ME 4005 Lab Report 6 – Airfoil Analysis/Aerodynamics

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Introduction

Lab six covers the obtaining of results from and comparing trends between results and expected values for a student's airfoil. In previous Pre-Labs the student will have created a design for their airfoil and performed theoretical pressure sensor data analysis. The 2 Pre-Labs will be used in this lab for data reading, calibration, and providing of the airfoil design. This lab requires knowledge of how to work the MSP432GUI, how to manipulate various fluid dynamics equations provided below and/or in the manual, and general knowledge of what pressure readings and pressure differential readings mean in the context of airfoils as well as in a real-world application context. The equations below were used in creating the data tables displayed in the Results and Discussion section of this report. [1]

$$p = \rho R T \tag{1}$$

$$U = \sqrt{\frac{2(p_3 - p_4)}{\rho}} \tag{2}$$

$$D = \int p \cos\theta \; dA \tag{3}$$

$$L = -\int p \sin\theta \; dA \tag{4}$$

$$D = p_0 \cos\theta_0 A_0 + \sum_{i=1}^{3} p_{s,i} \cos\theta_{s,i} A_{s,i} + \sum_{i=1}^{3} p_{p,i} \cos\theta_{p,i} A_{p,i} \tag{5}$$

$$L = -p_0 \sin\theta_0 A_0 - \sum_{i=1}^{3} p_{s,i} \sin\theta_{s,i} A_{s,i} + \sum_{i=1}^{3} p_{p,i} \sin\theta_{p,i} A_{p,i} \tag{6}$$

$$C_D = \frac{D}{\frac{1}{2}\rho U^2 A} \tag{7}$$

$$C_L = \frac{L}{\frac{1}{2}\rho U^2 A} \tag{8}$$

Methods

In conducting lab two the student is tasked to collect data on the pressure at various points on an airfoil they designed in a previous Pre-Lab. The results and discussion for this report will be done on the airfoil depicted below in Figure 1 and Figure 2

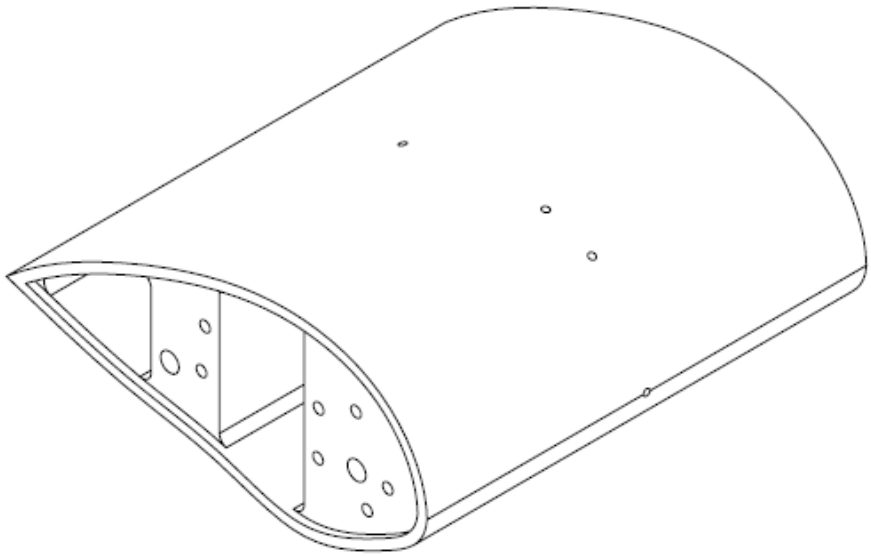


Figure 1: Airfoil CAD Picture

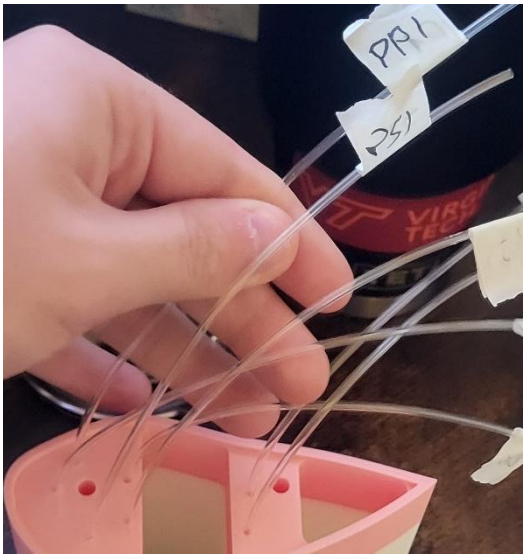


Figure 2: Airfoil Tap Labels Picture

As can be seen in Figure 2 the pressure tap tubes have been labeled as P0/Center, PP1 PS1, PP2, PS2, PP3, and PS3. To collect the required data for this lab the student will first collect calibration data for the sensor via connecting to a manometer and applying various pressures while collecting the resultant voltage data from the pressure sensor. Next the student will use the provided pitot tube to collect the freestream velocity data for their wind tunnel setup. Once the calibration data has been collected the student will mount their airfoil within the wind tunnel taking care not to bend the pressure tap tubes when inserting the airfoil into the tunnel. The student will then collect the pressure relative to room pressure data for each point on the airfoil at each angle of attack. Given that there are 3 angles of attack this will result in 21 experimental data files as well as 6 calibration files. After data is collected the student will use the equations provided in the introduction to find useful coefficients for the airfoil and find the baseline value (or reference) for their curves. Specifically, equations 1 & 2 are used for freestream velocity

calculations, equations 4-6 for experimental and theoretical drag and lift, and equations 7 & 8 for the coefficients of drag and lift respectively.[1]

Results and Discussion

The plots and table below show the data collected on the airfoil.

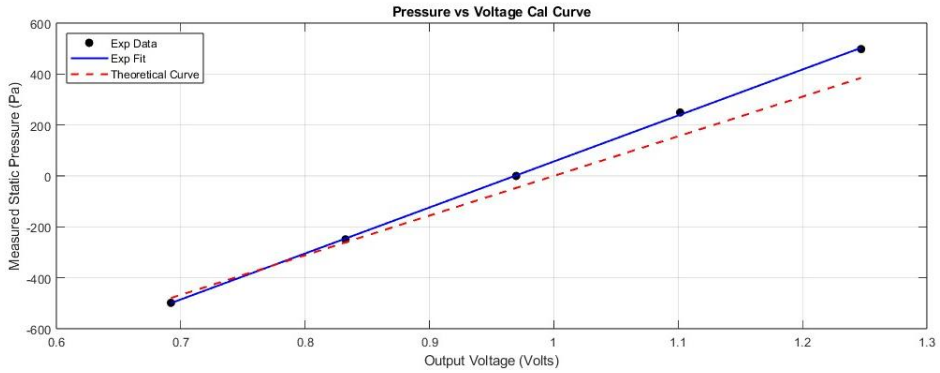


Figure 3: Calibration Curve/Pressure vs Voltage using Manometer Pressure Plot

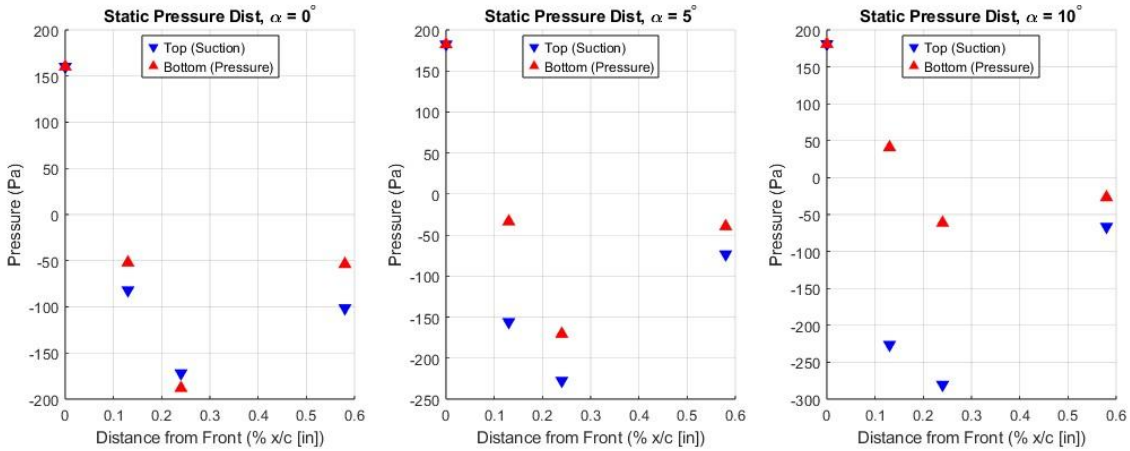


Figure 4: Pressure At Each Pressure Tap Location Plots

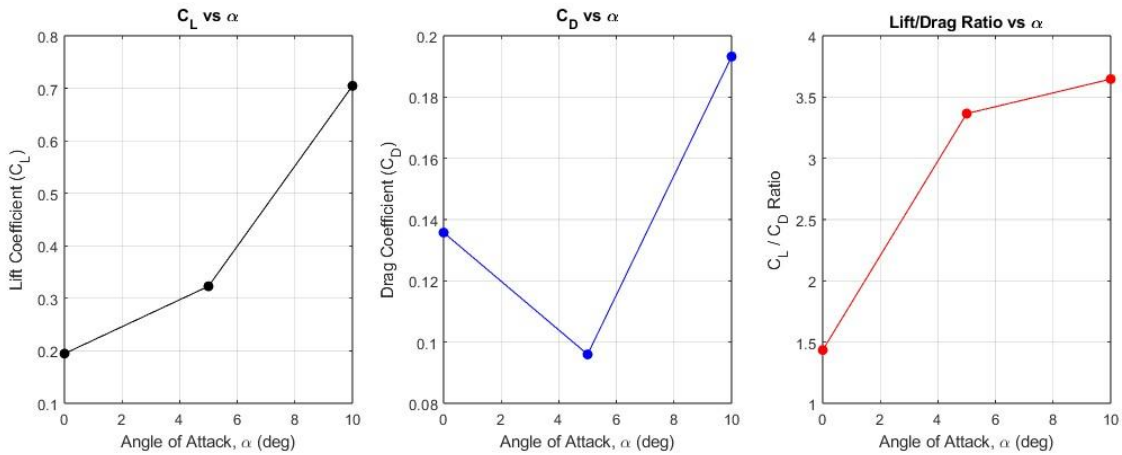


Figure 5: Coefs vs Angle of Attack Plots

Table 1: Coefficient Values for Varying Alpha

Alpha (deg)	C_D	C_L	C_L/C_D
0	0.1358	0.1948	1.4351
5	0.0960	0.3230	3.3653
10	0.1932	0.7047	3.6469

As can be seen in the above plots and table the pressure sensor is well within the expected range of values given the theoretical approximation curve (shown in Figure 3). This indicates that the equipment was likely performing well and any small deviation in the experimental and theoretical at this point is likely due to error introduced via requiring the student to hold exact pressure values for calibration with just a ballon style pressure pump.

Comparing the results from my modified RAF-34 profile to online available charts of expected coefficients of lift and drag vs changes in angle of attack there is a large difference between my value of drag versus expected. This is best explained by the significant difference between the thickness of my airfoil and a standard RAF-34 profile. This high thickness is creating flow separation which renders the drag and lift coefficient data collected inaccurate given that it violates the assumption of inviscid flow that the equations used operate on. My model can generally be seen to follow the expectations of the online resources available for the RAF-34 as it seems to have a decrease in Cd near an angle of attack of 5 degrees which agrees with online resources showing an optimum angle of attack of around 6-6.5 degrees for flows of Reynolds number 100,000 (approximately what was used in lab). Overall my profile seems to have lower values of CL and higher values of CD compared to a thinner profile which is expected but the effects of my high thickness are likely causing flow separation which would cause “bad” data values and make accurate comparison not possible.

If I were to repeat this experiment, I would reduce my thickness drastically as the high thickness value likely resulted in the generation of complex turbulent flows that the simplified models of flow used cannot account for. The high thickness also resulted in no good online resources for comparison of my experimental findings to an airfoil tested in a professional lab with the same characteristics. Unfortunately, when constructing the model for the airfoil I misread one of the requirements to make me think that 2 inches was the required minimum for the value of maximum thickness.

References 2 and 3 below were used in finding the barometric pressure reading and for evaluating the airfoil respectively. [2][3]

References

[1] ME 4005 Course Materials. Available: https://canvas.vt.edu/courses/187828

[2] "Historic weather for Blacksburg, Virginia," *timeanddate.com*. [Online]. Available: https://www.timeanddate.com/weather/@4747845/historic.

[3] "RAF 34 (raf34-il)," *Airfoil Tools*. [Online]. Available: http://airfoiltools.com/airfoil/details?airfoil=raf34-il#polars.