 70D
Dimensions	5472 x 3648
Edited Dimensions	5161 x 1513
Focal Length	37 mm
F number	f/22
Exposure time	1/400

Figure 2: Image specs and image dimensions

In darktable I edited the RGB curve to give a better balance of color, cropped to highlight the interesting areas, added a color tint to remove the green water in the background, and contrast and brightness to sharpen it up. I spent a while in Darktable trying to figure out how to add color to the image, below are the before and after editing images

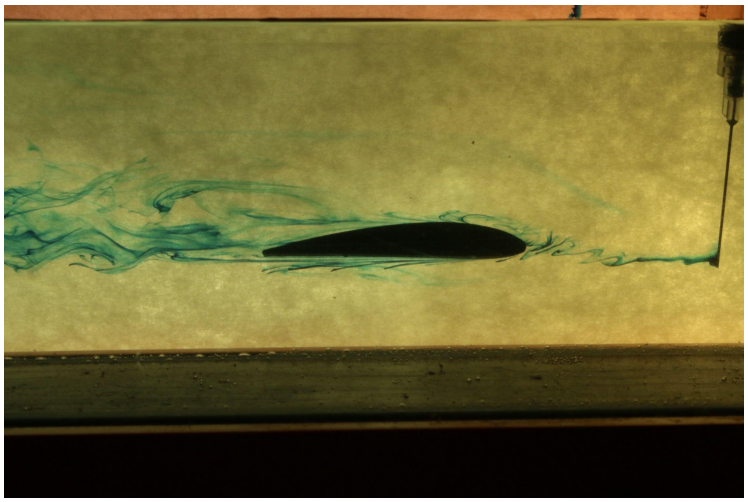

Figure 3: Original Unedited Image

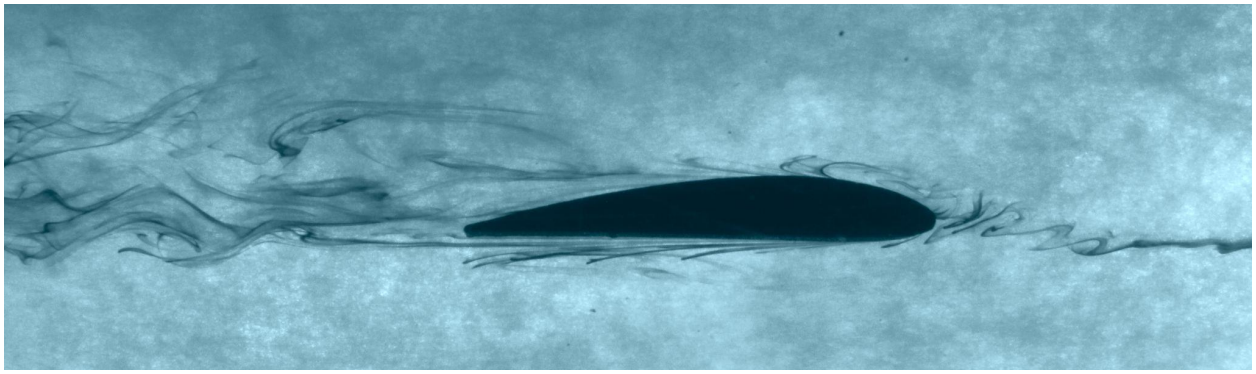

Figure 4: Final Edited Image

6 - Conclusion

This experiment was pretty cool, this experiment was the closest experience I've had to seeing a wind tunnel which is something I've always wanted to see in person. There were some challenges with the set up but I think our group executed it pretty well. I learned that the flow was turbulent even though the water gave the appearance of being laminar. I wouldn't have known that the flow was turbulent if it weren't for the dye flowing over the airfoil. To recreate this experiment you need a flume tank, syringe, food coloring dye, and a bunch of props that will fit in the flume. Advice would be not to use too much dye or it will saturate the water and make it a nasty color.