Hannah Schumaker
Flow Visualization
Project 3: Group Picture
Due: 3/19/13

Fluoescent Dye on Airfoil in Wind Tunnel

The first group assignment for Flow Visualization, a course focusing on capuring the natural beauty of fluids with the science of fluid flow. This project was performed in groups to encourage students to take on more difficult projects. In our group we wanted to examine the way fluids move on an airfoil. We wanted to illustrate this phenomenon by using fluorescent fluids and a black light to really highlight the fluid movement.

In this project we used a small, aluminum, airfoil designed for use in the wind tunnel. It was attached by a pin to the floor of the wind tunnel, see **Figure 1**. Air entered through the visible opening on the left side of the diagram, ran over and under the airfoil, and passed out through the right side. The square holes on the left and ride sides of the diagram represent the continuing ends of the wind tunnel. The airfoil was visible through the front panel, through which some images were taken (not the ones used here). The airfoil was lit using a black light that was placed on the top glass panel.

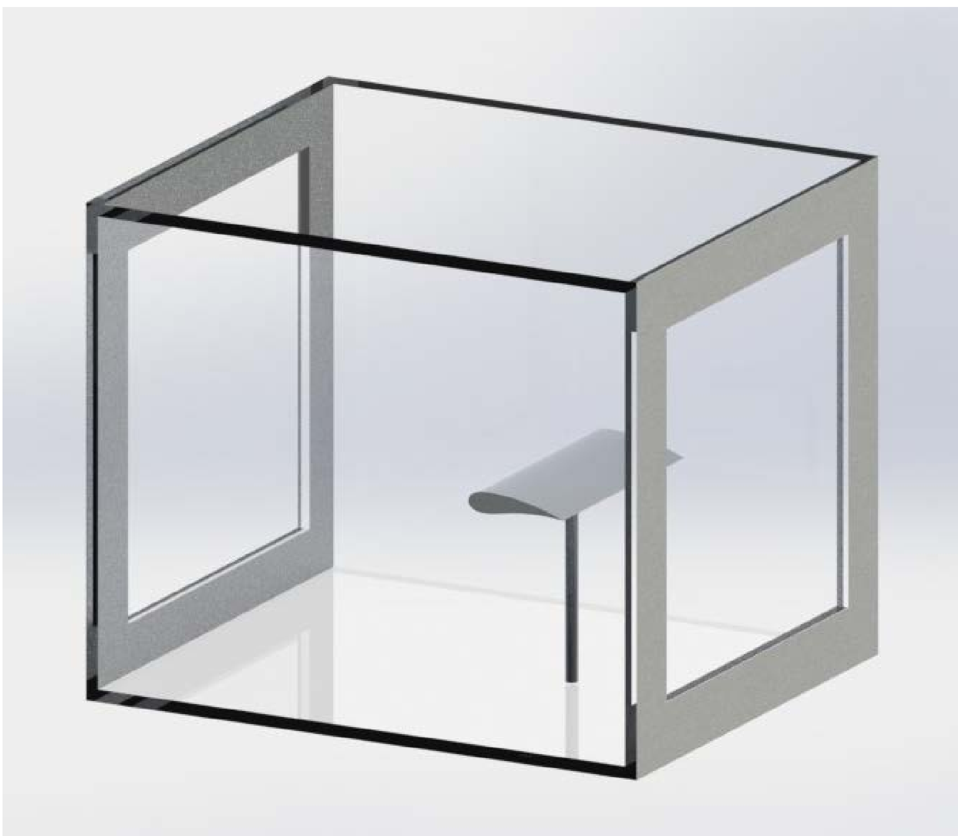

Figure 1. System Diagram – Airfoil in Wind Tunnel

The airfoil was approximately 6 inches in length and 3 inches from leading to trailing edge. The fluorescent fluids were dropped on the leading edge using an eyedropper. For this particular image, seen in unedited original form in**Figure 2**, there are two different kinds of fluid visible. The lower level is laundry detergent, blue to the naked eye. A stream of this detergent was applied to the leading edge of the airfoil and then placed in the wind tunnel at zero angle of attack at maximum airspeed (approximately 22 m/s). The fluid moved slowly toward the trailing edge due to its extreme viscosity, and when sufficiently thin stopped moving entirely and dried onto the airfoil. The brighter color is from a second layer of automobile dye. This was placed in drops on the leading edge, and once again placed in the wind tunnel at maximum speed and zero angle of attack.

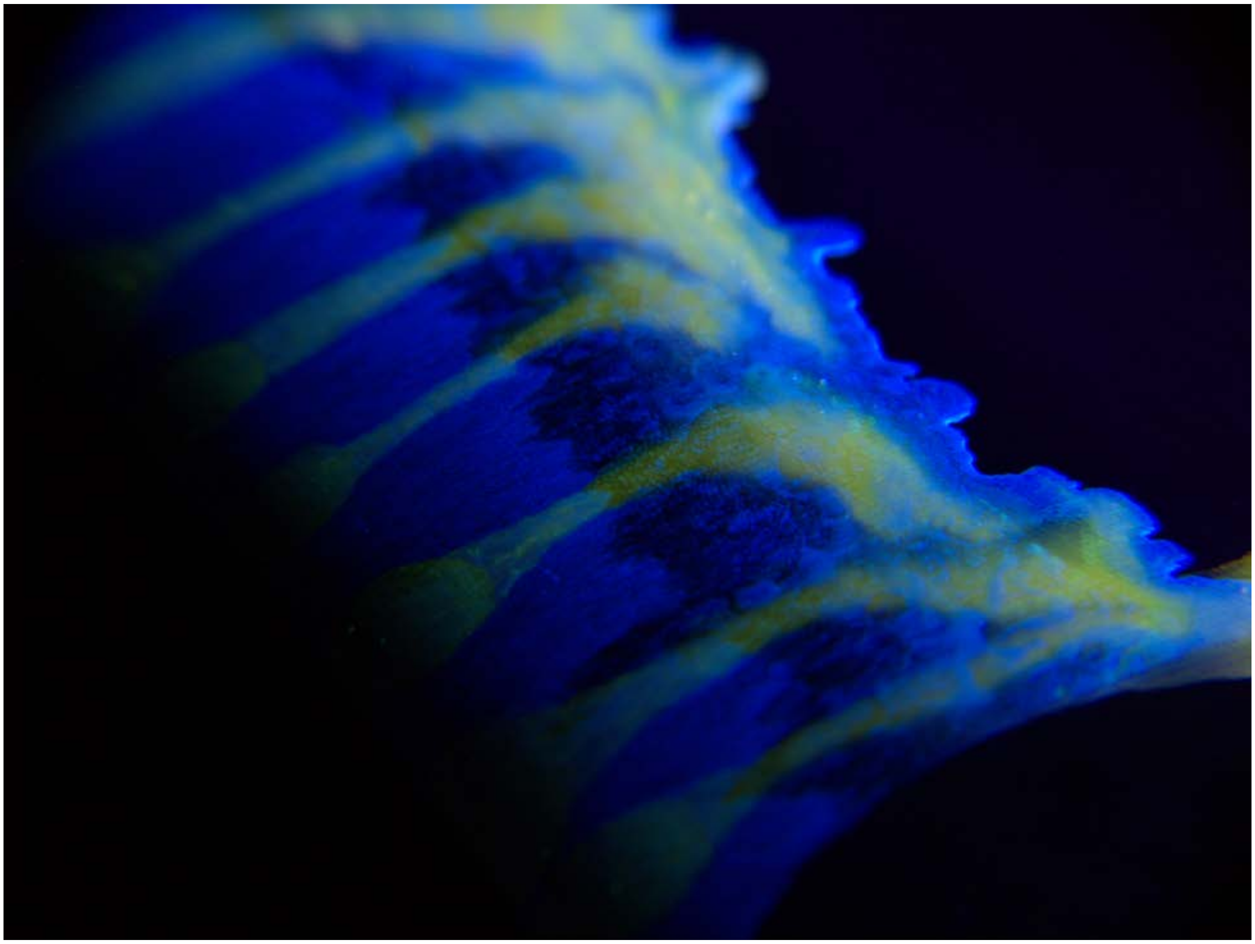

Figure 2. Original Image (Unedited)

The fluid spreads out across the width of the airfoil as it progressed from the leading towards the trailing edge. The spread is due in part to the flow of air over the airfoil. When the fluid was applied to the airfoil it was raised above the surface by a considerable amount. The more viscous fluids stay “bubbled” up until the wind tunnel is engaged. The speed of the incoming air flattens the fluid, spreading it out significantly as it moves forward. Some spread is also due to the uneven texture of the airfoil. In some parts of the image the almost waffle-pattern style is visible on the surface.

The following is a calculation of the Reynolds number for the airfoil with respect to the air flowing over it. The Reynolds number is a non-dimensional value relating the inertial forces to the viscous forces on a body. [1]

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$$R = \frac{Vc}{v} = \frac{\left(22\frac{m}{s}\right) * (0.07\ m)}{1.460 * 10^{-5} m^2/s} = 1.05\ e^5$$

Where V is the velocity of the airfoil with respect to the air, c is the chord length of the airfoil, and v is the kinematic viscosity of the fluid. The simple estimated calulation gives us a large value for the Reynolds number. A large R value tells us that the inertial forces outweigh the viscous forces, giving us a turbulent wake around the airfoil. It makes sense in the image to see inconsistent and seemingly random flow dissipation because the airflow becomes turbulent quickly over the airfoil.

In this image we also should consider the phenomenon of forced wetting. The airfoil surface is dynamically wetted by the liquid coating, and the front is illustrated by the fluorescent line in the image. This phenomenon is not well explained at this point, and the resultant front is dependent on many varying factors. [2]

Though the fluid design on the airfoil was created in the wind tunnel, the image was not taken there. The black light was placed above the wind tunnel while it was on, but the light was not as extreme as we wished. We moved the airfoil into a room in which we had complete lighting control, turned off all external lights, and lit the airfoil using the black light. The airfoil was placed on top of a piece of black poster board to reduce glare from the counter.

The image I chose was actually photographed by Jacob Varhus using his Canon PowerShot G9 camera. Images were taken on March 4^{th}. The following are the details of the unedited image:

Dimensions (Pixels)	4000x3000
Flash	Not Used
Lens	7-44 mm
Focal Length	9.86 mm
F Number	f/3.2
Exposure Time	1/30 s
Aperture	3.34
ISO	100

he edited image was only changed slightly (see **Figure 3**). The contrast was increased and the curves were changed, both only a little bit, as evidenced by the images.

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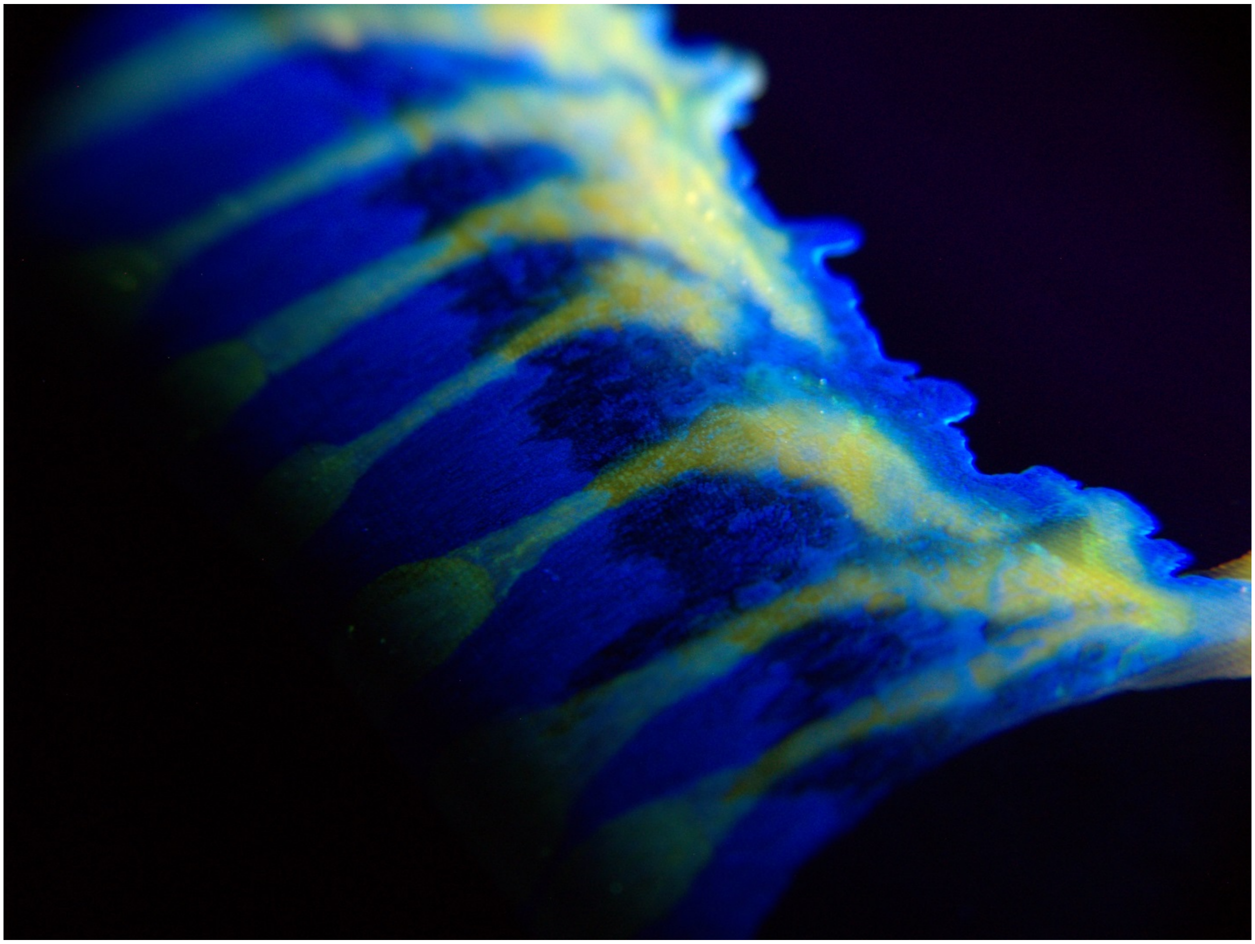

Figure 3. Final Image (Edited)

I really like the layering in the fluids. I think having two layers and using two different fluids illustrates how different the flows can be.The fluoerscent dyes illustrate the smaller details in the fluid flow, even down to the texture details on the airfoil. If I repeated the experiment I would try varying the angle of attach more to see if the fluids would pass the 3 way wetting line illustrated in these images. I would also try photographing from different angles.

References:

[1] Blake, T. D. "The Physics of Moving Wetting Lines." (n.d.): n. pag. Web. 18 Mar. 2013.

[2] "Reynolds Number." *Wikipedia*. Wikimedia Foundation, 18 Mar. 2013. Web. 19 Mar. 2013.