MODEL AIRFOIL ANALYSIS

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Abstract:

The purpose of this project was to construct a model airfoil and run wind tunnel tests to obtain data about this specific wind tunnel. The wind tunnel reports measurements of wind speed and lift forces generated by the airfoil. Using this data, it was observed that the lift forces produced by the airfoil increase as the angle of attack is increased. Additionally, a Reynold's number and lift coefficient can be calculated for each wind speed and that data can be compared to the theoretical data provided in class.

Results:

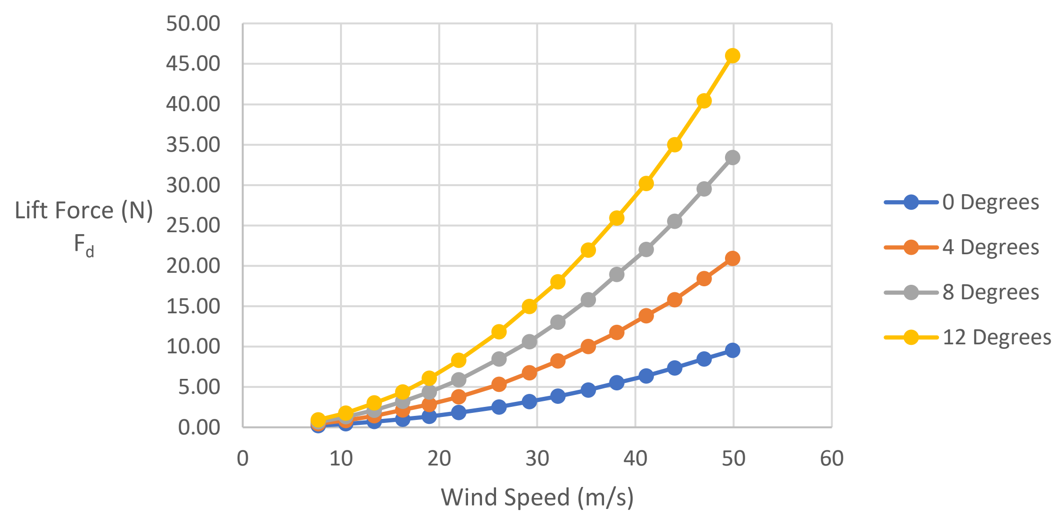

Figure 1. Lift Force vs. Wind Speed for various angles of attack.

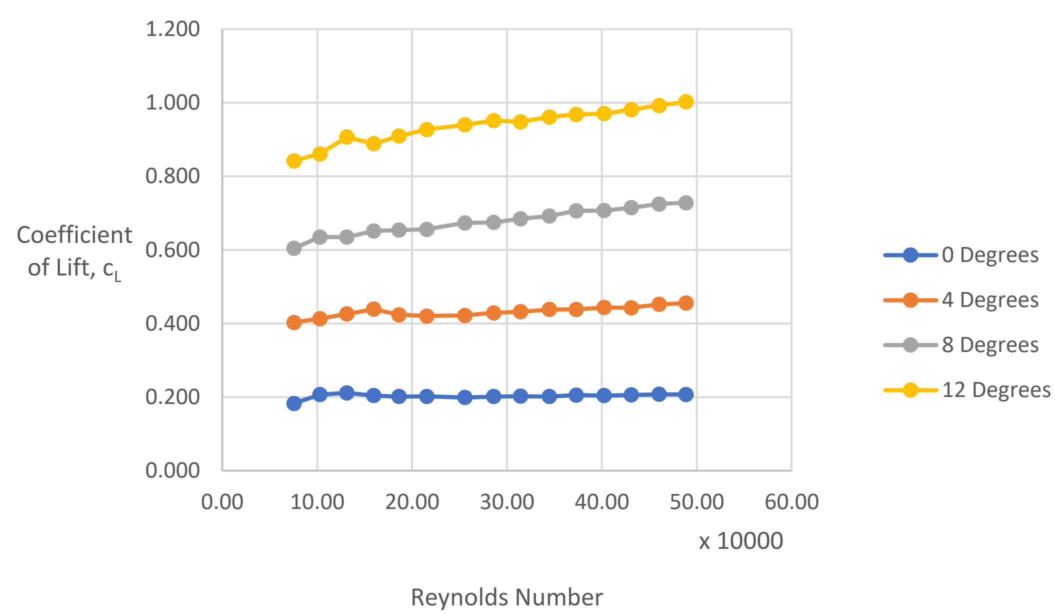

Figure 2. Coefficient of Lift vs. Reynolds Number for different angles of attack.

Methods:

A “general aviation” airfoil design was obtained from a database provided by the University of Illinois. That design was imported into SolidWorks and scaled up to 14% of the actual airfoil size. The 3D printed model was attached to the sting of a wind tunnel that records lift and drag measurements shown in **Figure 3**. The foil was initially set at a 0-degree angle of attack and exposed to various wind speeds and the lift forces generated were recorded into a Microsoft Excel document. The airfoil was then tilted to a 4-degree angle of attack and lift forces were recorded at the same wind speeds from the 0-degree angle of attack. This process was repeated for an 8-degree and 12-degree angle of attack. **Figure 1** shows the Lift Force vs. Wind Speed for the four different angles of attack.

Using the wind speeds provided by the wind tunnel and the airfoil’s chord length, the Reynold’s number was calculated for each wind speed following (**Eq.1**). Then using (**Eq.2**), the lift coefficient was calculated based on the lift force, wind speed, and airfoil dimensions. A plot of Reynold’s Number vs. Lift Coefficient is generated and compared to the one from the Fluid Mechanics textbook. This plot is shown above in **Figure 2**.

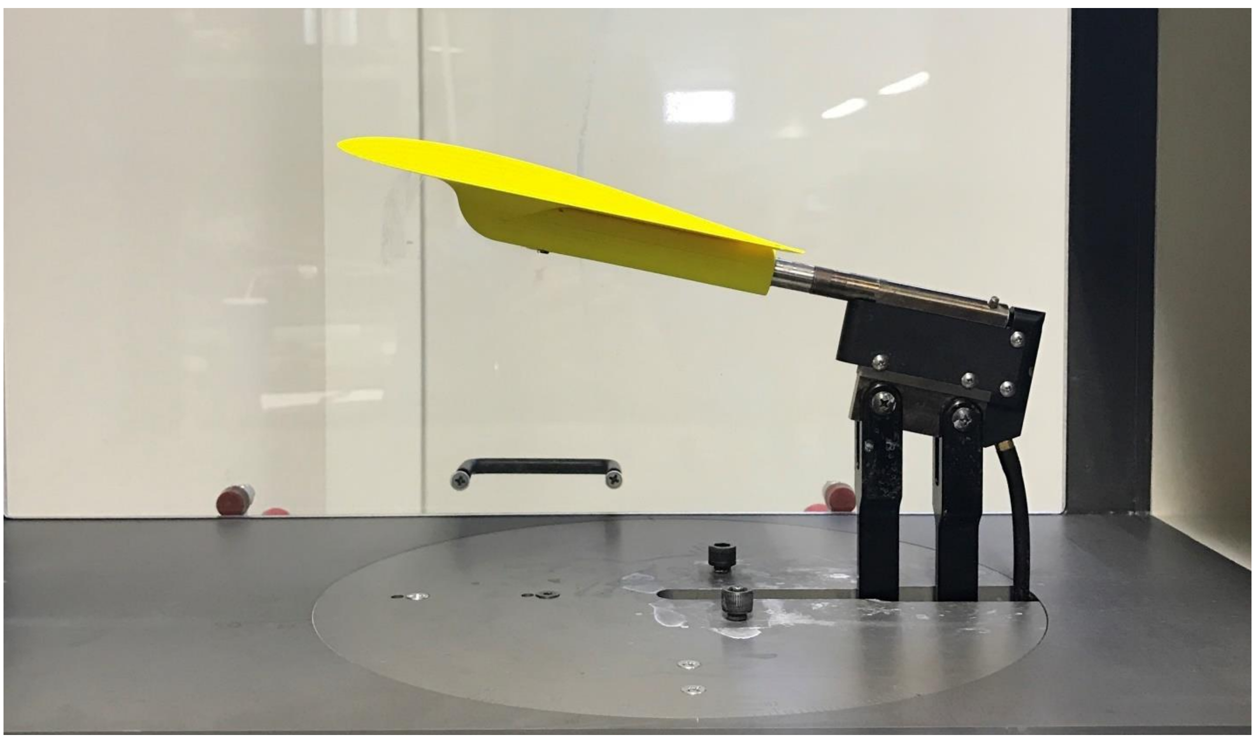

Figure 3. Airfoil mounted on sting with an angle of attack of 12 degrees.

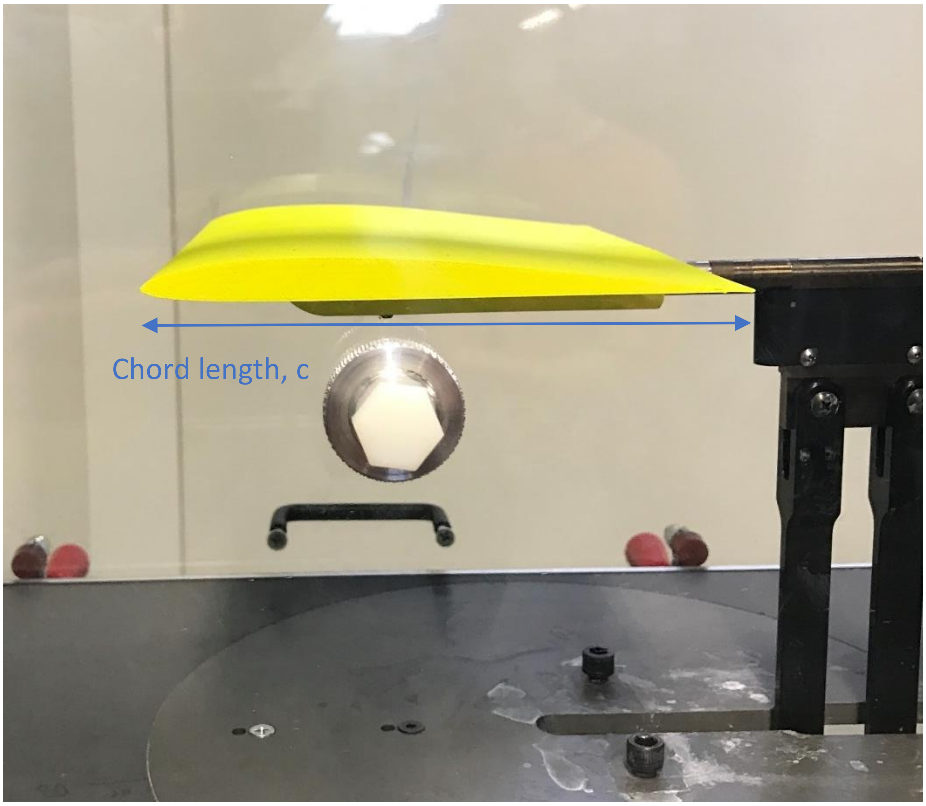

Figure 4. Airfoil mounted on sting with an angle of attack of 0 degrees.

$$Re = \frac{\rho V c}{\mu} \qquad \textbf{Eq. 1}$$

$$C_L = \frac{F_L}{\frac{1}{2}\rho V^2 A} \qquad \textbf{Eq. 2}$$

$Where\ \rho\ is\ density, V\ is\ air\ velocity, c\ is\ chord\ length\ (as\ shown\ in\ \boldsymbol{Figure\ 4}), \mu\ is\ dynamic\ viscosity, C_L\ is\ coefficient\ of\ lift, F_L\ is\ lift\ force, and\ A\ is\ wing\ area.$

Conclusion:

Based on the data collected, a consistent increase in lift force was observed based on our wind velocity. Similarly, when the angle of attack was increased, the lift forces increased, as anticipated. This can be seen in **Figure 1**. This data is consistent with what NASA's Glenn Research Center has concluded on the topic [1]. The coefficient of lift was plotted against the Reynolds number, and produced a very flat graph. In other words, our coefficient of lift was relatively constant for any given angle of attack. This is mostly because the Reynolds numbers were large for any air speed or angle of attack. If the collected data was imposed on the Fluids textbook data, the data would be off the graph due to the large Reynolds numbers [2].

Dimensional analysis was not utilized to compare the model wing with a real plane. This is because when scaling a plane to 14% of its size, the model air speeds required to create a meaningful representation are unreasonable. Similarly, specs like take off speed and cruising speed cannot be extrapolated from our model because those quantities are a function of the aircraft's weight. As demonstrated in the homework, a water tunnel would be better suited for this situation.

Bibliography

[1]

NASA Glenn Research Center. (n.d.). *Inclination Effects on Lift*. Retrieved from NASA Website: https://www.grc.nasa.gov/www/k-12/airplane/incline.html

[2] Young, D., & Munson, B. (2011). *A Brief Introduction to Fluid Mechanics.* USA: Wiley.