Analysis of Low-Speed Stall Aerodynamics of a Business Jet's Wing Using STAR-CCM+

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Outline of the Presentation

- Objectives.
- Description of the NASA Dryden GIII testbed aircraft:
  - Subsonic Aircraft Roughness Glove Experiment (SARGE).
  - Adaptive Compliant Trailing Edge (ACTE).
- Validation of the STAR-CCM+ CFD code for low-speed wing stall analysis.
- Low-speed stall aerodynamics:
  - Subsonic Aircraft Roughness Glove Experiment (SARGE).
  - Adaptive Compliant Trailing Edge (ACTE).
- Conclusions.

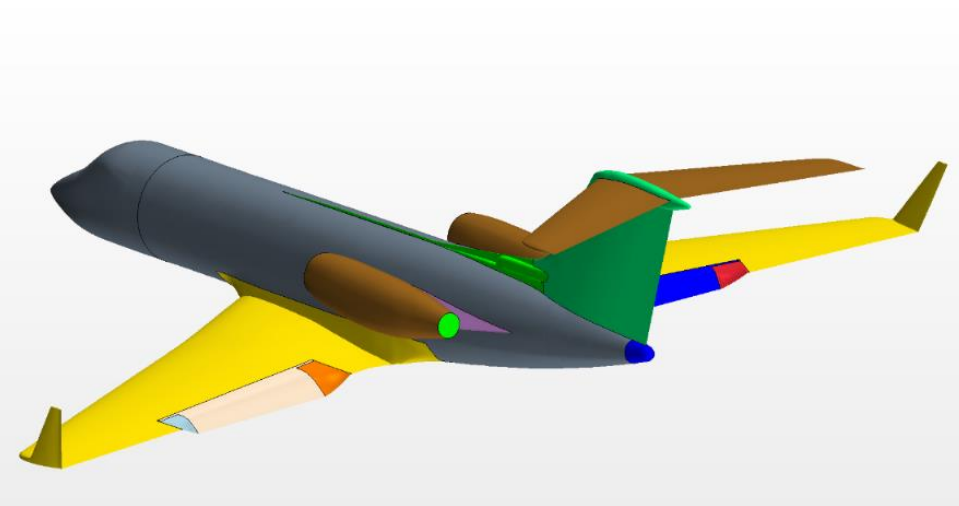
Objectives

- Validate the Star-CCM+ CFD code for low-speed wing stall predictions.
- Laminar-flow wing glove low-speed wing stall characteristics.
- ACTE flaps low-speed wing stall characteristics.
- ACTE wing stall characteristics in ground effect.
- Flow physics behind low-speed gloved wing and ACTE wing stalls.

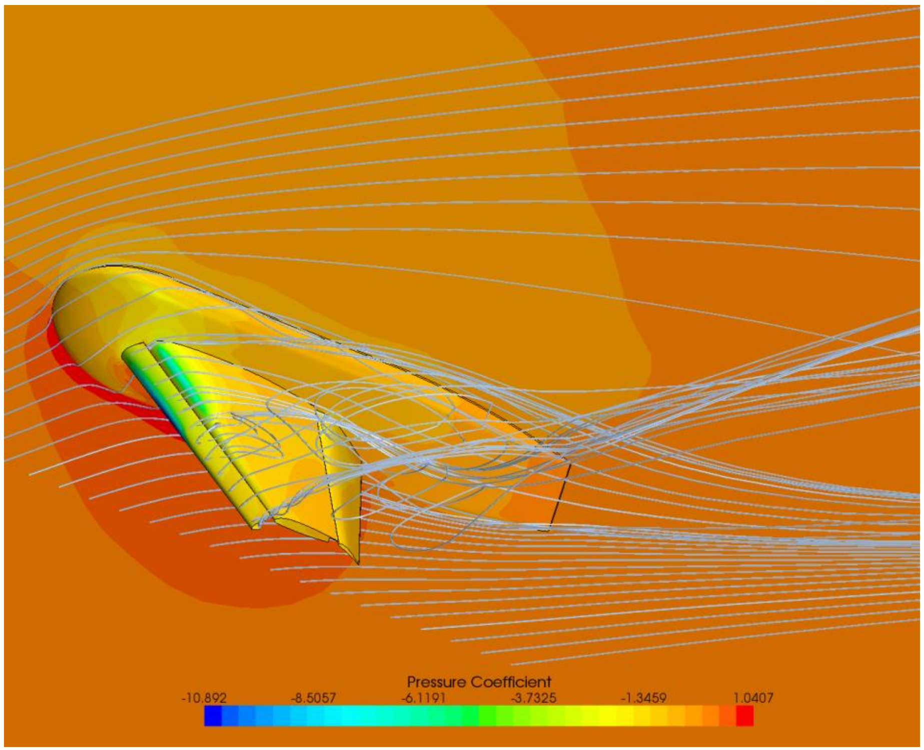
NASA GIII aircraft description

NASA GIII Tail No. 804:

- SubsoniC Research AircrafT (SCRAT)
- Subsonic Aircraft Roughness Glove Experiment (SARGE)
- Adaptive Compliant Trailing Edge (ACTE)

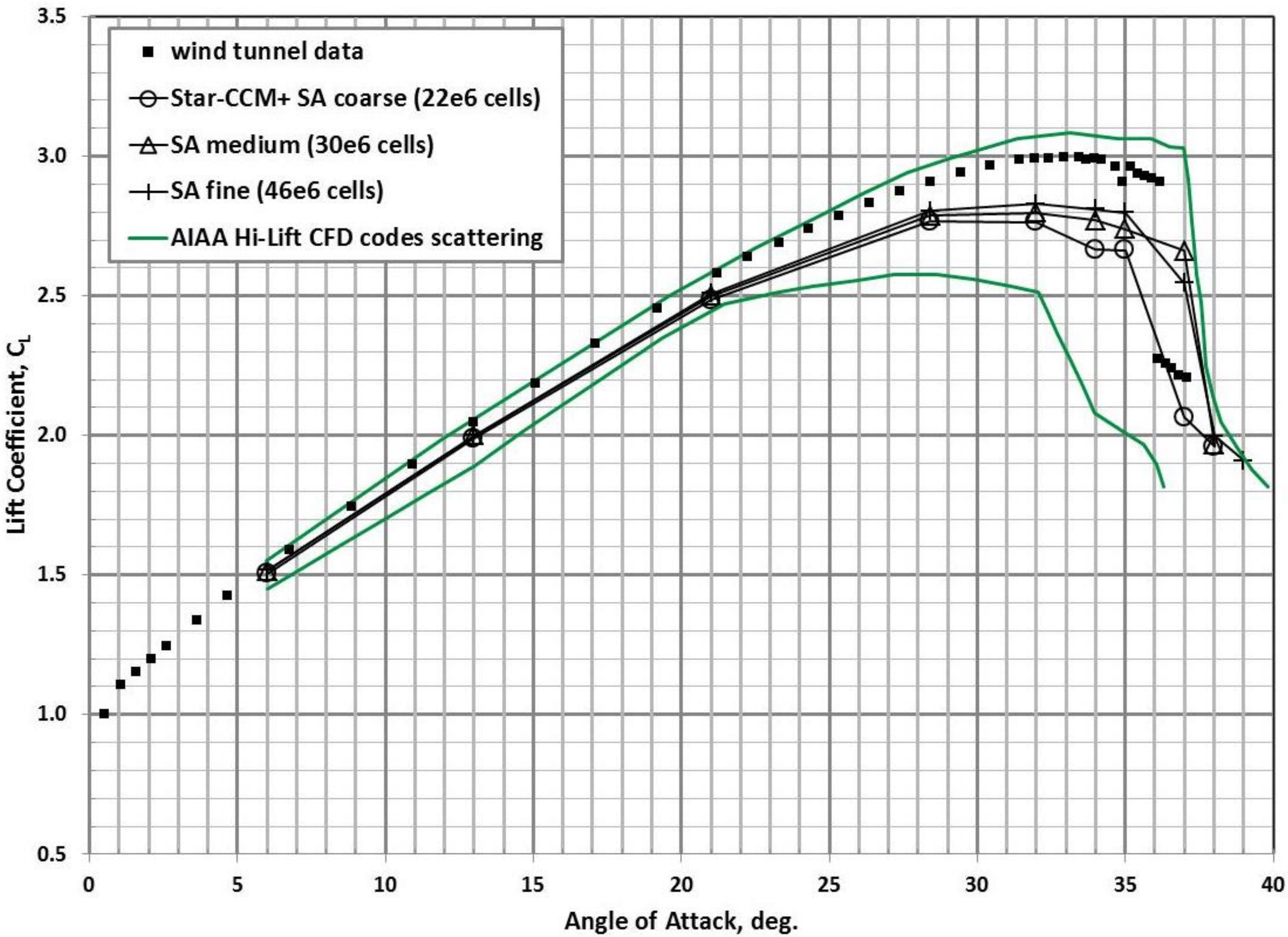


Star-CCM+ Validation Study

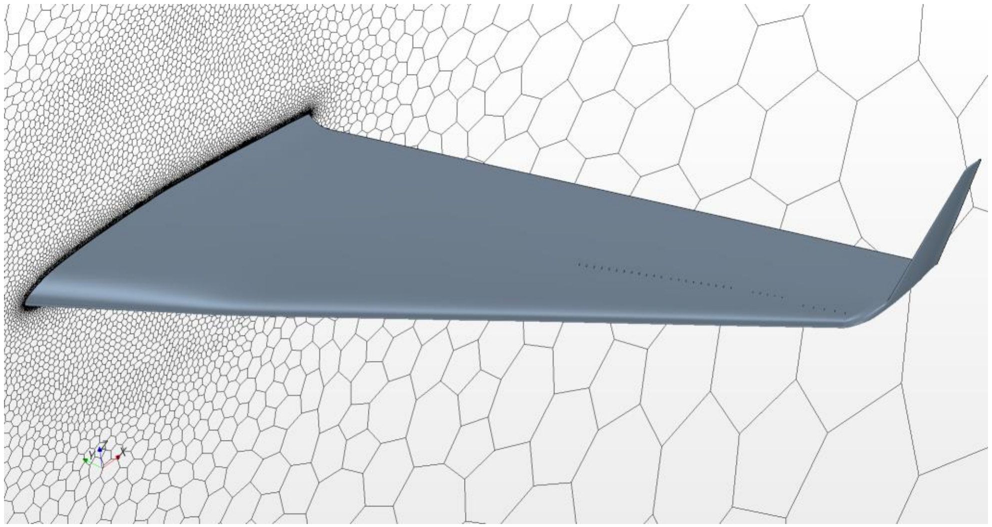


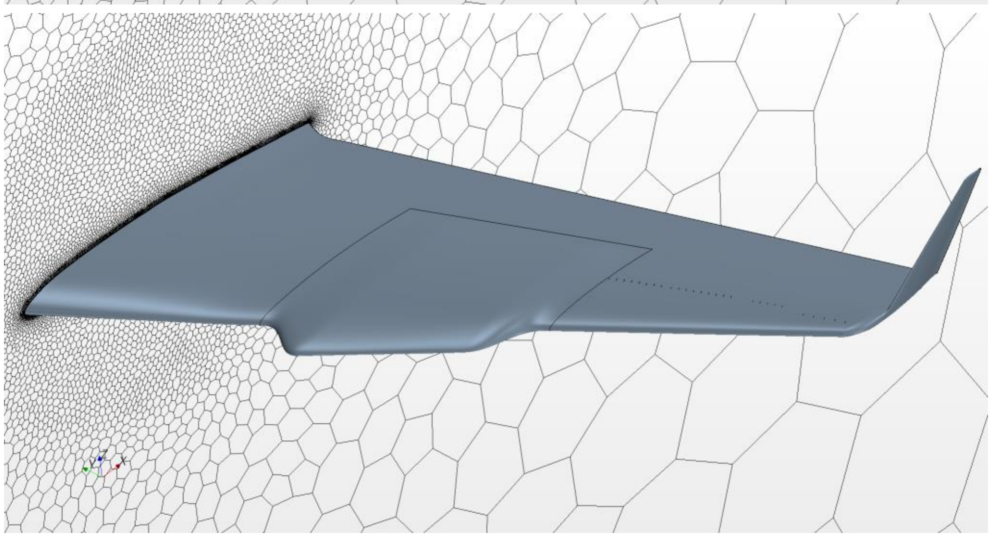
- First AIAA CFD High-Lift Prediction Workshop wing-body geometry.
- Wing-body configuration 1 with 30-deg. slat and 25-deg. flap.
- Mach 0.2, Reynolds no. of 4.3 million based on MAC.
- Used recommended best practices from the workshop for Star-CCM+ stall validation runs.
- Accuracy of Star-CCM+ results is within the range of the CFD codes considered at the workshop.
- Star-CCM+ is able to predict wing stall to within 1 degree of AOA as compared to wind tunnel test data

CFD Code Validation Results



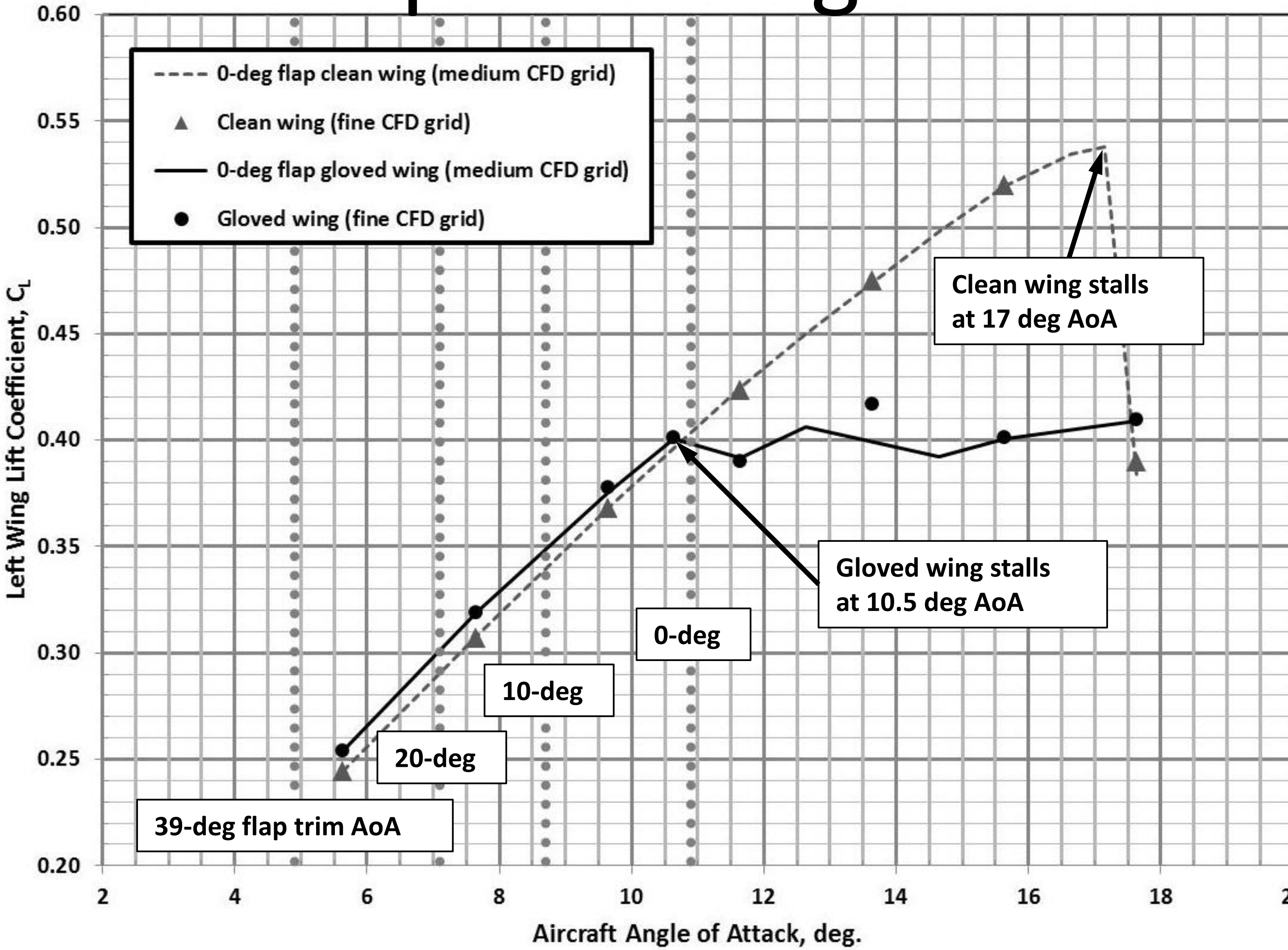
GIII Aircraft Wing Modifications by the SARGE DRE Laminar-Flow Wing Glove





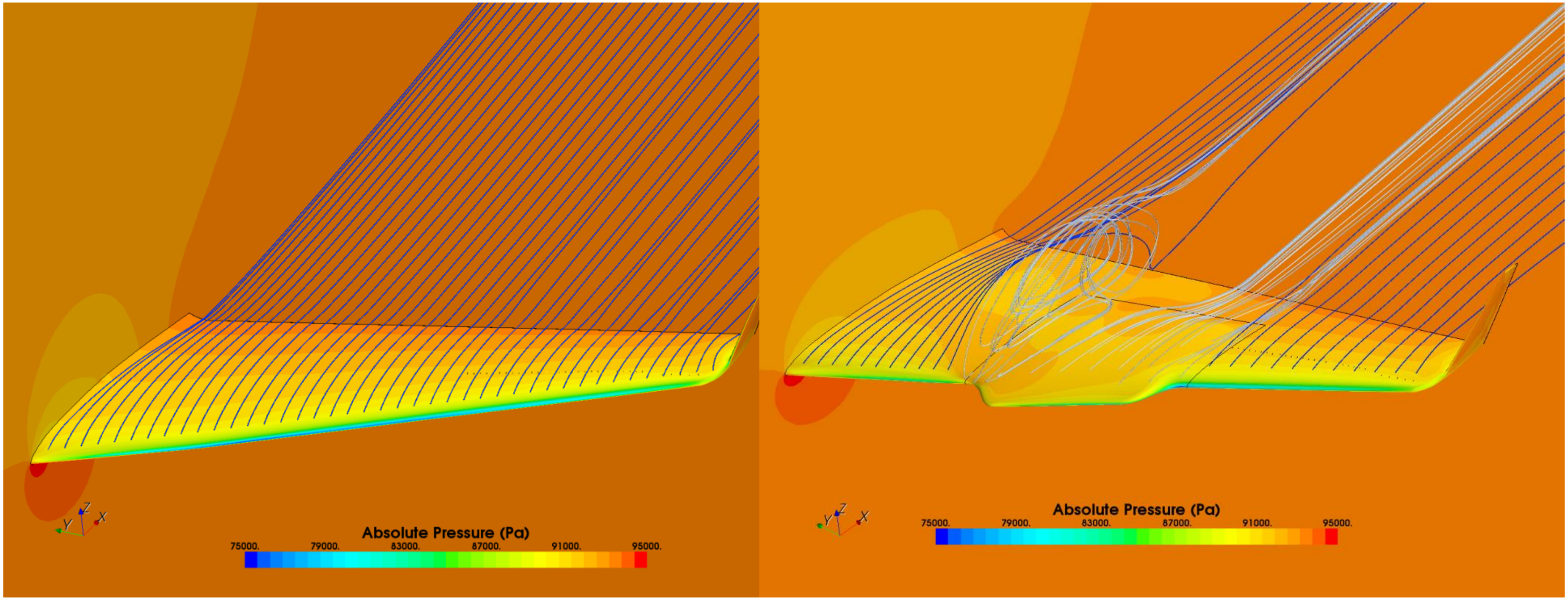
- Glove spans approx. 30% of the aircraft wing's halfspan.
- Smaller leading edge (LE) radius.
- Longer chord length.
- A smaller thickness over chord (t/c) ratio.
- Modified airfoil camber line.
- Two leading-edge snags introduced by the glove extending beyond the unmodified aircraft wing's leading edge.
- Four standard aircraft wing vortex generators (out of a total of 31) are removed on the left gloved wing.
- The clean right wing retains the full 31 vortex generators.

GIII Low-Speed Wing Stall Results



Mach 0.183 (120 knots), 2300 ft. ASL, left wing only with a symmetry plane, 0-deg. flap, with vortex generators.

Gloved Wing Stall Visualization

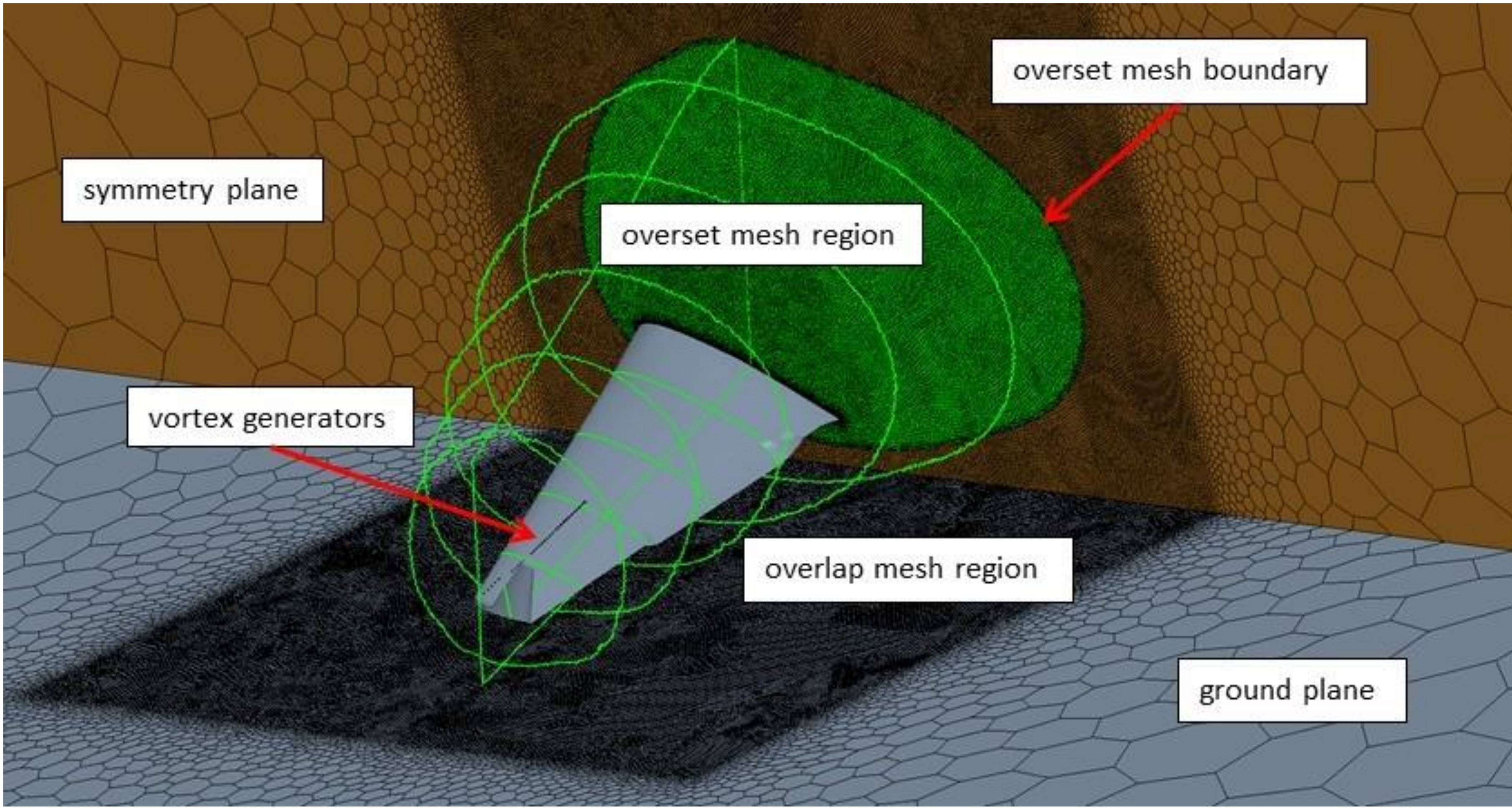


Clean unmodified wing

Gloved wing

Mach 0.183 (120 knots), 2300 ft. ASL, 12-deg. AoA. Glove causes early wing stall as compared with clean unmodified wing.

ACTE overset mesh for ground effect analysis

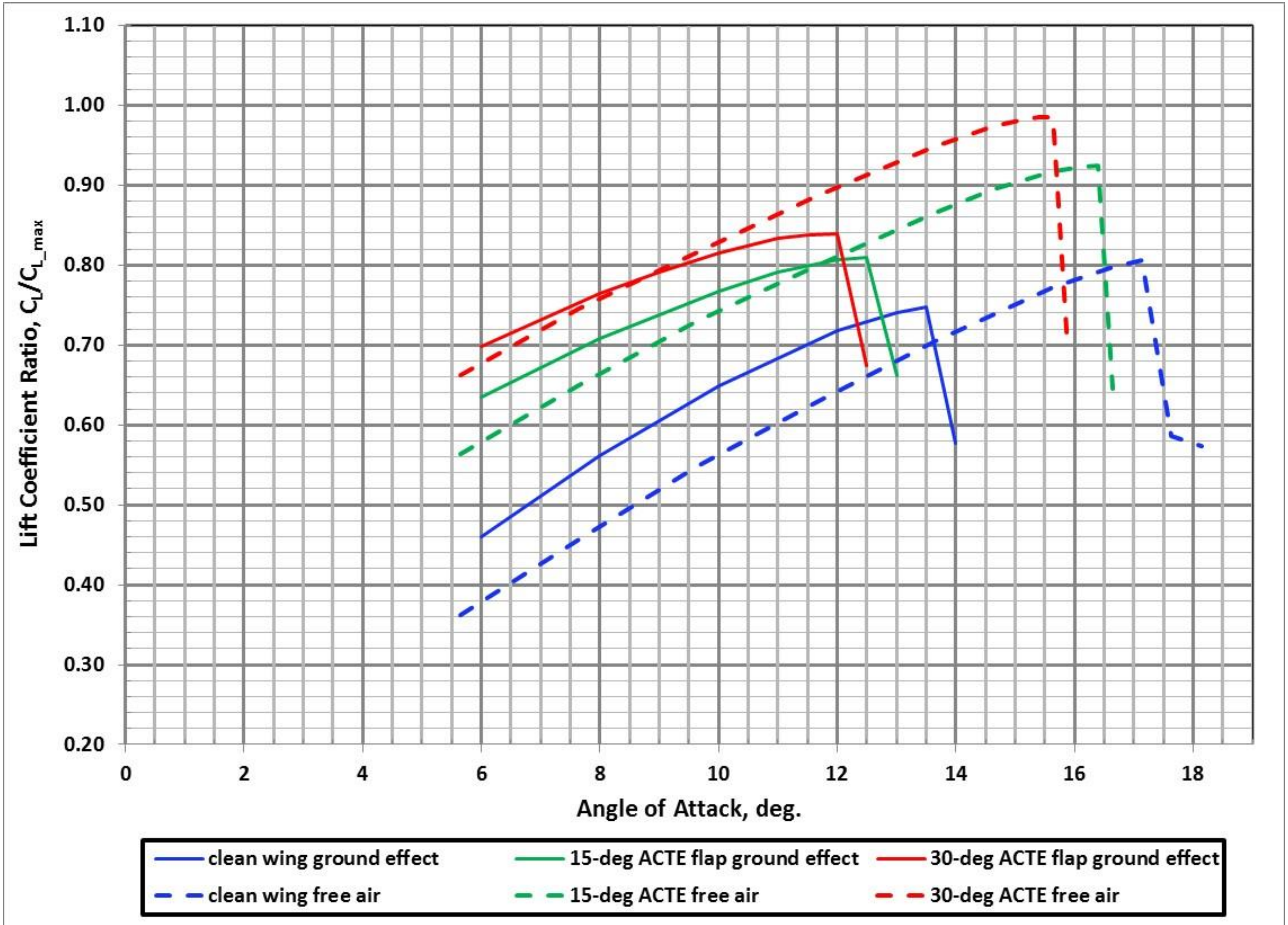


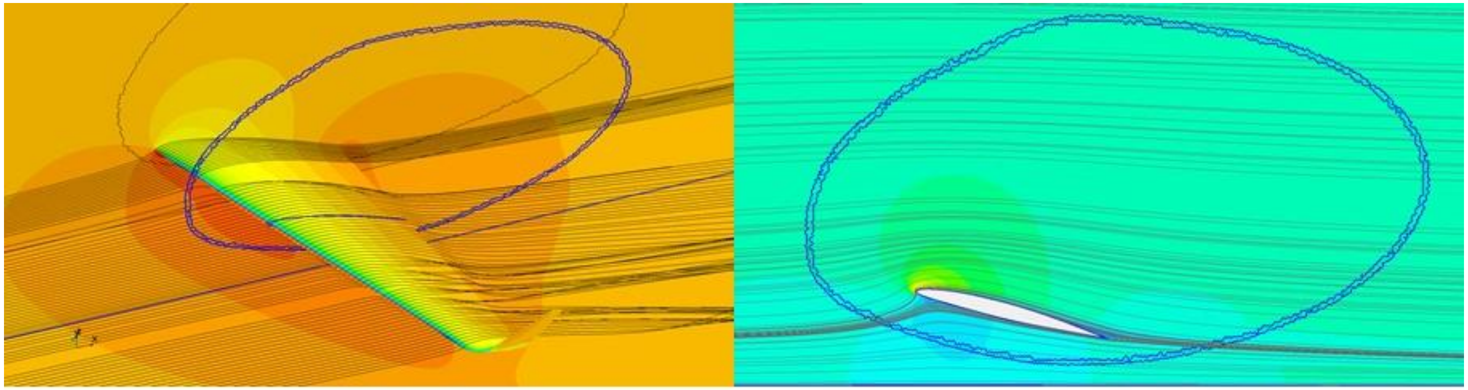
CFD strategy for generating wing lift curves

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

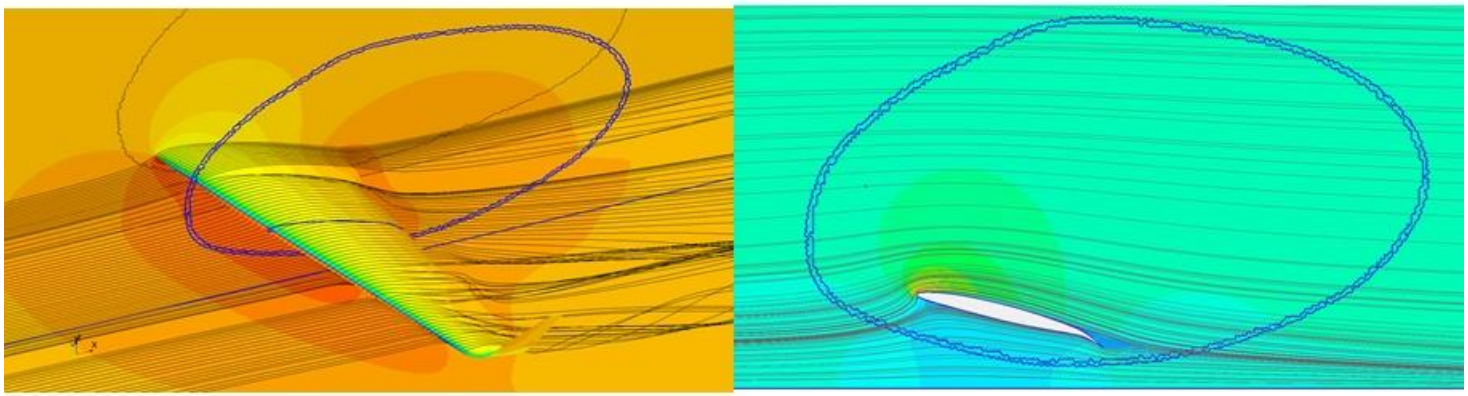
- With large values of AoA increment or large values of initial AoA, premature CFD wing stall occurred
- Starting AoA increment value was 2 deg
- Last AoA increment value was 0.5 deg
- Therefore, our stall solution is within 0.5-deg AoA tolerance
- We could use even smaller AoA increment if necessary

ACTE CFD Wing Stall Results

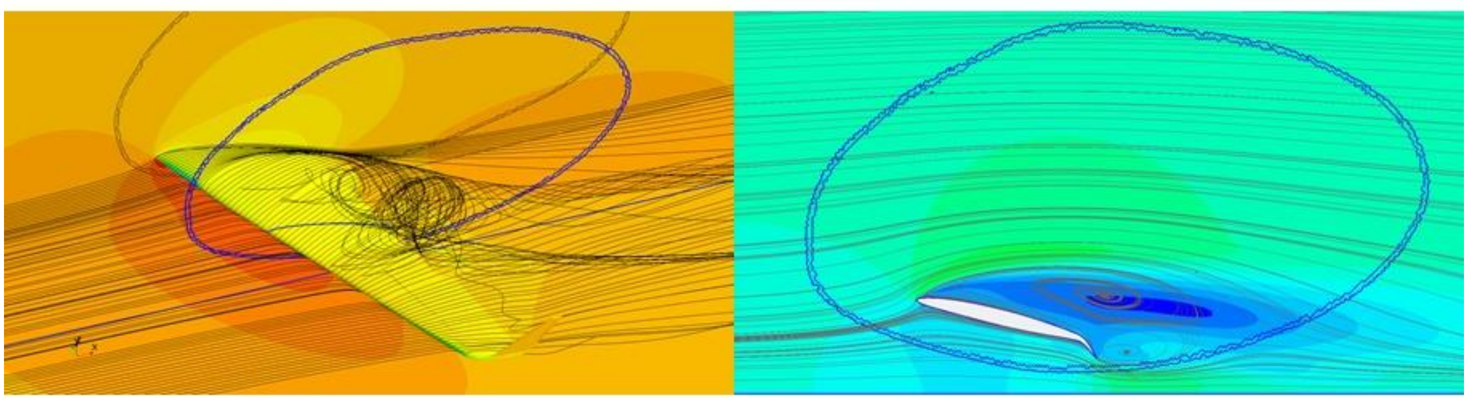




a. Clean wing, AoA = 13 deg



b. 15-deg ACTE, AoA = 12.5 deg



c. 30-deg ACTE, AoA = 12.5 deg

Conclusions

- Star-CCM+ CFD code can produce high-lift results that are within the spread of other CFD codes considered at the First AIAA High-Lift Prediction Workshop.
- Star-CCM+ CFD code was able to predict wing stall for the AIAA wing-body geometry to within 1 degree of angle of attack of the wind tunnel test data.
- Addition of the laminar-flow wing glove causes the modified and gloved aircraft wing to stall much earlier than the unmodified clean wing.
- The gloved wing also has a different stall characteristic than the clean wing, with no sharp lift drop-off at stall.
- 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 regions are predicted to occur directly above the SARGE glove and the ACTE flap.