Airfoil Lab

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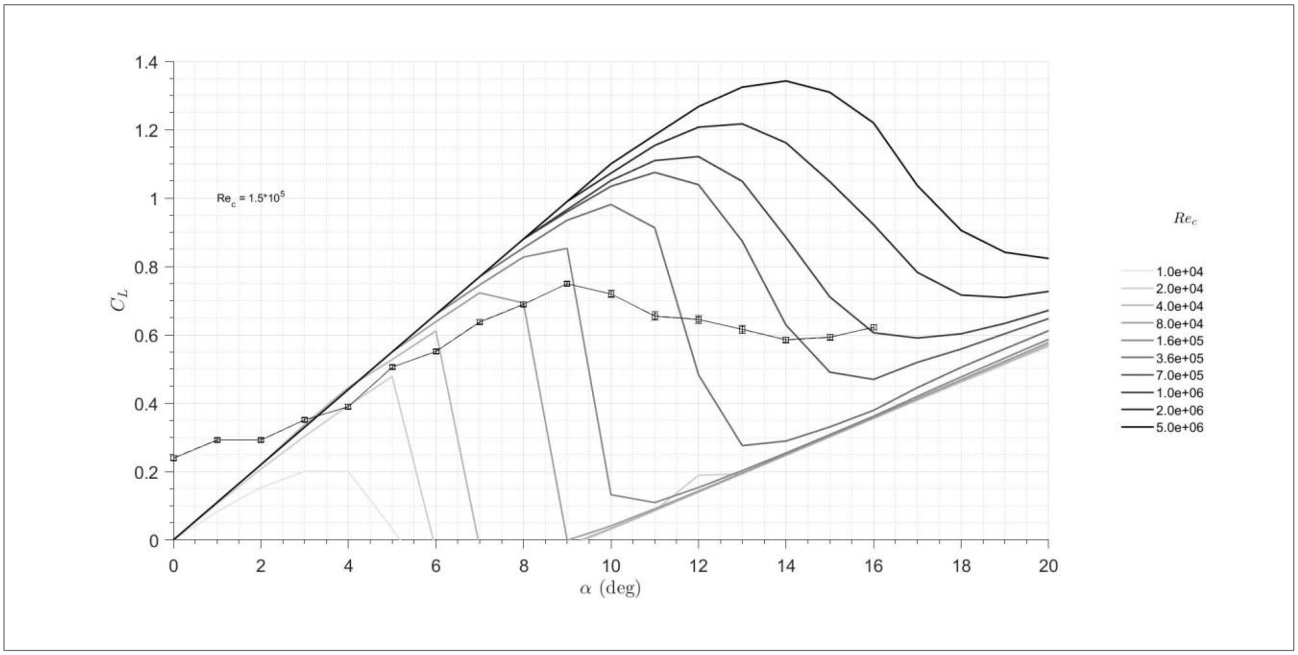


Figure 1a. Coefficient of lift on the y-axis versus angle of attack on the x-axis for the NACA0012 air foil at a chord Reynolds number of $1.5 * 10^5$. The experimental data has been plotted over published results using black square markers. Each marker is accompanied by error bars that represent the uncertainty of the data acquisition to within a 95% confidence interval.

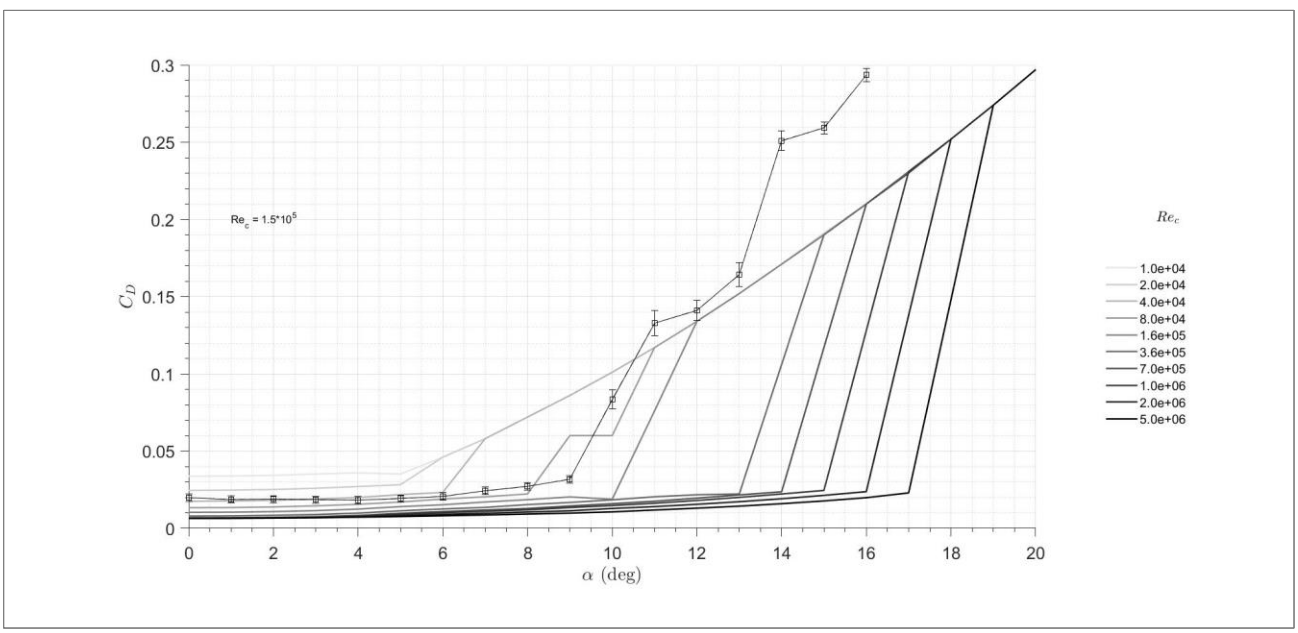


Figure 1b. Coefficient of drag on the y-axis versus angle of attack on the x-axis for the NACA0012 air foil at a chord Reynolds number of $1.5 * 10^5$. The experimental data has been plotted over published results using black square markers. Each marker is accompanied by error bars that represent the uncertainty of the data acquisition to within a 95% confidence interval.

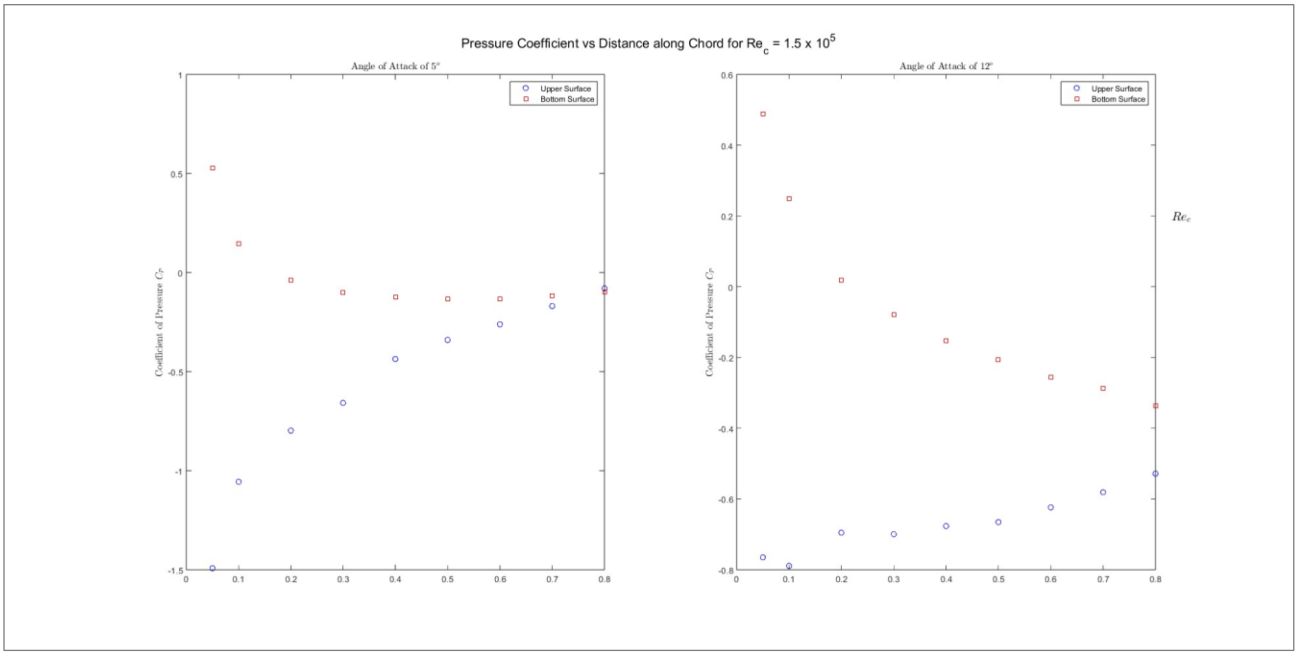


Figure 1c. (Left) Coeffcient of pressure on the y-axis versus distance along the chord on the x-axis for the NACA0012 airfoil at an angle of attack of 5 degrees at the chord Reynolds number of 1.5 * 10^5. The blue markers represent the data measurements on the upper surface while the red markers represent the measurements on the bottom surface. (Right) Coeffcient of pressure on the y-axis versus distance along the chord on the x-axis for the NACA0012 airfoil at an angle of attack of 12 degrees at the chord Reynolds number of 1.5 * 10^5. The blue markers represent the data measurements on the upper surface while the red markers represent the measurements on the bottom surface. The published results for this airfoil show stall occurring at an angle of attack of 10^o while the measured results show stall occurring at an angle of attack around 9^o.

Short-Answer Questions

2a. State the angle of attack at which stall occurs (α_{stall}) for your data. Your response should in the following form (where XX denotes the value from your data): "Based on the present lift and drag measurements at Re_c =XX, stall is observed to occur at an angle of attack of about XX°." Describe how your measured lift and drag coefficients vary with angle of attack. [3–4 sentences]

2a. Based on the present lift and drag measurements at $Re_C = 1.5 *10^5$, stall is observed to occur at an angle of attack of about 9°. Starting from an angle of attack of 0° and working our way up to 9°, the measured lift coefficient slowly increases from about 0.25 to 0.85 and the measured drag coefficient slowly increases from about 0.02 to 0.025. After the angle of attack of 9°, the coefficient of lift starts to decline down to about 0.65 and the drag coefficient drastically increases up to around 0.29 at an angle of attack of 16°.

2b. State the average percent uncertainty in your C_L and C_D measurements to within a 95% confidence interval. Describe how the uncertainty in your experimental measurements varies with angle of attack, if at all. [2–3 sentences]

2b. The average percent uncertainty in the coefficient of lift and drag for this experiment was 0.77% and 0.39% respectively. The uncertainty in the experimental measurements is consistent with the behavior of the coefficient of lift and drag where the uncertainty is smaller before stall and slightly increases after stall.

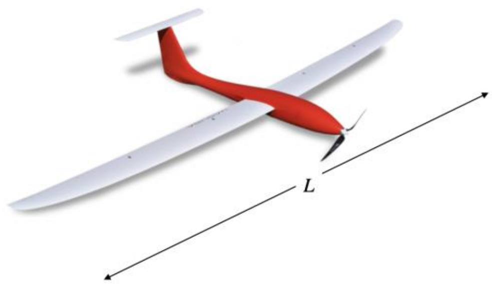
2c. Compare your data to previously published results and examine Re_c trends:

- State 2 ways each that your measured C_D and C_L values disagree with previously published results at a similar Re_c. Be specific in your response. For example, do not simply state that your values are larger than the published data, but provide the actual numeric values, both for your data and the previously published results. [4 sentences]
- Examine the trends in the previously published results, and state 2 ways each that C_D and C_L vary with Re_c. [2–4 sentences]

2c. The first way in which the measured values disagree from the published results at a similar Reynolds number is that the coefficient of lift at zero angle of attack for the published results is zero while the experimental value is 0.24. This is due to the experimental setup where the pivot support is located at the center of mass and not the center of pressure which creates a moment that results in a non-zero lift coefficient for an angle of attack of zero. The second way in which the measured values disagree from the published results at a similar Reynolds number is that the coefficient of drag trends higher and non-linearly after stall as compared to the approximately linear trend after stall for the published results. After stall, at angles of attack of 11, 14, and 16 degrees, the measured drag coefficient is 0.133, 0.251, and 0.294 which show a trend of discrete non-linear jumps while the published results at the same angles of attack are 0.117, 0.171, and 0.210 respectively which shows a rough linearly increasing trend.

As Re_C increases, the max coefficient of lift for the published results increases as well which is also increasing the angle of attack at which stall occurs. As Re_C increases for the drag coefficient, the point at which the drag coefficient has a jump discontinuity and a massive increase in drag increases resulting in a larger angle of attack needed for stall.

2d. Imagine that you are trying to use your experimental results to select the correct size electric motor to power a small Unmanned Aerial Vehicle (UAV) such as the one shown, where the wings are comprised of NACA 0012 airfoils. The total wingspan is $L = 4$ ft. and the chord is $c = 6$ in. Assume that the cross-section of each wing is uniform, i.e., the wings do not taper and the planform area looks rectangular. State the speed V_w at which the UAV would have to be flying in order for your wind tunnel results to be applicable. If the UAV were cruising at V_w, state the maximum mass it could have (to ensure that it would remain flying at this speed). Use an air density and air viscosity consistent with what is typically observed in Salt Lake City at around 23°C. [2–3 sentences with equations]



2d. The speed at which the UAV would have to be flying in order for the wind tunnel results to be applicable was found using similitude by matching Reynolds numbers. The Reynolds number in the experiment was $1.5*10^5$. To calculate the speed of the UAV, we can set this Reynolds number equal to the equation

$$Re_c = \frac{V_w c}{\gamma}$$

After substituiting in $1.5*10^5$ for Re_c, $15.34*10^{-6}$ m^2/s for γ and 0.1524 m for c, we find that V_w is equal to 15.1 m/s.

To find the mass that the UAV could have to ensure it would be flying at the speed V_w, we can utilize the equation

$$F_L = \frac{1}{2}\rho {V_w}^2 A_p = mg$$

After substituiting in 15.1 m/s for V_w, 1.2 kg/m^3 for ρ, 0.279 m^2 for A_p, and 9.81 m/s for g, we find that the mass m of the UAV is 3.89 kg.