Winglet Effectiveness for Small-Scale Applications Based on Angle of Attack and Winglet Scale

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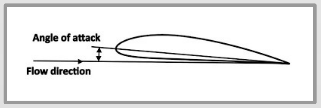
Introduction

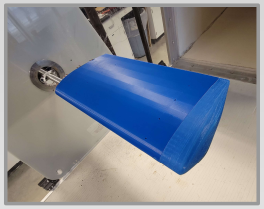
- On large aircraft, winglets are used to improve fuel efficiency
  - This is done by increasing lift while simultaneously reducing lift-induced drag
  - On a large scale, winglets are typically 4% of the aircraft's wingspan
- An airplane's wings can also be fixed at different angles to increase lift
- Due to the Reynold's Number – which is dependent on many variables – large-scale aerodynamic designs cannot simply be scaled down for smaller applications
- This project looks at how a winglet's scale and a wing's angle of attack affect a small-scale airfoil's lift to drag ratio



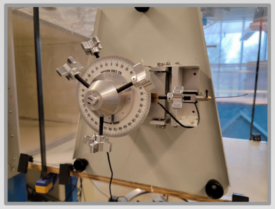
Experimental Process

- 3D modeled a NACA0021 airfoil
  - We chose this model because it has zero lift (N) at 0° AOA.
- 3D modeled 4 custom winglets: normal, small, medium, and large
- Gathered lift, drag, and pressure data for all 4 winglets using the wind tunnel in Kingsbury Hall
- Determined lift and drag coefficients (CL/CD) as well as pressure values using the following equations:

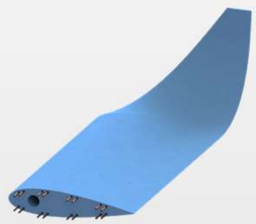
$$C_L = \frac{2F_L}{\rho_{air} A_{wing} V^2} \qquad C_D = \frac{2F_D}{\rho_{air} A_{wing} V^2} \qquad P = \rho_{water}\, g(\Delta h)$$



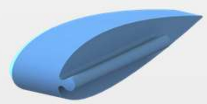
Normal wingtip in wind tunnel



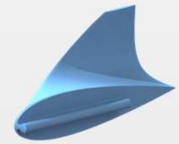
Measurement system for angle of attack and lift/drag force



Wing Assembly



Normal Wingtip

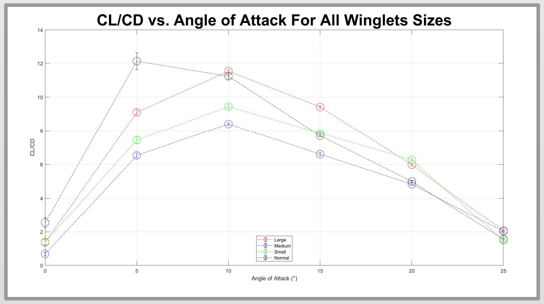


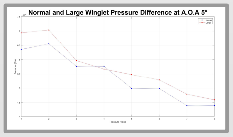
Small Winglet

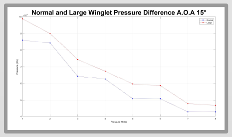
Medium Winglet

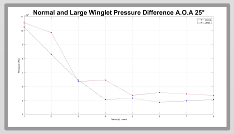
Large Winglet

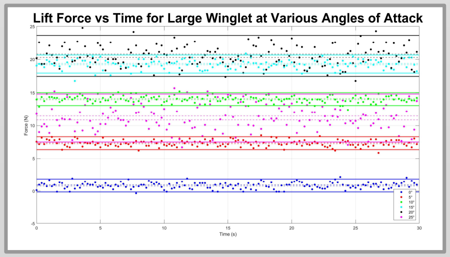
Results

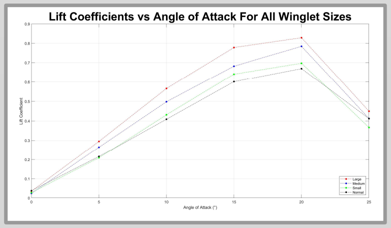


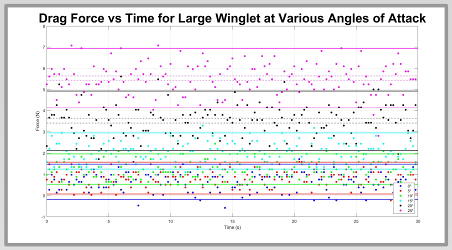


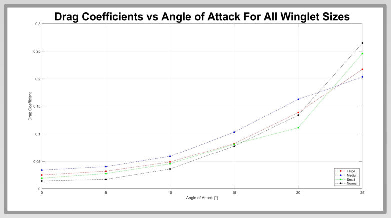












- The area of the normal wingtip was used for all winglet calculations
- For our lift and drag forces, at each angle of attack, we assumed a 95% confidence interval

Summary/Conclusion

- At high angles of attack, the airflow begins to separate, and therefore there are large fluctuations in the lift and drag data
- At lower angles of attack, the normal wingtip has the highest CL/CD ratio and therefore is the most efficient overall
- At all angles of attack, the large winglet has the highest CL and therefore is the most efficient in producing lift
  - The pressure data gathered confirms these results, as the difference between the bottom and top pressure holes along the airfoil is always greater for the larger winglet
- The error bars for CL/CD vs Angle of Attack show the mean standard deviation of the data
- At angles of attack between 10 and 20 degrees, the large winglet has the highest CL/CD ratio and produces the most lift
- Even though the large winglet is roughly 65% of the wing's length, the difference between the lift and drag force it produces is significantly larger than the other winglets
- As a result, it would be optimal to use a large winglet on a wing with a fixed angle of attack between 10 and 20 degrees on a small-scale aircraft such as a drone or UAV

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