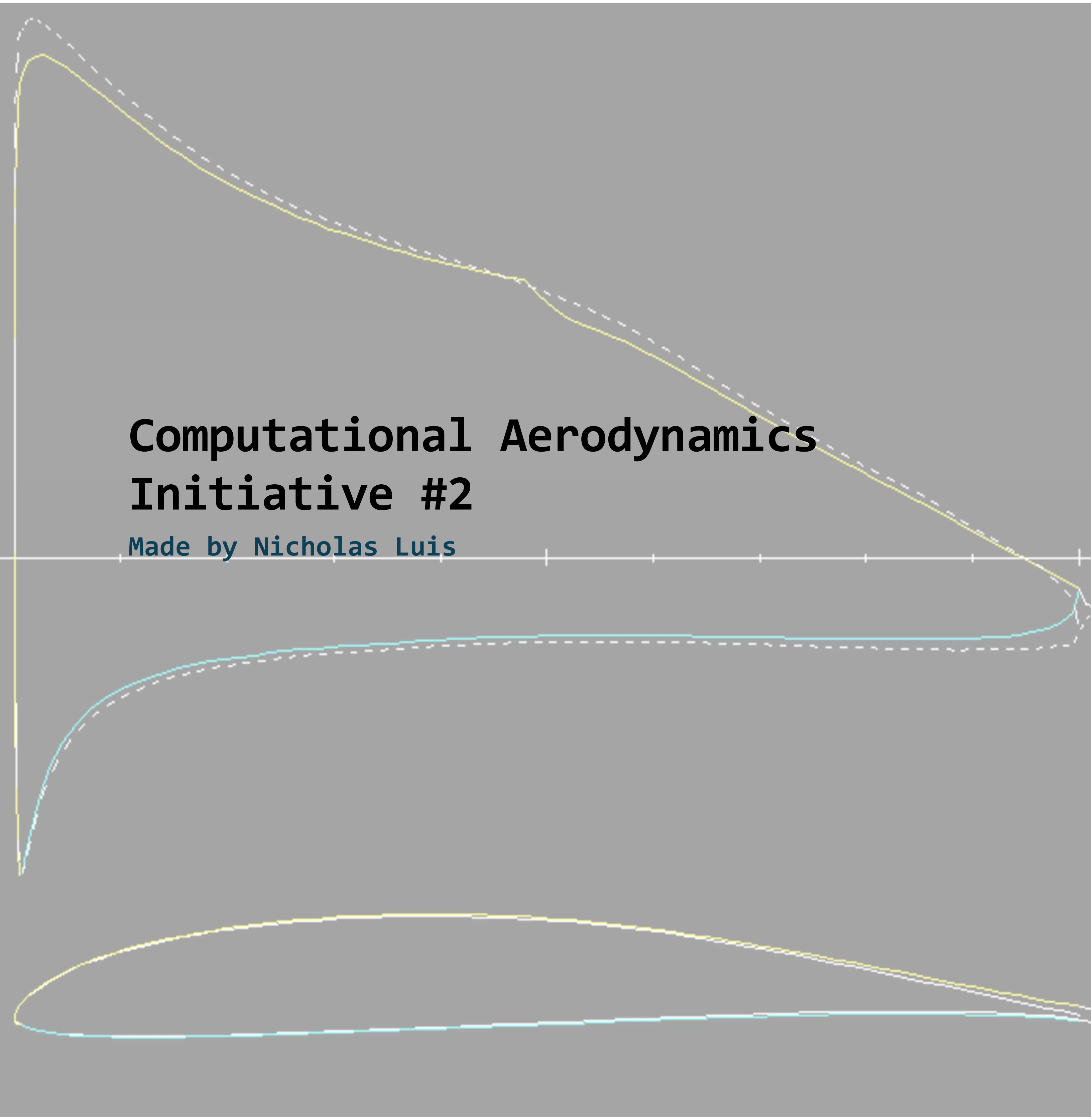
Computational Aerodynamics Initiative #2

Made by Nicholas Luis



The purpose of this project is to compare wind tunnel data collected on airfoil PSU94-097 to data simulated in XFOIL in order to make observations about the trends of the laminar-turbulent boundary layer transition point, lift and drag coefficients, as well as the limitations of computational aerodynamics.

The most important observation was the limitations of the computational method. As seen in Figure 1, the experimental data and the XFOIL data begin to diverge at an angle of attack of around 10 degrees. The drop-off itself is due to flow separation and stall, which indicates that computational methods have difficulty predicting this behavior, especially because this occurs in the turbulent boundary layer regions. Also, comparing the XFOIL data on its own, we see a slight increase in the C_L at high angles of attack as you increase the Reynolds number. This increase in the C_L can also be seen in Figure 2. As for the reasoning behind these trends: A higher Reynolds number is associated with a more turbulent boundary layer, which is good at preventing flow separation due to having more energy. This reduction in flow separation improves lift at high angles of attack.

The differences between the XFOIL data and the experimental data are also noticeable on the C_L vs C_D graph (Figure 2). XFOIL once again overestimates the higher end of the lift coefficient. Comparing the XFOIL data alone, it also looks like increasing the Reynolds number also causes the C_L to rise. However, it doesn't appear that increasing Reynolds number has much effect on the profile drag, C_D.

These limitations of turbulent flow predictions are not seen as much at lower Reynolds number, however, since that is when the flow is mostly laminar. The C_P vs x/c graph at Re = 300,000 (Figure 3) shows how the XFOIL data matches up with the experimental data. Another reason the data lines up well in Figure 3 is because it is still at a low angle of attack. These graphs also display the C_P bumps on the upper surface characteristic of the laminar-turbulent boundary layer transition and how it occurs closer to the leading edge as the angle of attack increases. The overall trends also show a significant upwards shift in the C_P curves on the upper surface, which we know to be true because the C_L increases initially with increasing angles of attack.

In conclusion, there are noticeable differences in the data collected by Dr. Maughmer and his team in 1994. However XFOIL is still useful and accurate, especially at low angles of attack where the data matches up very closely to the experimental data. This is useful information because it informs us where testing is needed and gives a sense of the limitations of XFOIL, or computational aerodynamics in general. It's also worth mentioning that there is also the possibility for error in experiments and data collection, as seen by random values of zero in the C_D data.

PSU94-097 Airfoil Data

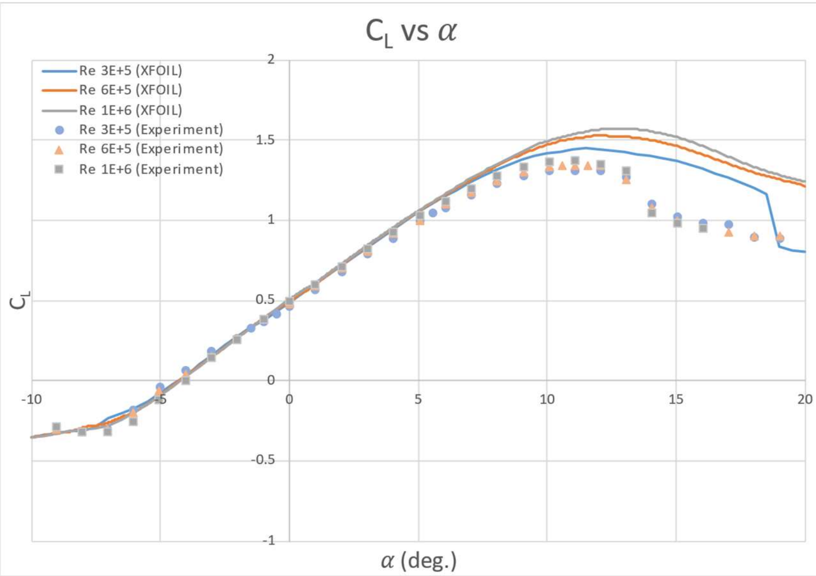


Figure 1

Comparing C_L vs α for varying Re numbers

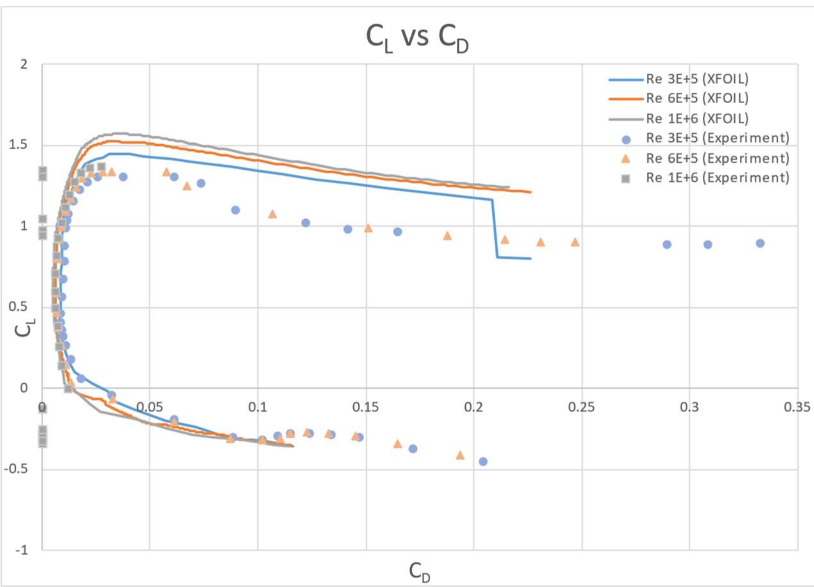


Figure 2

Comparing C_L vs C_D for varying Re numbers

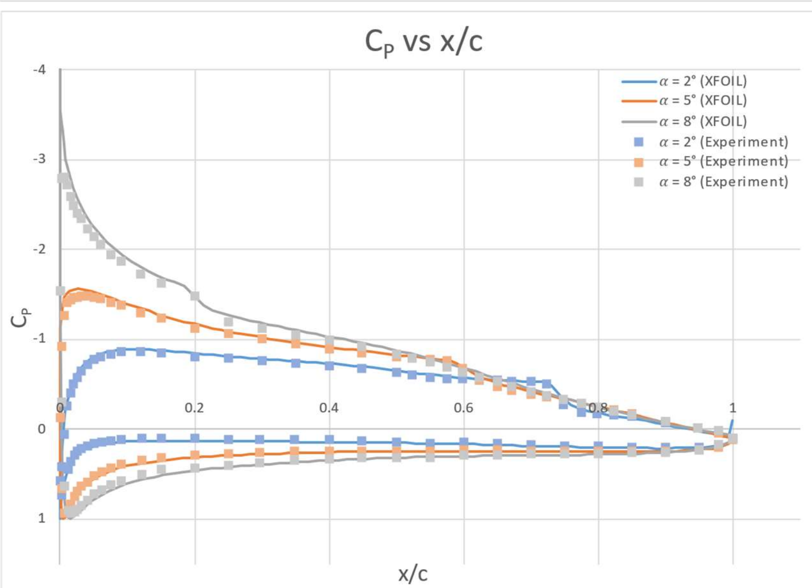


Figure 3

Comparing C_P vs $\frac{x}{c}$ for varying Re numbers & and angles of attack

Works Cited

Maughmer, M. D., Swan, T. S., Willits, S. M., “Design and Testing of a Winglet Airfoil for Low Speed Aircraft,” AIAA Journal of Aircraft, Vol. 39, No. 4, pp. 654-661, 2002