DESIGN AND DEVELOPMENT OF DELTA WING WITH LOITERING CAPABILITY

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Introduction

In modern aerospace, Unmanned Aerial Vehicles (UAVs) play a pivotal role in intelligence, surveillance and reconnaissance missions [1]. By minimising human risk on the battlefield, UAVs offer a competitive advantage over traditional methods of warfare [2]. Among the various UAV configurations, delta wings are particularly prominent. However, while delta wings offer distinct advantages, they also present certain challenges.

Advantages

- High manoeuvrability
- Delayed stall angles
- Aerodynamically efficient at supersonic speeds

Disadvantages

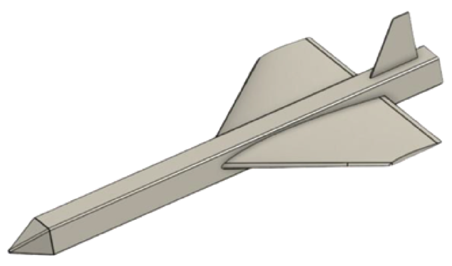
- Aerodynamically inefficient at low speeds
- High drag and low lift production

Objective

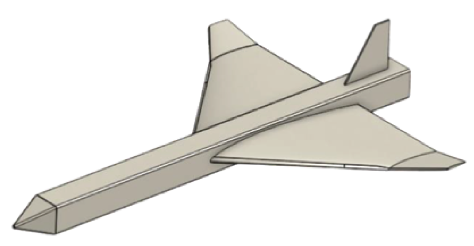
Better understand how the combination of different modifications to the delta wing affects its loitering capability and efficiency at subsonic speeds

Methodology

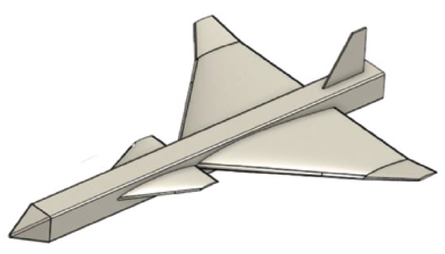
CAD software Onshape was used for the design of the plane models. NACA2408 airfoils were used for the main wings



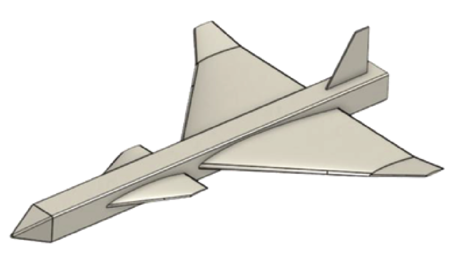
Model A
A basic delta wing with no modifications



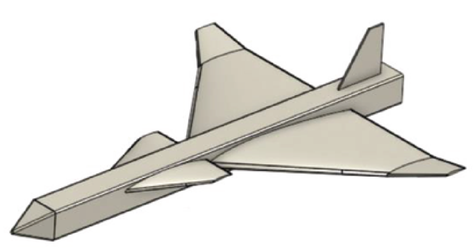
Models B1-B10
Basic delta wings with winglets of differing sweep angles 0°- 90°



Models C1-C10
Models B1-B10 with added canards of NACA 4606 airfoil



Models D1-D6
Model C9 with varying horizontal lengths between canards and main wing from 0 m - 0.10 m



Models E1-E5
Model C9 with varying vertical height of canards from 0 m - 0.008 m

Using Breguet's equations for propeller planes,

Range

$$Range = \frac{\eta}{SFC}\frac{C_L}{C_D}\ln\left(\frac{W_i}{W_f}\right)$$

Endurance

$$Endurance = \frac{\eta}{SFC}\frac{C_L^{1.5}}{C_D}\sqrt{2\rho_\infty S}\left(\frac{1}{\sqrt{W_i}}-\frac{1}{\sqrt{W_f}}\right)$$

where:
- η = Propulsion Efficiency of Propeller
- SFC = Specific Fuel Consumption
- C_L = Lift Coefficient
- C_D = Drag Coefficient
- ρ_∞ = Pressure of Atmosphere
- W_i = Initial Weight of Aircraft
- W_f = Final Weight of Aircraft
- S = Reference Wing Area

Use of ANSYS 2024 R2 Student Version (Fluent With Fluent Meshing) to conduct **Computational Fluid Dynamics (CFD)** analyses on the models

Turbulent airflow
- Use of SST k-omega model
- Turbulent intensity of 1%

Airflow conditions
- Ideal Gas Law
- Sutherland's Law for viscosity
- Freestream velocity of 0.05 mach

Results

Model A

- Peak CL/CD of 3.89
- Stall angle of 28°

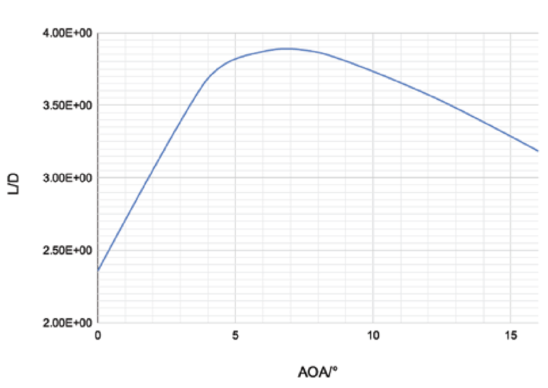


Fig 1a: Graph of CL/CD against AOA/° for Model A

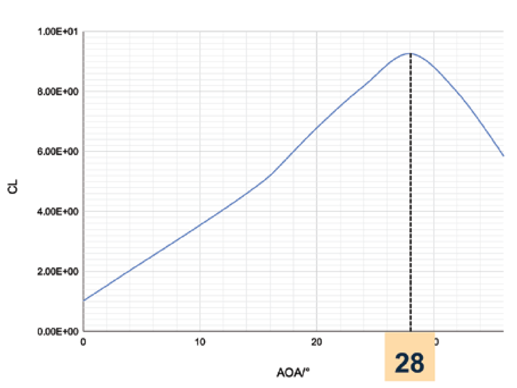


Fig 1b: Graph of CL against AOA/° for Model A

Addition of winglet

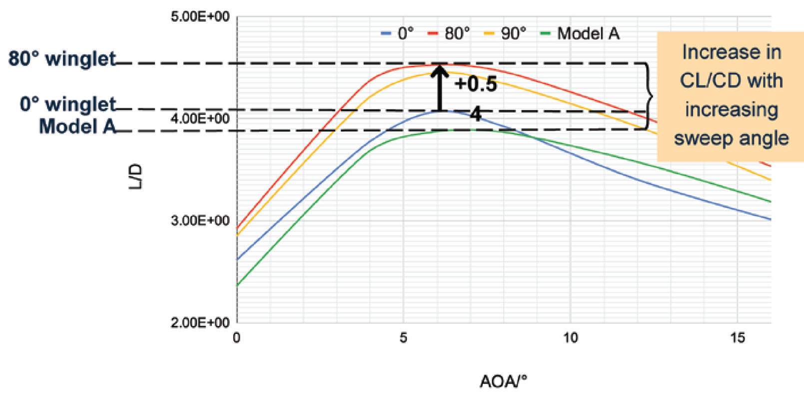


Fig 2a: Graph of CL/CD against AOA/° for Models B1-B10

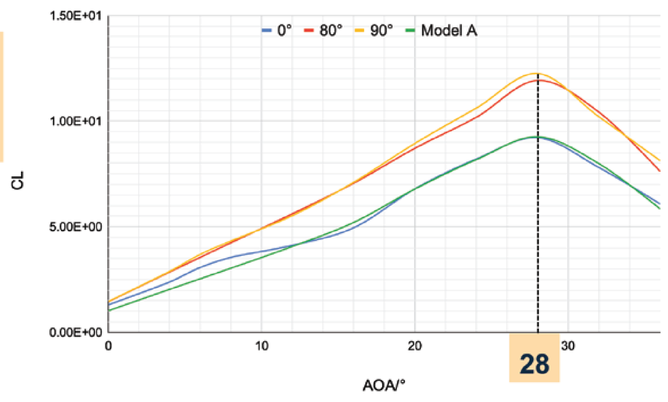


Fig 2b: Graph of CL against AOA/° for Models B1-B10

- CL/CD increases from 4.06 to 4.54 as sweep angle of winglet increases from 0° to 80°
- Stall angle for all models remain at 28°

Addition of winglet + canard

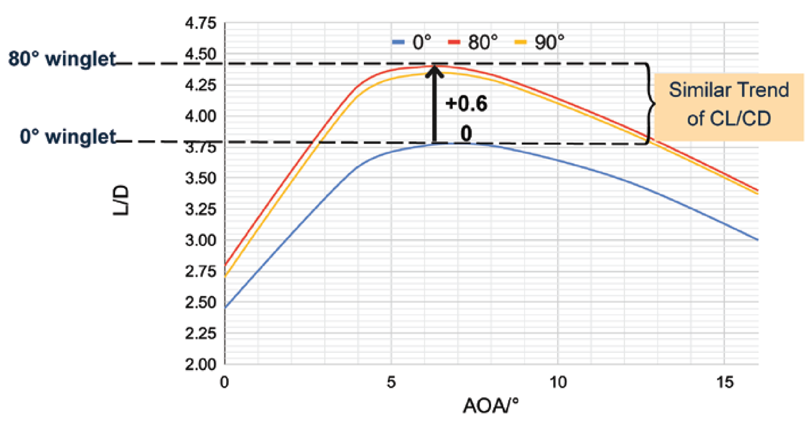


Fig 3a: Graph of CL/CD against AOA/° for Models C1-C10

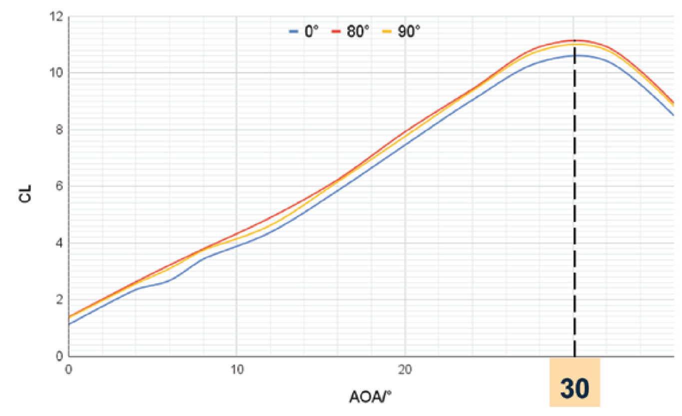


Fig 3b: Graph of CL against AOA/° for Models C1-C10

- CL/CD decreased for all sweep angle of winglets
- Stall angle is delayed from 28° to 30°

Varying canard distance

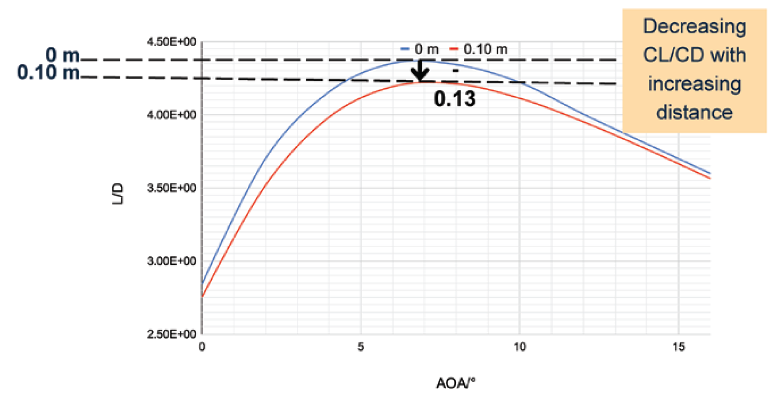


Fig 4: Graph of CL/CD against AOA/° for Models D1-D6

Varying canard height

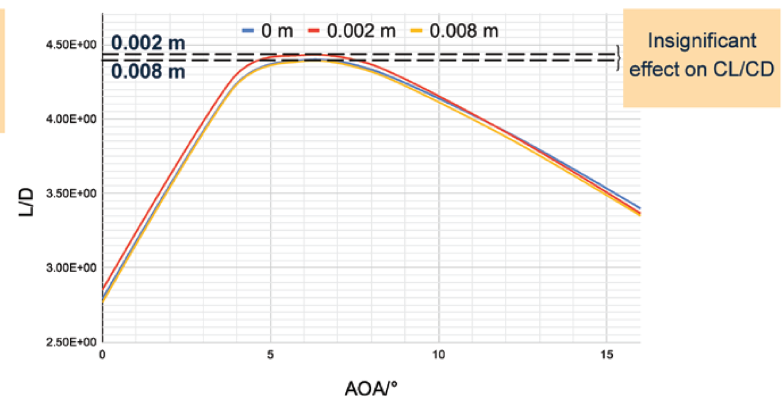


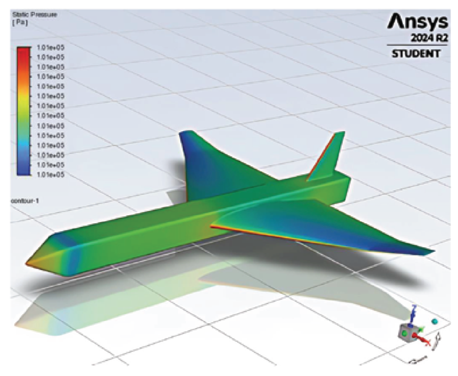
Fig 5: Graph of CL/CD against AOA/° for Models E1-E5

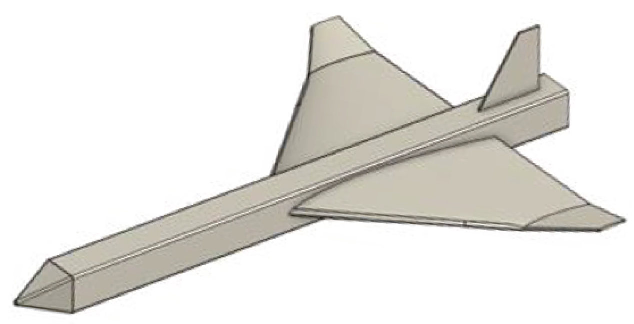
- Varying canard distance and height showed no positive effect on the aircraft's CL/CD

Conclusion

Canards
- ✅ Minimally effective in delaying stall angle
- ❌ Ineffective in increasing CL/CD of aircraft
  - Boundary layer separation at low speeds causes higher pressure drag
  - Insufficient lift generated to overcome additional drag

Winglets
- ✅ Effective in increasing CL/CD of delta wing aircraft
  - Reduces formation of wingtip vortices, reducing induced drag
- ❌ Ineffective in delaying stall angle





Final design: Model B9
Delta Wing with 80 degree winglets

Future Work

Future studies could involve varying the Aspect Ratio of the wings as it has been shown to reduce induced drag and improve manoeuvrability, increasing the aircraft's versatility in diverse environments.

References

[1] O. Molloy, "How are Drones Changing Modern Warfare? | Australian Army Research Centre (AARC)," Army.gov.au, Jul. 31, 2024.
[2] O. Molloy, "Drones in Modern Warfare | Australian Army Research Centre (AARC)," Army.gov.au, Oct. 22, 2024.