DESIGN AND DEVELOPMENT OF DELTA WING WITH LOITERING CAPABILITY

Objective

Delta wings, while known for their stability, agility and responsiveness [1], have reduced endurance and range compared to other wings due to large wing area which results in high drag. Hence, this study hence aims to investigate how changes in sweep angle [2], airfoil thickness [3] and addition of wing fence [4] may strengthen leading-edge vortex (LEV) cores in low-loitering situations to maximise lift, endurance and range of delta wings.

Methodology

Simscale software *Solidworks* was used to create 8 Delta wings (0.125m^2)

Models A1-5: Basic deltas with differing sweep angles from 45° to 65°, NACA2408 airfoil
Model B: Delta A1 with NACA2404 airfoil
Model C: Delta B with 0.25 and 0.5 (from fuselage) wing fences
ANSYS FLUENT student version was used to conduct CFD analysis.

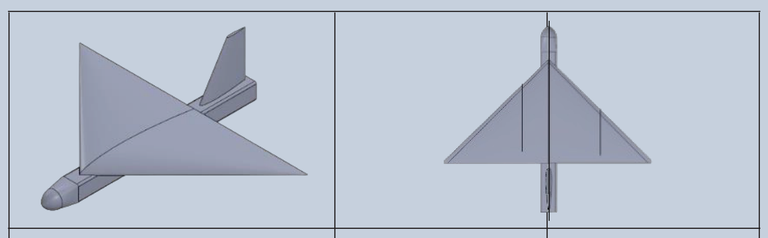


Figure 1A: Isotopic View of Delta A1 | Figure 1B: Top view of Delta C1 | Figure 1C: Top view of Delta C2

Results and Discussion

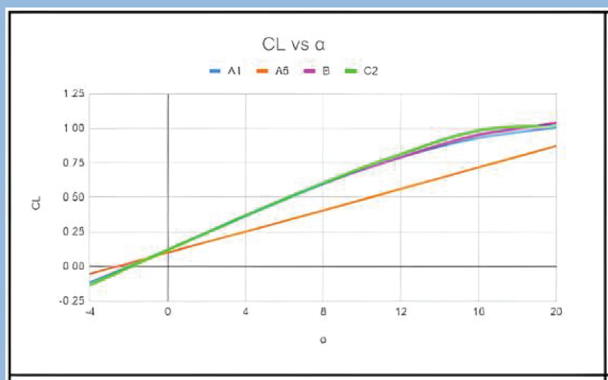


Figure 2A: C_L vs α

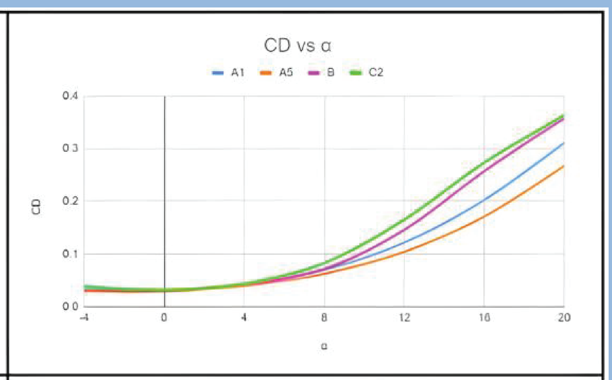


Figure 2B: C_D vs α

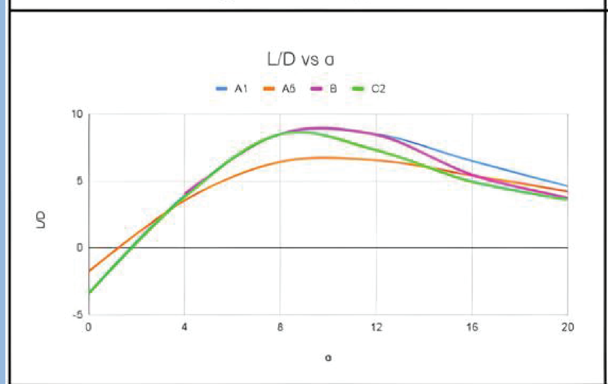


Figure 2C: L/D vs α

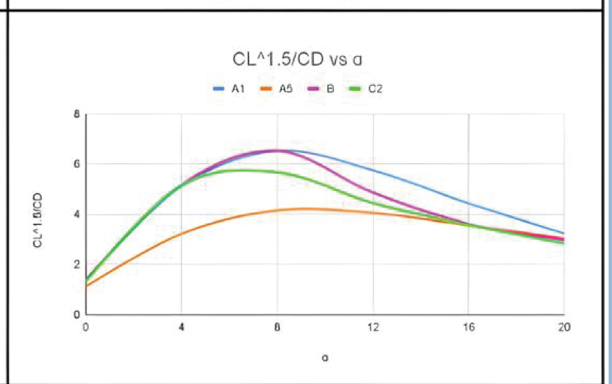


Figure 2D: $C_L^{1.5}/C_D$ vs α

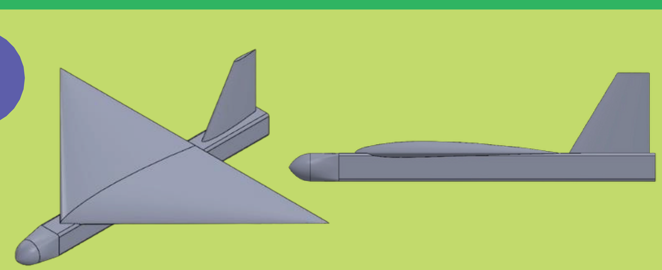
Results:

1. Sweep Angle Variation (Variable 1):
   - Higher sweep angles (Delta A2, A3, A4, A5) delayed stalls, achieving higher CL Max than Delta A1.
   - Ansys Fluent CFD simulation on Delta A5 showed increased formation of LEVs at 16°, confirming the correlation between sweep angle and LEV formation.
   - Delta A1 exhibited higher aerodynamic efficiency at lower angles of attack (α) compared to other models.
2. Airfoil Thickness Variation (Variable 2):
   - Delta B with a thinner airfoil aimed to address the lack of LEVs on Delta A1
   - Thinner airfoil increased CL but unexpectedly led to higher drag (CD), resulting in a lower L/D ratio compared to Delta A1.
3. Wing Fences Addition (Variable 3):
   - While CL marginally improved, CD increased significantly for Deltas C1 and C2, adversely impacting range and endurance.

In summary, higher sweep angles contributed to later stalls and increased efficiency, thinner airfoils increased lift but also drag, and wing fences, while controlling spanwise flow, negatively impacted overall aerodynamic performance.

RC Model

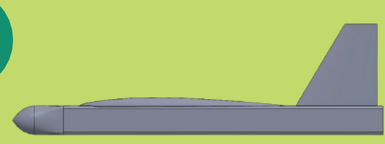
1



Delta A Design Process

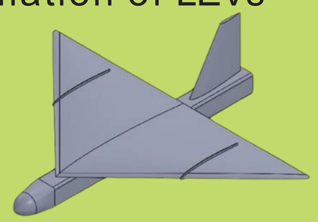
- Wing area of 0.125m^2 was able to provide ample lift for a 250g aircraft, as calculated by Lift Coefficient
- Airfoil: NACA2408 for ease of construction and reliability
- High wing: stability, structural integrity of wing and storage space in fuselage
- Vertical tail: taper ratio of 0.4 and Tail Volume Coefficient of 0.04

2

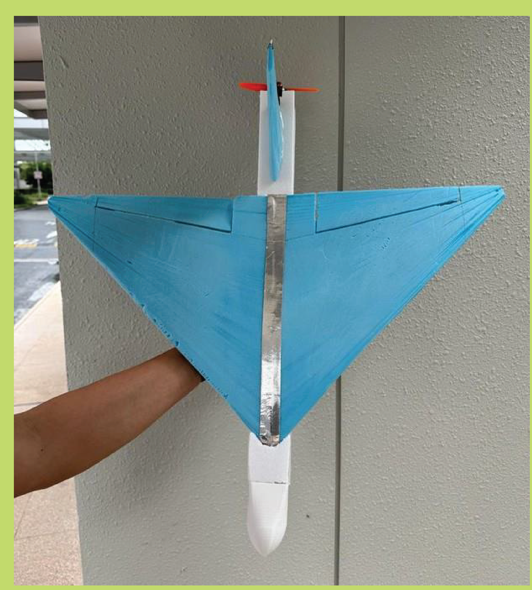


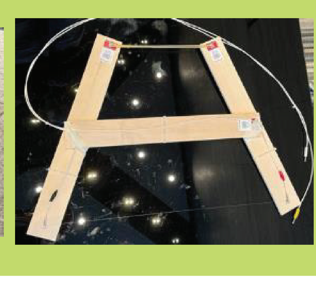
Delta B: NACA2408 airfoil to the thinner NACA2404 to increase formation of LEVs

3



Delta C: addition of wing fences to Delta B to further increase LEV formation





Building Process

- Made a wire cutter and cut the wing and vertical stabiliser out of blue foam with the wire cutter
  - Airfoils were very thin
  - Stronger and more rigid blue foam was chosen to ensure wing does not break
- Electronics were wired up
- Fuselage was made out of foam board
  - Lightweight, to adhere to weight limit
  - Fuselage was hollow to store electronics
- Nose cone was 3D printed
  - Keep to the symmetrical and aerodynamic shape of the design, which cannot be replicated easily with foam
  - Heavy, to maintain a favourable centre of gravity position for the aircraft

Conclusion & Future Work

Delta Models:

- Delta A1 is recommended for loitering due to superior endurance and range.
- Other configurations utilising thinner airfoil and wing fences showed marginal increase in lift but excessive increase in drag, decreasing overall efficiency

Recommendations:

- While wing fences increase drag, they also promote the formation of LEVs, hence producing more controllable lift; suggest retrofitting in existing planes for versatility.
- Strategic reduction in wing fence length to mitigate the increase in drag.

Future Research:

- Advocate for expanded research on delta-wing aircraft, focusing on subsonic flight with varied wing fence configurations.
- Propose a targeted initiative to explore non-uniform aircraft for optimal performance.

References

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