ETSD059

Hypothesis and Problem Statement

- Yearly, aircraft emit 918 million tons of CO_2 into the Earth's atmosphere accounting for 10-15% of global transportation emissions
- This project seeks to create novel winglet designs that improve on the efficiency of current wing designs by 1%.
- This would, at a minimum, increase an aircraft's fuel efficiency by 1.5% which, if applied to all aircraft, reduce fuel consumption, and thus global industry emissions by 14.72 million tons of CO_2 annually. This would also reduce the operating cost for airlines and ticket prices for air travelers.
- **Hypothesis:**
  - The novel winglet designs that are tested will produce a wing that demonstrates a 1% increase in the lift to drag ratio over current wing designs.

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Wingtip Vortices

- Air from under the wing seeks to regain equilibrium as explained by Le Chatelier's Principle.
- It not only pushes up from the bottom of the wing, but also comes up over the outside edge.
- This results in a loss of pressure differential on top of the wing and thus, reduced efficiency.
- The flow also creates a spiral pattern, resulting in the telltale wingtip vortex
- This flow also causes drag on the aircraft, known as induced drag, because the vortices exert a backwards pull on the plane as it flies.
- Currently, aircraft use winglets, small vertical elements at the wingtips, to reduce the effects of the vortices on efficiency.

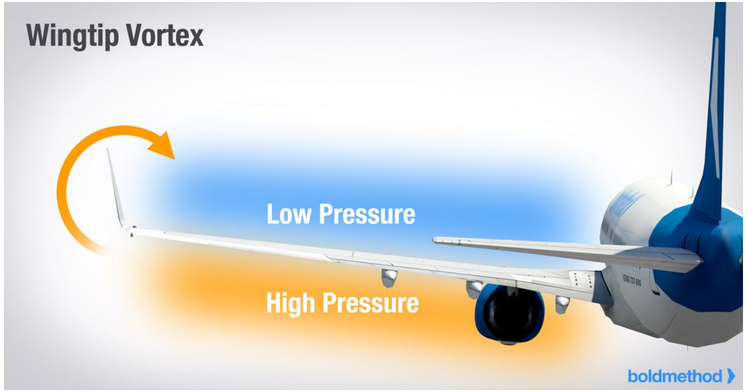

Image credit: boldmethod.com

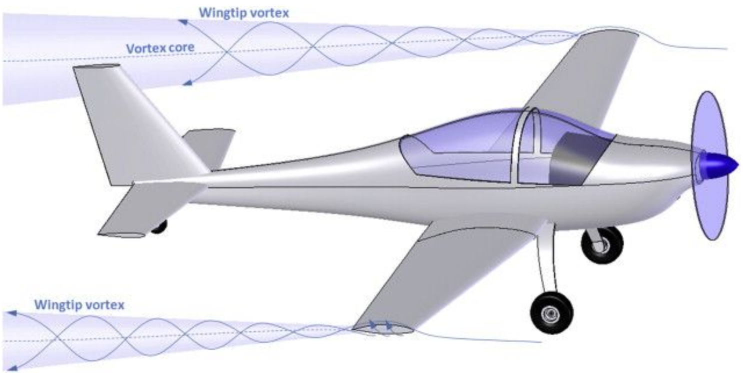

Image credit: Kaẏnak et. al.

Data Collection

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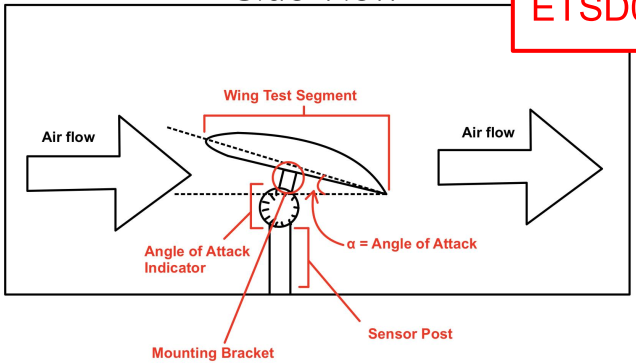
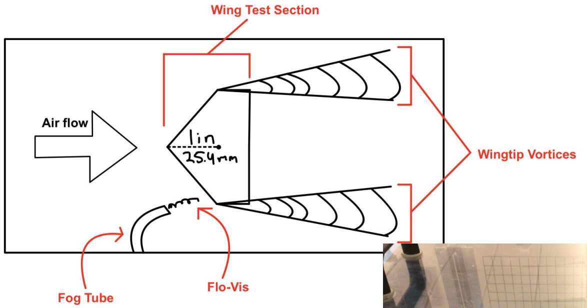
- To collect data, 3 samples of each wing design were 3D printed, this was to reduce the impacts of the variability in 3D printing
- Each wing then had a square coupling hot glued to a slot in the bottom that was located at the aerodynamic center of the wing.
- Then, the sections were mounted in the wind tunnel and taped in place.
- The sensors were then zeroed.
- Each wing section was then tested at each of the three angles of attack (5°, 15°, and 20°) five times with the lift and drag recorded in a table for later analysis.
- This was repeated for the control and each of the different wing designs.

Side View



Top View



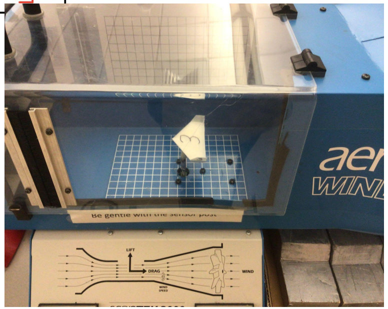


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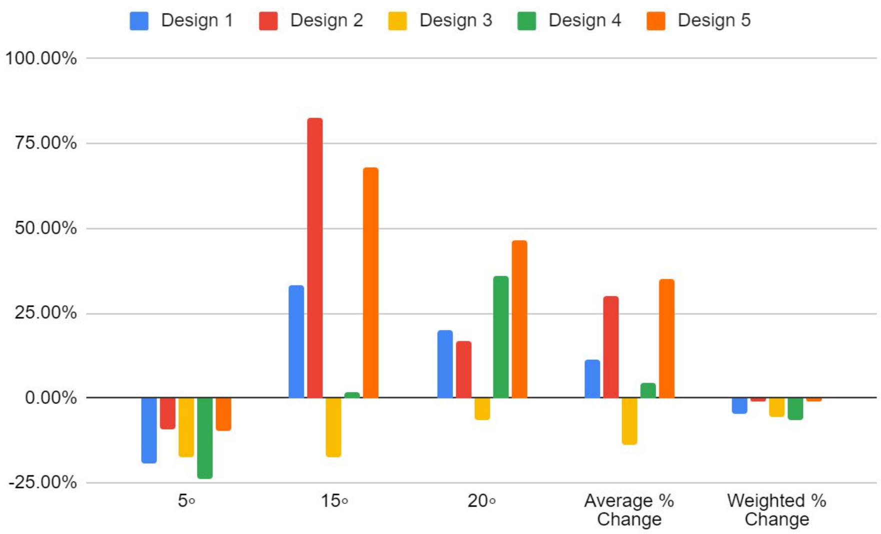
Figure 1: Percentage Change in Lift to Drag Ratio of Designs Versus Control



This figure clearly shows that D5(Orange) was the most efficient using a simple average with a 34.88% improvement in the lift to drag ratio. However, this metric is misleading as it would imply that a typical commercial aircraft spends ⅔ of its flight time at 15 and 20 degrees where, in reality, it is only at these angles during ascent which accounts for only 10% of the total flight. As such, a weighted average was performed giving a 90% weighting to the 5-degree value, as it constitutes 90% of the total flight time. The 15 and 20-degree values were both given 5% weightings each to account for the remaining 10% of flight time. This led to none of the wings performing better than the control wing. D5 and D2 were the closest to matching the performance of the control with a 0.98% and 1.16% decrease respectively.

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Next steps

- Develop the wingtips that showed the best performance further.
  - In D5, the volume, height, and taper of the central gap could be adjusted to optimize the possible lift and drag further. (Figure 1)
  - For D2, the venturi tube entry to exit area ratio could be changed along with the angle and height of the tube itself. (Figure 2)
- Conduct experiments at a better facility with a focus on small unmanned aerial vehicles

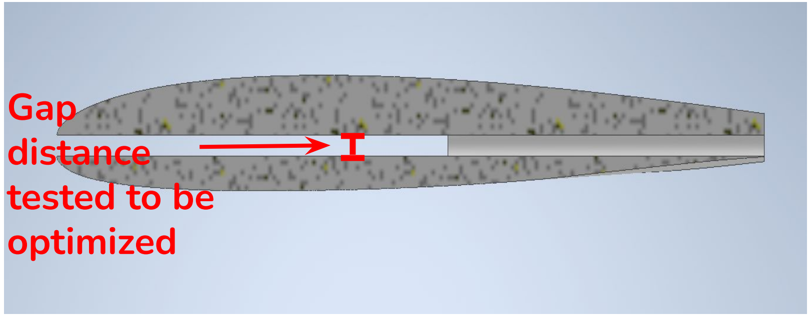

Figure 1

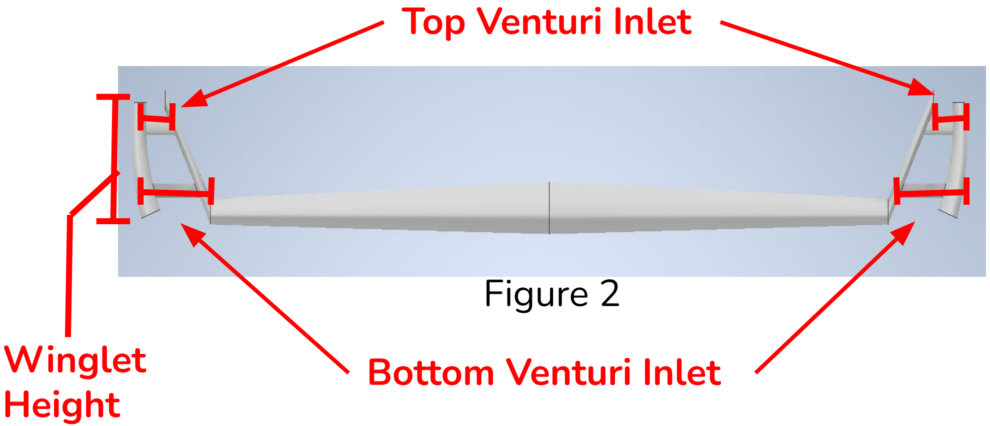

Figure 2

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