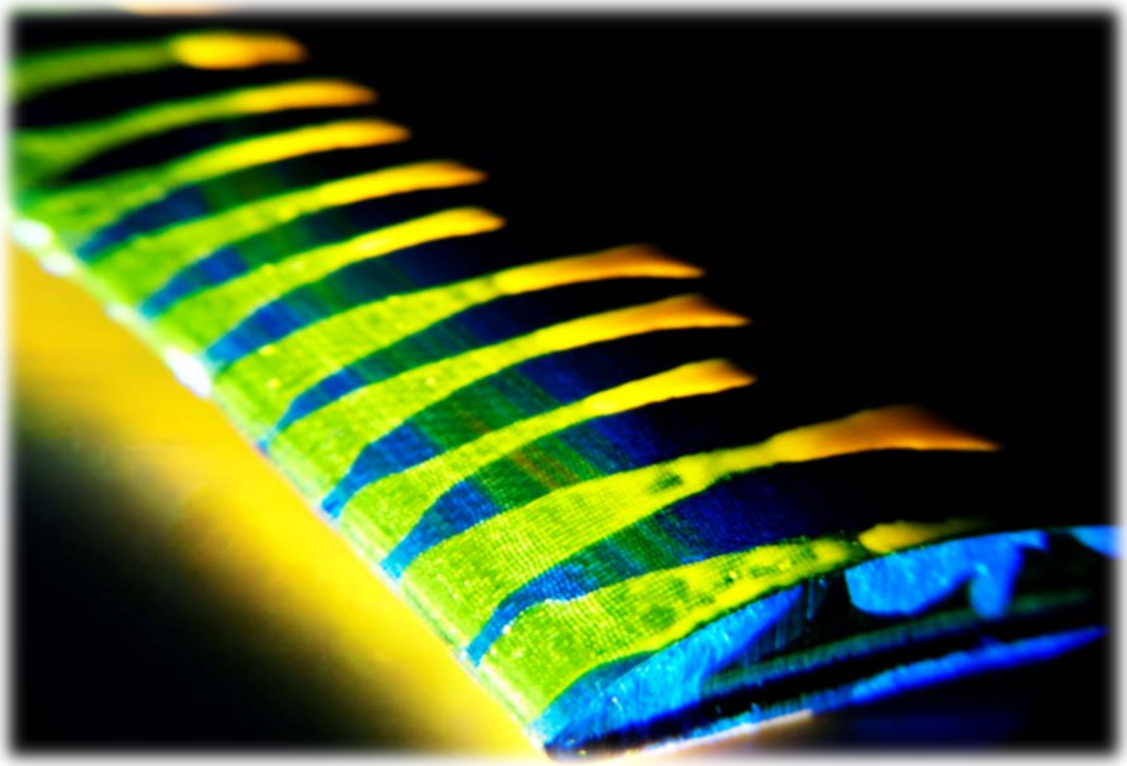
First Team Assignment



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MCEN 4151: Flow Visualization
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This report outlines the use of oil surface imaging to investigate the local airflow behavior on a small airfoil in a low-speed wind tunnel. A florescent dye was added to the oil and images were captured under a black-light. Air flowing over the airfoil caused the oil to move in the direction of the local airflow. Analysis of the oil's movement reviled information about the local airflow.

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I. Introduction

The purpose of this assignment was to satisfy the requirements for the first group project of Flow Visualization at the University of Colorado. Surface flow can often be very difficult to model and often needs to be observed in a wind tunnel environment. A widely used method for doing so is oil surface flow imaging. Oil surface flow imaging involves the application of a thin film of colored oil on the surface of an object and placing it in a wind tunnel. The oil is then disbursed and follows the streamlines allowing the fluid's motion to be seen. Although often very qualitative, methods have been developed to perform measurements on the oil in order to gather qualitative results. This image was created using an oil surface flow technique in a low speed wind tunnel.

II. Experimental Setup

The experiment used an aluminum, finite wing, airfoil attached to a sting balance in a 12 in x 12 in wind tunnel in the Integrated Teaching and Learning Laboratory (ITLL) at the University of Colorado. Basic parameters of the airfoil are summarized in Table 1.

Table 1: Airfoil Parameters

Airfoil	Selig - S4243
Chord	2.5 in
Span	10 in
Aspect Ratio	4
Angle of Attack	-3.5 deg

The wind tunnel was prepped by placing flat black foam board along its windows to limit the amount of light entering the tunnel. A black-light was placed over the top window, and one of the side windows was left un-obstructed to allow for the taking of pictures. The airfoil was affixed to the sting balance.

The airfoil was coated in blue laundry detergent and the tunnel was run at about 21 m/s until the detergent quit moving. Small, approximately 1/8 in diameter, dots of oil were then placed on the leading edge of the airfoil. The airfoil was maneuvered to slightly negative angle of attack before running the wind tunnel up to a velocity of 21.5 m/s. Once the wind tunnel reached its velocity the oil began to travel along the surface of the airfoil in the direction of local streamlines.

III. Description of Flow Physics

A. Observations

It was observed that the flow pushed the oil straight back along the chord of the airfoil until it reached a point a little past half chord where the oil pooled. After observing this for every trial it was concluded that this point corresponded to the separation point where the flow transitioned from laminar to turbulent. When the flow separated from the surface of the airfoil it no longer moved the oil along the surface. The location of the separation bubble seemed to change slightly with angle of attack.

In addition to the separation bubble it was noticed that the oil "streamline" nearest to the tip of the airfoil angled toward the edge of the airfoil. After some discussion it was decided this was due to the formation of wingtip vortices. The airfoil was observed to be at a negative angle of attack, which was reinforced by the negative normal force recorded by the sting balance. The exact angle is unknown due to imperfections in the airfoil's design, however it is assumed to be between -2 and -5 degrees. This angle of attack explains why the streamlines tended toward the wingtip on the top surface of the airfoil. Since the airfoil did not span the entire test section wingtip vortices were likely present.

B. Reynolds Number

The Reynolds number was easily calculated using Equation 1 using 15.68E-6 m^2/s as the kinematic velocity, 21.5 m/s for the free stream velocity, and 0.0635 m for the chord length.

$$Re = \frac{VL}{\nu} = 87069.5$$

Equation 1: Reynolds Number

The calculated Reynolds number of 87069.5 is very reasonable considering the small airfoil in a relatively slow free stream. This low Reynolds number also explains the early transition from laminar to turbulent flow which caused oil to pool on the airfoil and not travel to the trailing edge.

IV. Photographic Technique

C. Image Capture

A Cannon PowerShot G9 digital camera with a macro lens adapter was used to capture the image. Various shutter speeds, exposures, and ISO settings were experimented with in order to capture the image. Creating photographs in the low light, blacklight, conditions proved difficult. Originally photographs were taken using high ISO settings and high F-stop values in order to maximize depth of field. However these photographs were grainy so the ISO was lowered to 100. The final image was captured using a shutter speed of 0.8 sec, F-stop of f/4.0, ISO of 100, and focal length of 7.4 mm. At these slow shutter speeds a clear image was difficult to capture without a tripod. Fortunately the stationary fluid made this process less difficult. The macro lens allowed the images to be captured with the lens a mere 2 inches from the airfoil.

D. Post Processing

After capturing the image it was adjusted using Adobe Photoshop. The most significant alteration was the adjustment of contrast. Overall contrast was adjusted using a manual S-curve to better highlight the lights and darks in the image. After contrast adjustments were completed the image was cropped to remove extraneous background. The "Spot Healing Tool" was used to carefully remove miscellaneous spots on the airfoil leftover from previous trials. Extreme care was used to avoid adjusting the appearance of the fluid and only remove the blemishes. Figure 1 and Figure 2 show the image before and after editing in Photoshop respectively.

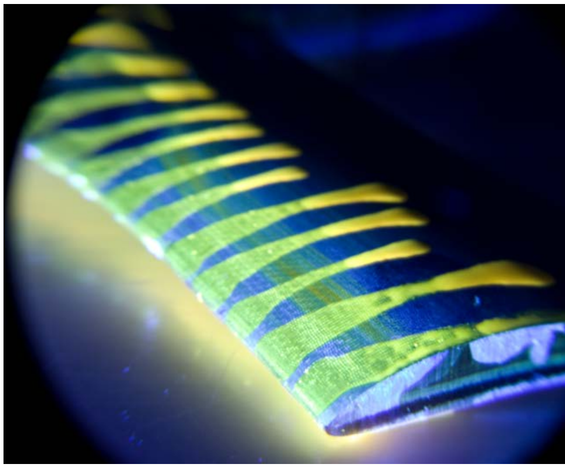

Figure 1: Before Editing

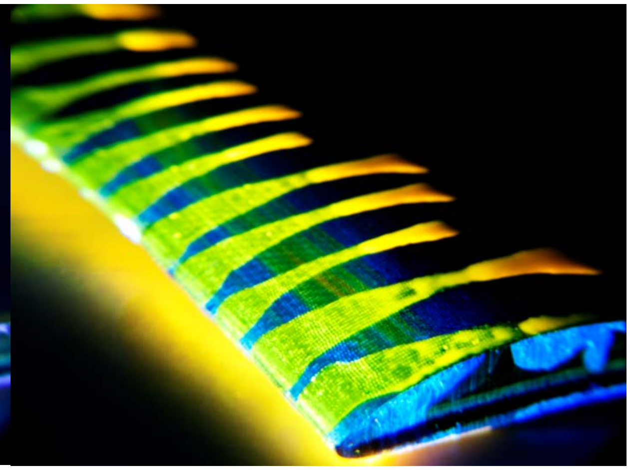

Figure 2: After Editing

The original image was 4000x3000 pixels in dimension. After editing the final image size was 3620x2480 pixels. As can be seen, very little image was cropped.

V. Conclusion

Although the results from this experiment were not as expected, the image effectively portrays the flow's behavior along the airfoil. It was disappointing the flow lines did not follow the entire airfoil, but the fact that they did not clearly illustrates the location of the separation bubble. Further perfection of this method could field some great results.

VI. References

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VII. Acknowledgements

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