Analysis of Low-Speed Stall Aerodynamics of a Swept Wing with Seamless Flaps

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Presentation outline

- ACTE aircraft description
- CFD Methodology:
  - CFD code description
  - Overset mesh strategy for ground effect analysis
  - CFD strategy for generating wing lift curves
- Analysis Results:
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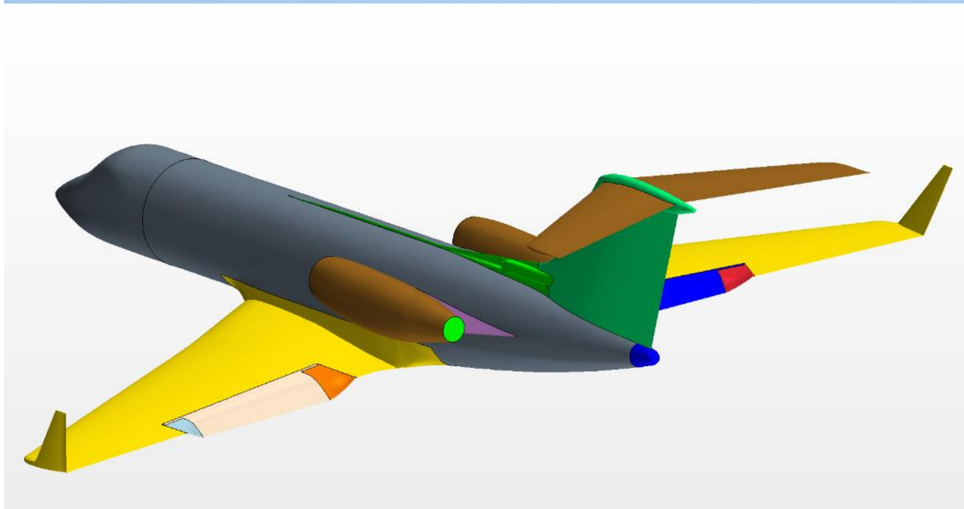
ACTE aircraft description

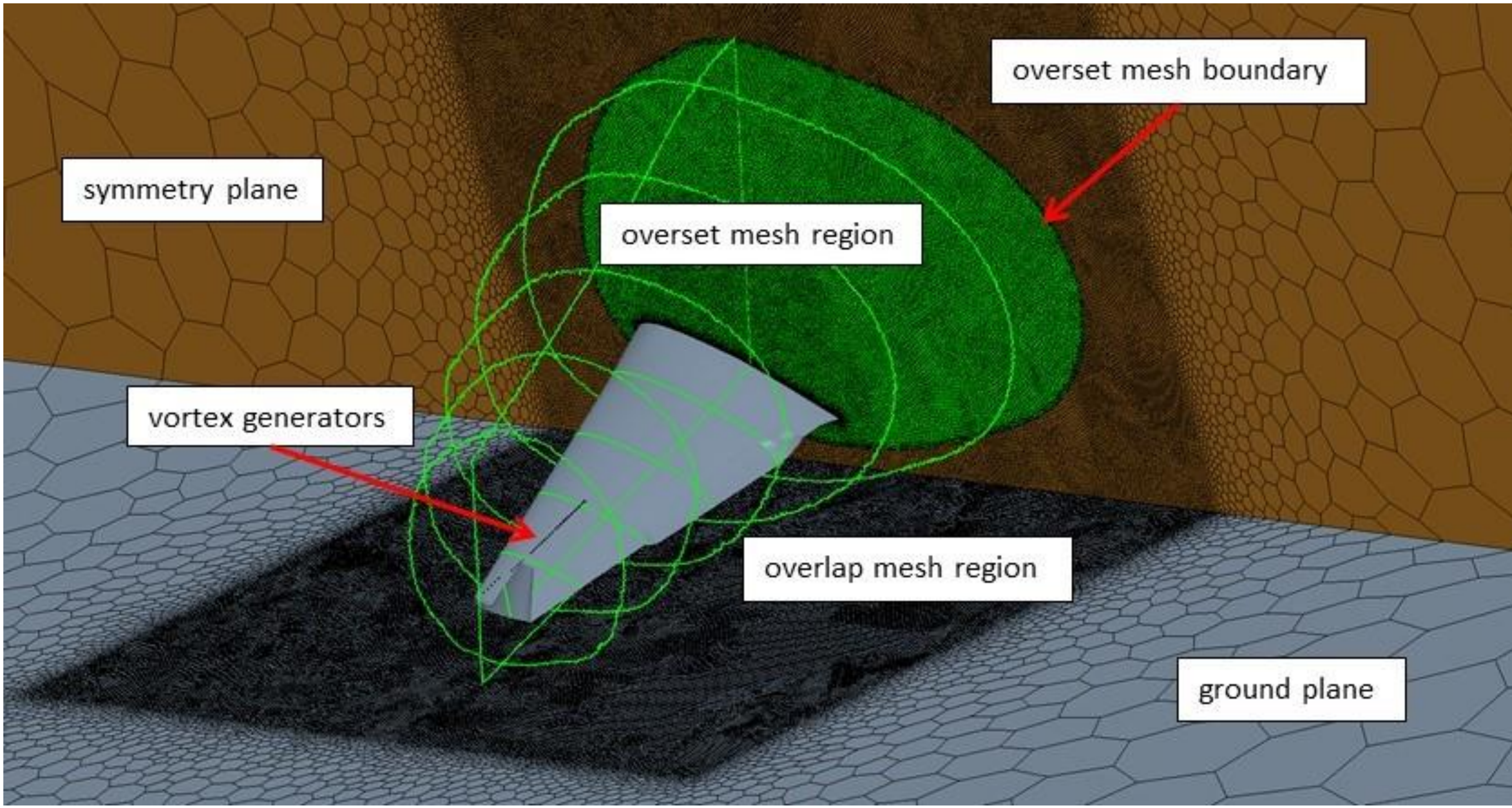
- NASA GIII Tail No. 804:
  - SubsoniC Research AircrafT (SCRAT) – Extensively instrumented for subsonic jetliner-class flight research
  - Adaptive Compliant Trailing Edge (ACTE) – Conventional GIII flaps replaced by experimental compliant ACTE flaps



STAR-CCM+ CFD Methodology

- Implicit, coupled steady flow solver with perfect gas air model
- 2nd-order spatial discretization with Hybrid Gauss-LSQ reconstruction
- Roe FDS with Venkatakrishnan limiter
- Symmetry plane used for half-wing CFD simulations
  - No aircraft fuselage
  - No landing gear
- Mesh sizes range from medium (39 to 50 million cells) to fine (61 to 76 million cells)
- Spalart-Allmaras one-equation turbulence model
- Low-y+ wall treatment without wall function
  - Typical near-wall y+ values around 0.2, ranges from 0.05 at TE to 0.4 at LE
  - 19 (medium) and 23 (fine) prism layers were used within a normal distance of approximately 2.2 inches from the wall
- Overset meshing required for ground-effect CFD simulations

Overset mesh strategy for ground effect analysis

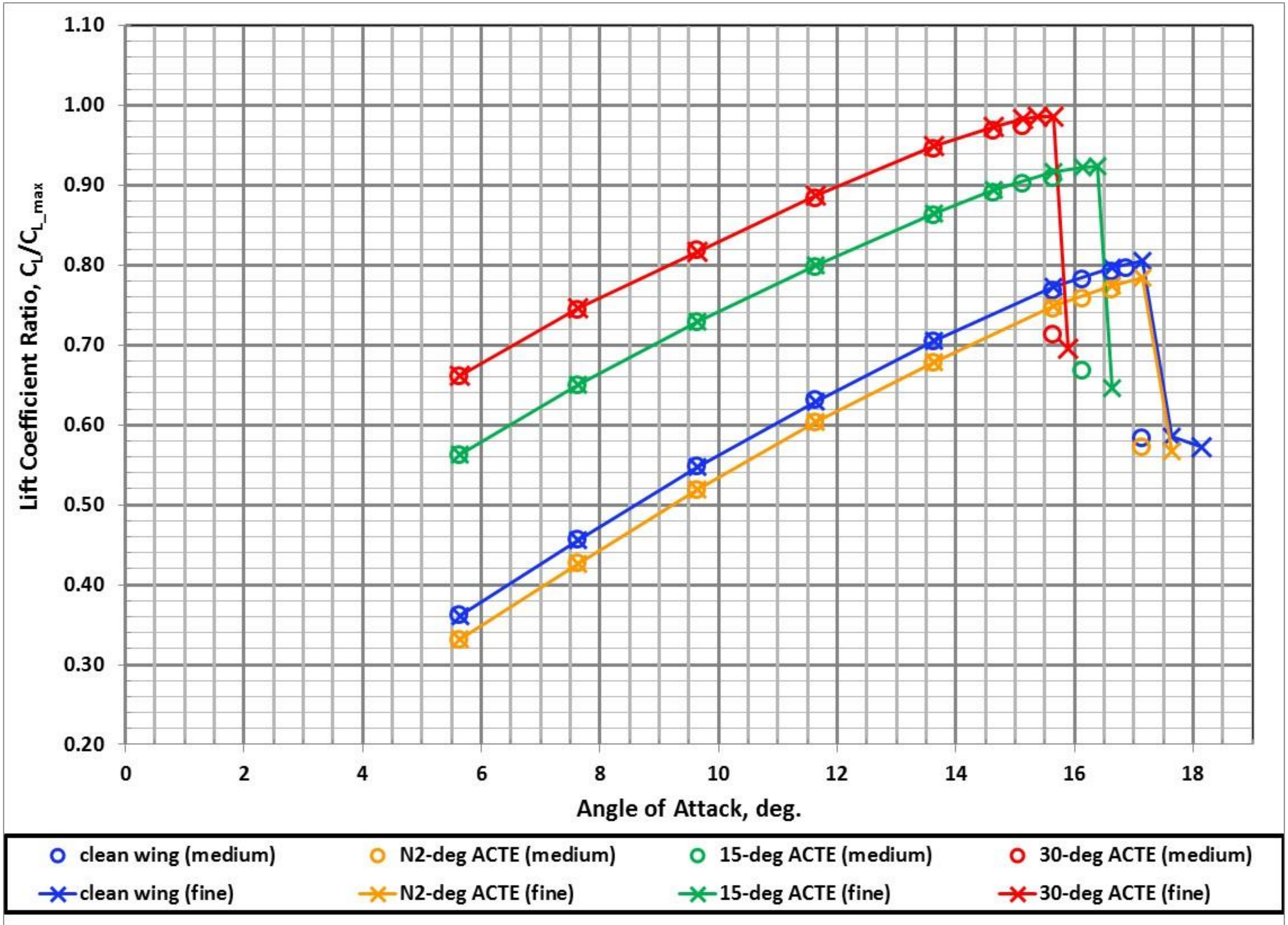


CFD strategy for generating wing lift curves

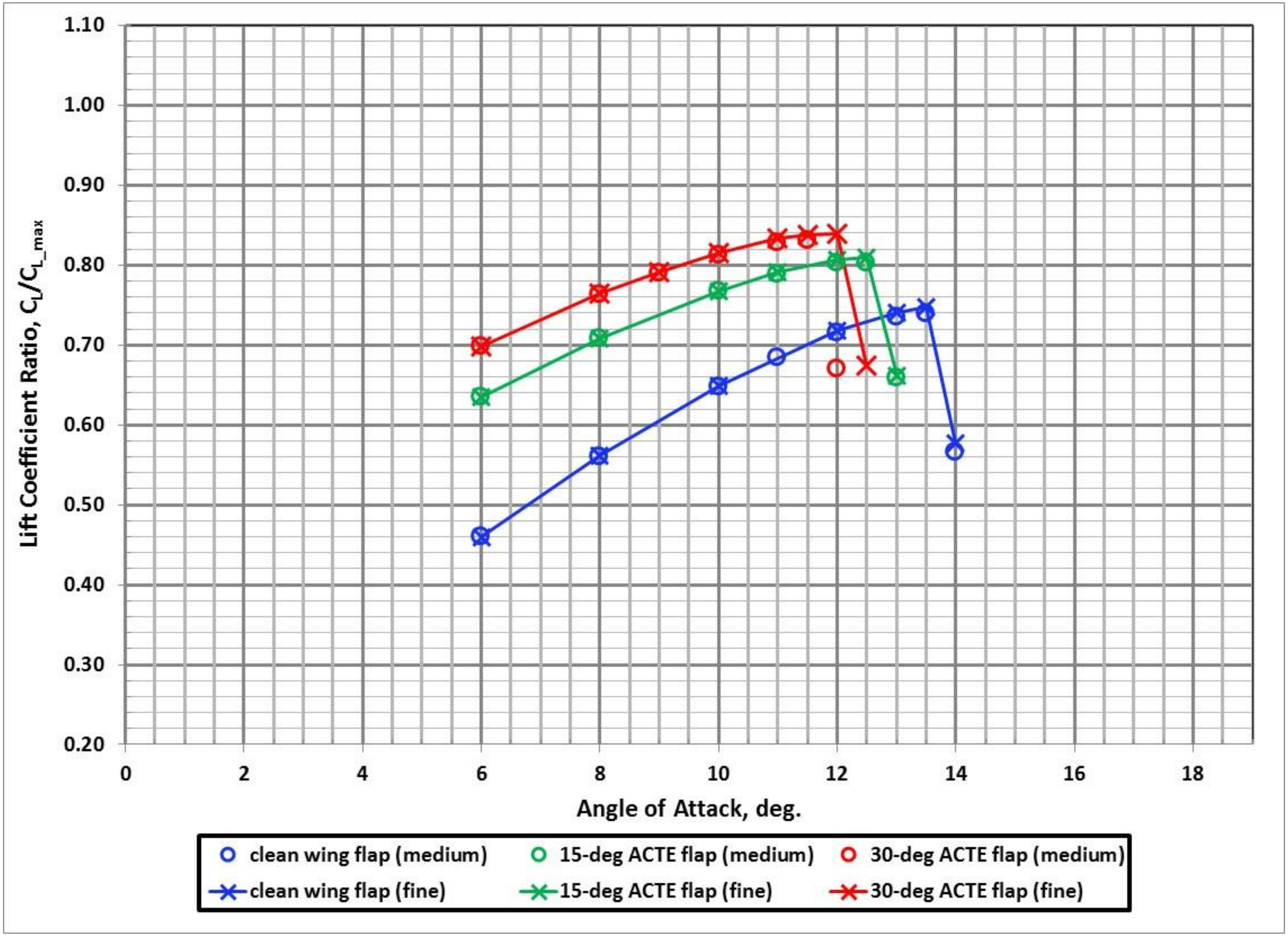
1. Start the AoA sweep with a CFD simulation of the wing at a small initial AoA value
2. After the lower AoA-value solution converges, increase the AoA to the next higher value
3. Restart the new higher AoA simulation from the previous converged lower AoA solution
4. Repeat steps 2 and 3 above until wing lift is lost indicating wing stall has been reached
5. Repeat step 4 from the last maximum lift solution, but with an AoA increment that is half as large as the previous AoA increment
6. Repeat step 5 above keep decreasing the AoA increment until the desired tolerance of AoA increment is reached

- With large values of AoA increment or large values of initial AoA, premature CFD wing stall occurred
- Starting AoA increment value was 2 deg
- Last AoA increment value was 0.5 deg
- Therefore, our stall solution is within 0.5-deg AoA tolerance
- We could use even smaller AoA increment if necessary

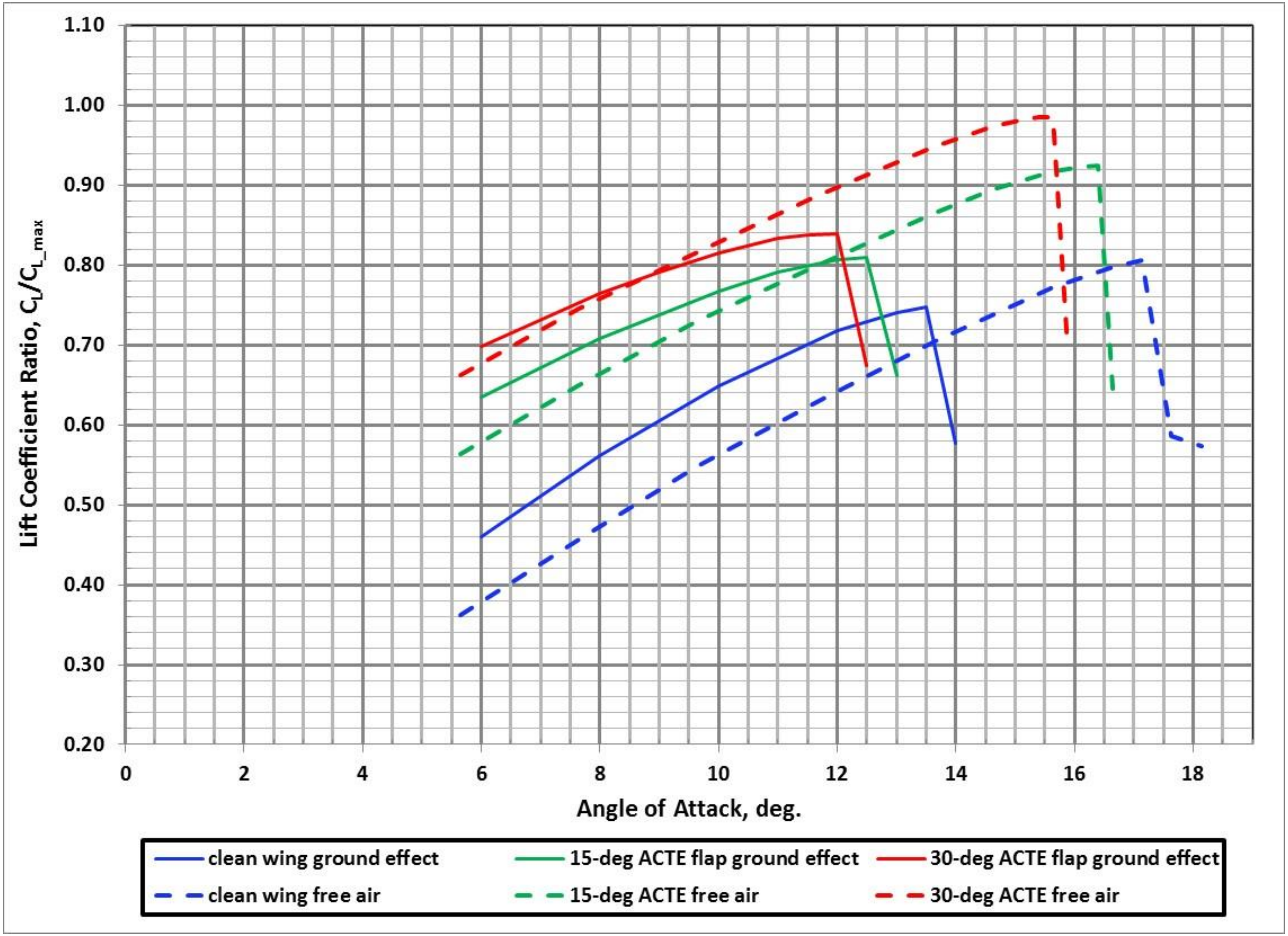
CFD grid convergence results – free air

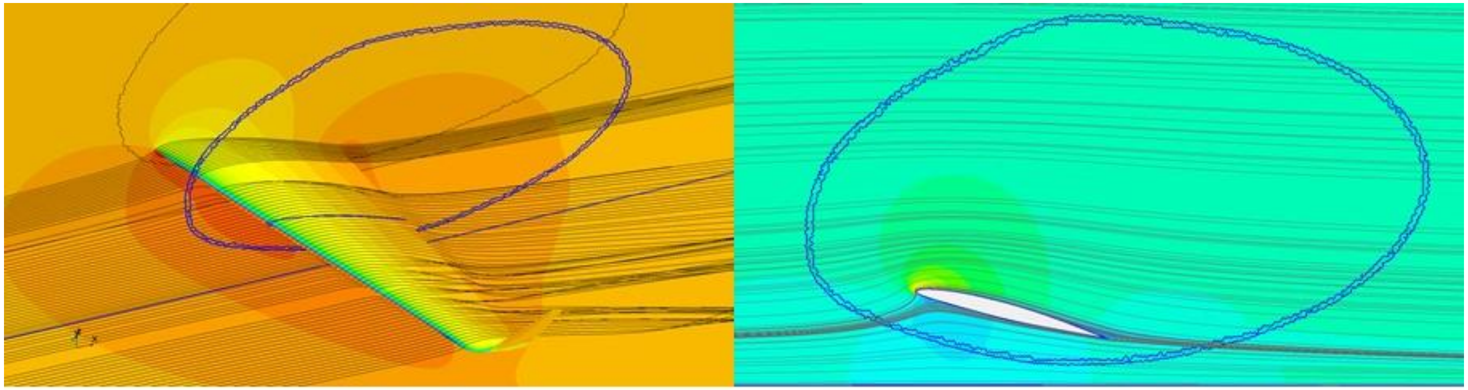


CFD grid convergence results – ground effect

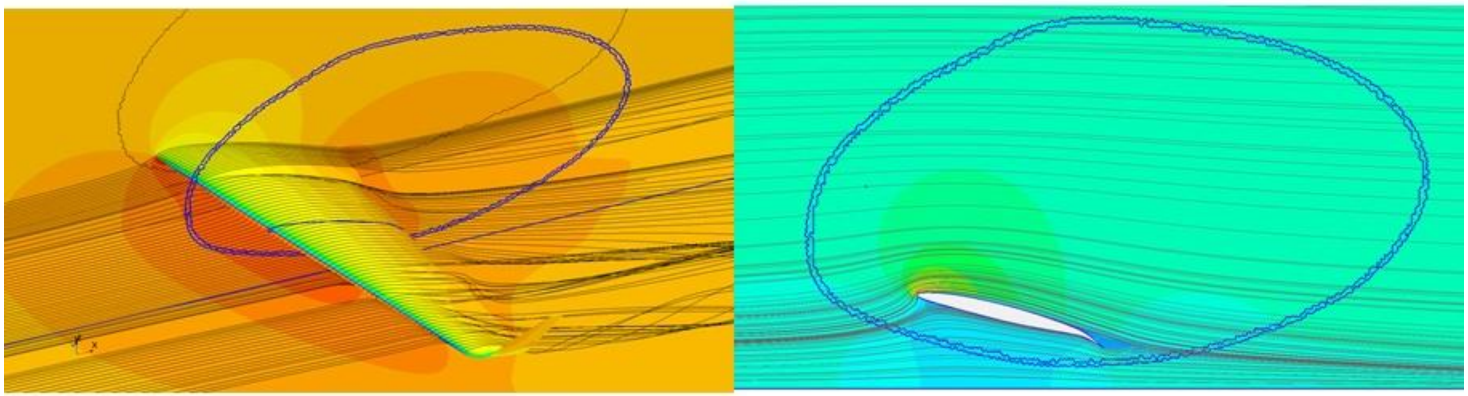


ACTE CFD Wing Stall Results

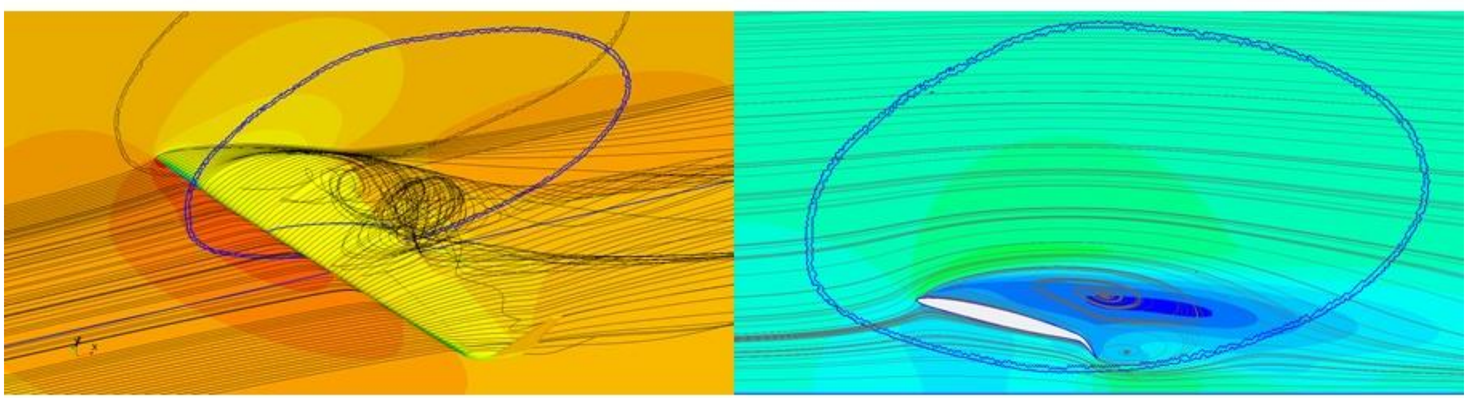




a. Clean wing, AoA = 13 deg



b. 15-deg ACTE, AoA = 12.5 deg



c. 30-deg ACTE, AoA = 12.5 deg

Conclusions

- Grid-independent CFD results were obtained from the STAR-CCM+ code for the ACTE wing stall aerodynamics
- The 15- and 30-deg ACTE wings are predicted to stall at earlier angle of attack values than the clean wing. The negative 2-deg ACTE wing stalls at approximately the same angle of attack value as the clean wing
- Ground effect is predicted to decrease the stall angle of attack for all wings
- Ground effect is predicted to decrease the maximum lift coefficient for all wings
- Higher ACTE flap deflections are predicted to have less lift increase in ground effect than the clean wing
- Large flow separation region is predicted to occur directly above the ACTE flap and is responsible for the earlier wing stall