Flow separation Control using Delta Type and Rectangular Vortex Generators

Background

Boundary layer separation causes loss of lift, increased drag and aerodynamic stall. Vortex generators (VGs) are passive, low-cost devices that energise the boundary layer by creating streamwise vortices, delaying flow separation. The NACA 4412 is a key aerofoil used in UAVs, general aviation and wind turbines and have shown to stall (loss of lift) beyond 14 degrees angle of attack.

Aims and Objectives

1.Literature review on flow separation & boundary layer behaviour

2.CAD model of wing plus delta and rectangular VGs in Autodesk Inventor

3.3D CFD simulations in ANSYS Fluent (k-ω SST) at 8 AoA values

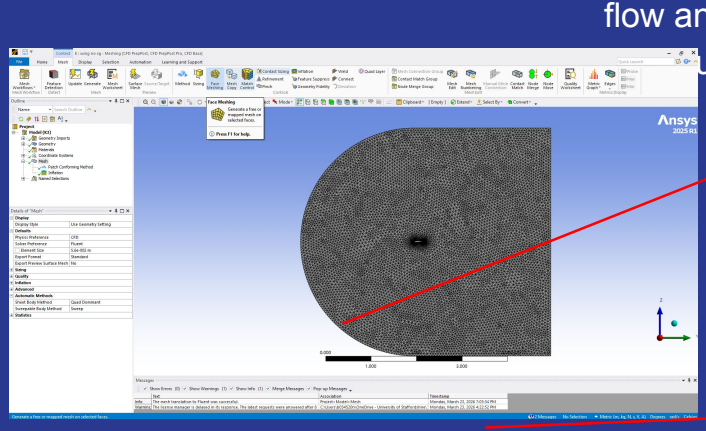
4.Evaluate CL, CD, pressure & flow and compare VG urations

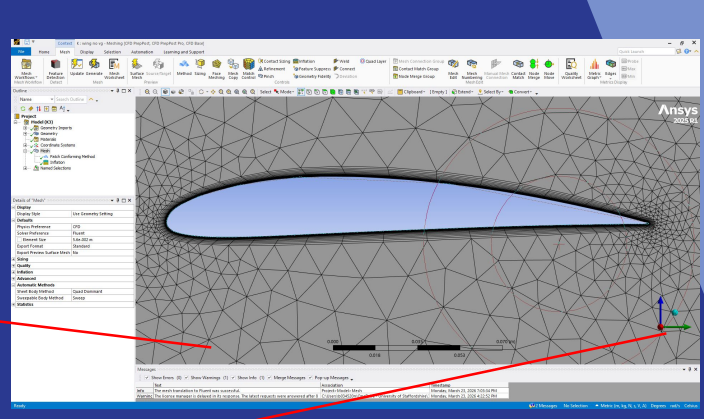
Methodology

Wing modelled in Autodesk Inventor with a chord of 300 mm and span of 600 mm. VGs placed at 20% chord, 14° incidence, 40 mm pair spacing. Mesh: 1.85M tetrahedral elements, 25 inflation layers, y+ = 0.75. 25 total simulations across 3 wing configurations.

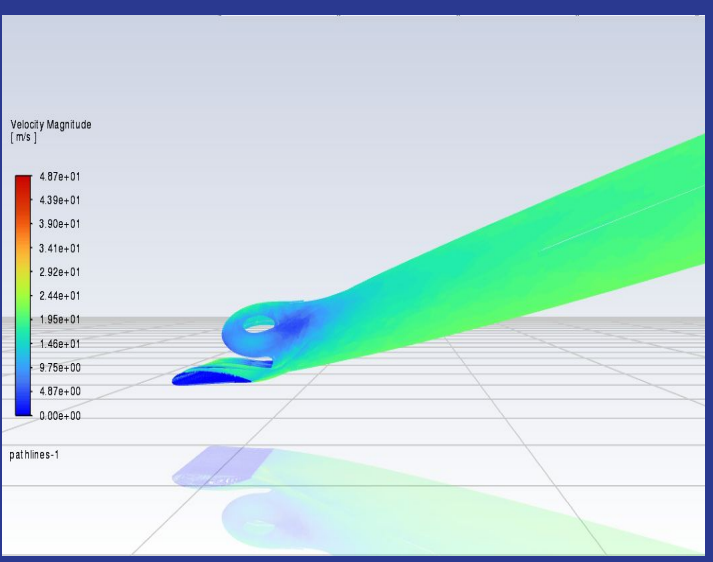
Research Gap

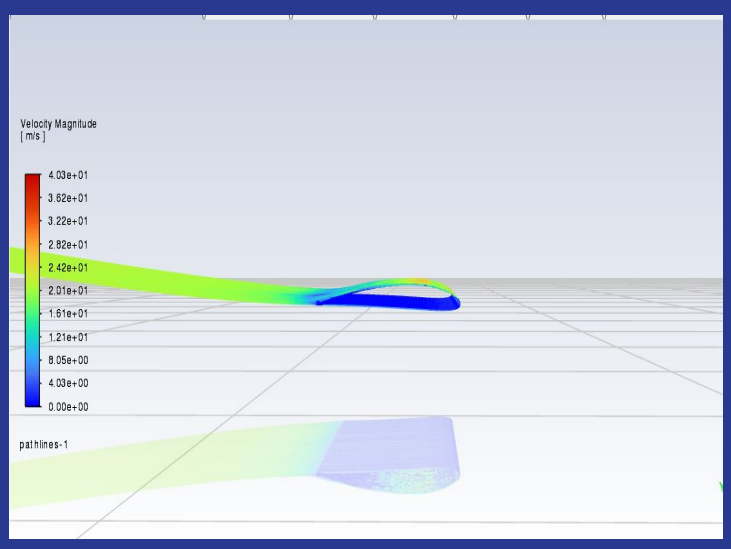
Most CFD studies test a single VG geometry. Direct three dimensional comparison of delta-type vs. rectangular VGs on the NACA 4412 across the full pre-stall to stall range 0 and 14 degrees at Re ≈ 291,000 remains limited in research.

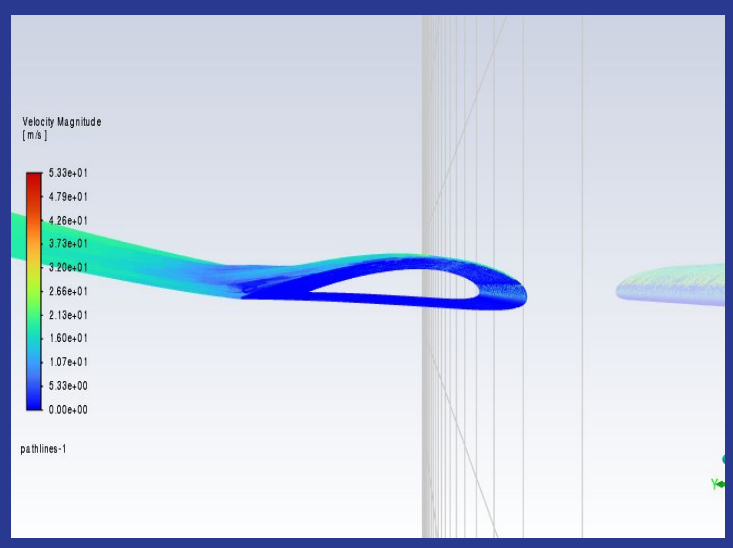




- C - shape inlet to allow the air to enter at various angles to change angle of attack.
- 25 Inflation layers to better capture the airflow close to the wing
- Large domain to avoid interference
- Fine mesh for tighter angles, courser mesh further afield to save computational power



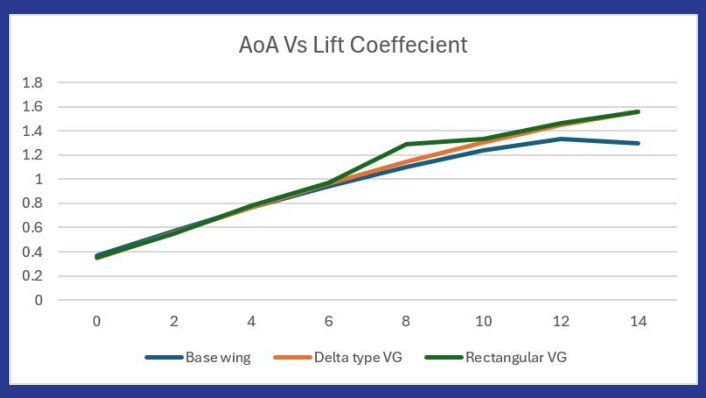




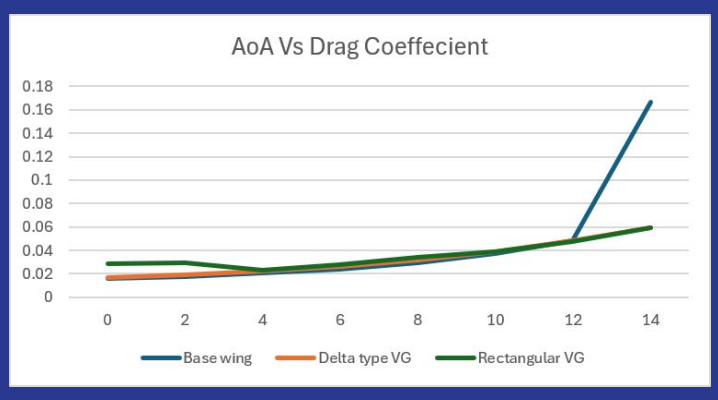
At 14 degrees angle of attack, the flow separates from the unmodified wing, showing a aerodynamic stall.

At 14 degrees angle of attack, the flow remains attached to the wing due to the delta type Vortex Generators.

At 14 degrees angle of attack, the flow remains attached to the wing due to the rectangular vortex generator



Lift force generated by the wing for each configuration.



Drag force generated by the wing for each configuration.

Conclusion

Delta VGs are the recommended choice for low speed fixed wing UAVs where cruise efficiency matters. Rectangular VGs suit applications where near stall lift is the primary objective. Results validated against Solnay et al. (2025) with strong correlation. For future work i would use wind tunnel validation, tip-vortex modelling, and geometry optimisation for each VG type.

+20%
CL gain at 14° (Delta VG vs. baseline)

-64%
CD reduction at 14° (both VG types)

L/D 26.3
vs. 7.8 baseline at 14° (+237%)

-5–6%
CL penalty at 0°–6° (parasitic drag)