The Lift and Drag on a NACA 0012 Airfoil

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# Abstract

Drag and lift are natural phenomenon that are studied to enhance our knowledge of flight. The goal of this research is to compare the measured drag and lift of a NACA 0012 airfoil within a wind tunnel with the measured sum of the integrated pressure distribution on the airfoil and estimated skin friction and induced drag. The measured drag and lift were done separately on a NACO 0012 3D printed airfoil in a wind tunnel at a constant speed, and the calculated drags were a combination of pressure data along the airfoil using manometers and skin and induced drag equations. Upon completion of the analysis, a clear relation between the methods used to predict the drag of the airfoil based on its conditions and angle of attach and the measured, actual values of the airfoil were clear, but with error. The maximum lift was seen at an angle of attack of 15 degrees, and a minimum drag was measured at an angle of attack of 0 degrees.

# Introduction

The lift and drag lab was meant to experiment with the comparison between lift and drag on a symmetrical, 3D printed airfoil within a controlled wind tunnel. The airfoil was equipped with a force balance that allowed the precise measurement of total drag and lift on the airfoil given its angle of attack to incoming airflow. It also had 20 pressure taps attached, both on the bottom and top of the airfoil to give us real-time manometer readings that could be converted to pressure to provide an analysis on the calculated drag to the real, measured drag. This was accomplished by integrating the pressure readings from the manometer to lift and drag forces, as well as use modern equations for skin drag and induced drag, all adding up to total calculated drag that could then be compared with the total measured drag from the force balance. The force balance was used to measure the drag and lift of the airfoil with angles of attack ranging from -9° to 21° in exactly 3° increments. The following equations were utilized to explicitly calculate the coefficients of lift and drag (, respectively) on the airfoil with the results of the airfoil providing total lift and drag for each angle of attack.

The following report will follow with the experimental methods used during the test, following the final analysis and results. Once the results have been clearly shown, a final conclusion was made towards the accuracy and final relations on the lift and drag induced on an airfoil when in a fluid flow field. Relevant data is also supplied within the appendix detailing specific and significant results on the findings within the lab.

# Experimental Methods

The NACA 0012 airfoil was attached within the test section of the UNH Mechanical Engineering wind tunnel. A force balance was equipped onto the attachment to get real-time lift and drag readings on the foil while the wind tunnel was on. 10 pressure taps were attached to the top of the airfoil in parallel with the fluid flow so actual pressure measurements could be obtained along the length of the foil. The same was done to the bottom so overall drag and lift forces could be calculated. The specific locations of the pressure taps were known and is attached at the end of this report in the appendix. When the wind tunnel was activated, it was set at a constant speed that could be calculated by using the following equation with all known variables on the right by having logically places manometers readings for the stagnation and static pressure on the airfoil providing the change in pressure along the airfoil,

The density of air,, was calculated using the classic ideal gas law with measured values of temperature and pressure within the room during the test, yielding . By having collected pressure measurements for three different angle of attacks, 0, 9, and 18°, 3 different calculated velocities could be calculated. The mean of these values were taken as the velocity of the flow, but the uncertainty of the calculation returns a more accurate calculation of 25.8 ± 0.2 m/s.

The manometer readings were then converted to pressure readings with the simple relation of fluid displacement vertically to the difference in pressure at the two ends:

Where these measurements were read in at angles of attack of 0, 9 and 18°. The force balance that was used to obtain measurements of lift and drag utilized a load cell at different configurations: oriented on the top of the balance to measure lift, and oriented on the side to measure drag force. The angle of attack of zero was found by tilting the balance to a degree so to zero the lift as the NACA 0012 is a symmetric airfoil. The force balance could then rotate and reach angles of 21° to study the effect on how drag and lift increase with these steep angles against the fluid flow.

The exact locations in the x-axis of the airfoil were given and are attached within the appendix, while the y component of its location is given by the equation



Where t is the maximum thickness of the airfoil as a fraction of the chord, and c is the chord length. With any location measurement, there is error ingrained into the number supplied, so exact manometer locations could vary with an uncertainity of at least ± 0.2 mm. Once the complete positions of the manometer reading were calculated, an analysis could be completed displaying the total force in the x-direction (drag) and the y-direction (lift). The following equations could be derived using the top and bottom geometry of the airfoil to calculate these forces:

*Top of the Airfoil Calculations:*

*Bottom of the Airfoil Calculations:*

Where is given by the equation below and takes in the airfoil geometry at each specific manometer location while integrating across the surface:

# Results and Discussion

