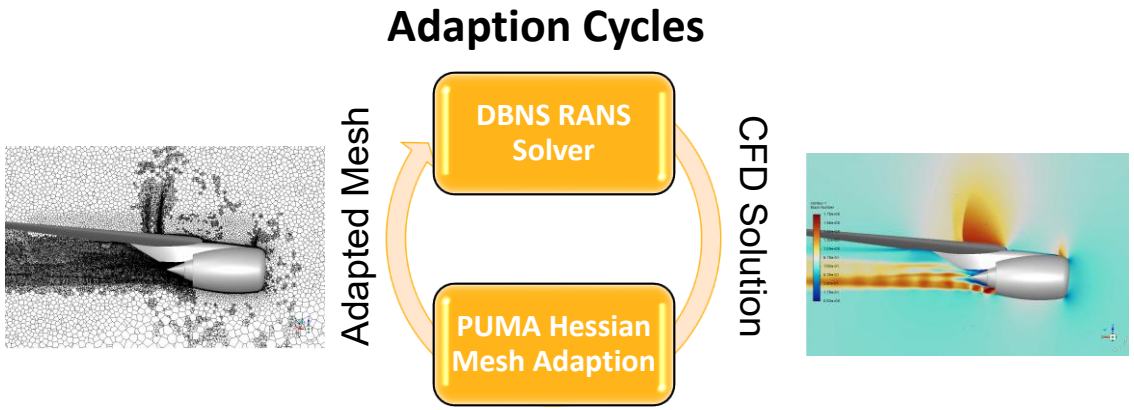
High Lift Workshop 6
Test Case 1

Cristhian Aliaga, Jeya Selva

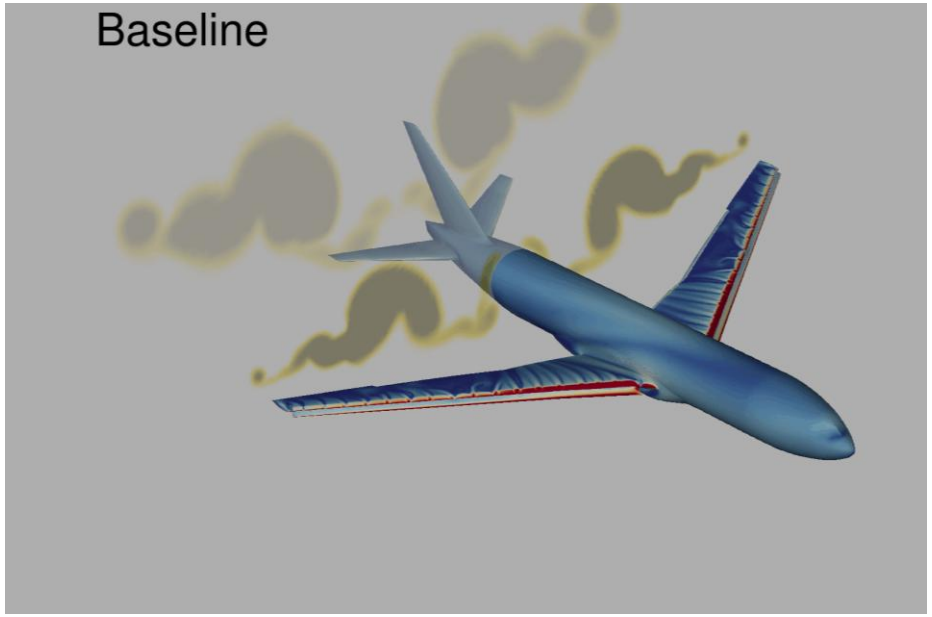
RANS TFG Meeting – May 20, 2026

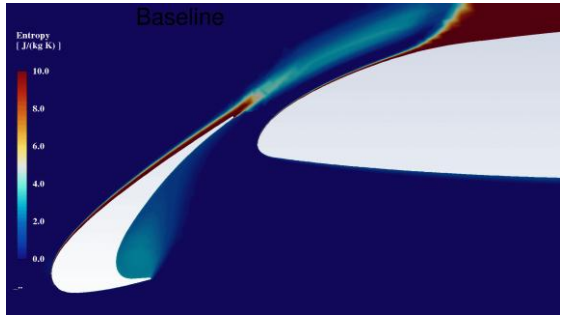
CFD Methodology – RANS (Fixed-grid & Adapted)

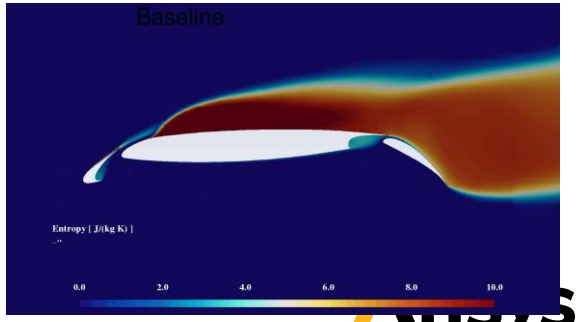
- **Solver Settings & Models**
  - Similar approach to what has been used during HLPW5
  - **RANS**
    - DBNS (Density Based Solver): Coupled Roe-FDS
    - Spatial discretization: 2nd Order Upwind
    - Iteration method: Implicit Euler, local time-stepping (steering to reach max CFL)
    - Initialization method: Full Multi Grid (FMG), cold start
    - Turbulence model – **SA**
    - Air as Ideal Gas with temperature dependent properties
    - Workshop provided meshes: Pointwise – HexVol (F1) – Quad dominant
  - **Mesh Adaption**
    - PUMA – Polyhedral Unstructured Mesh Adaption
    - Isotropically refines or coarsens cells
    - Used Combined Hessian Indicator - Entropy
      - Primitive of RANS (Density, Pressure, Velocity & Temperature)
      - Entropy
    - Solution interpolated between each adaption cycle
    - Number of Iterations per each adaption cycle - 2000
    - Wall surfaces and adjacent cells are not refined



HLPW5: Case 2.3 – AoA = 20.7°

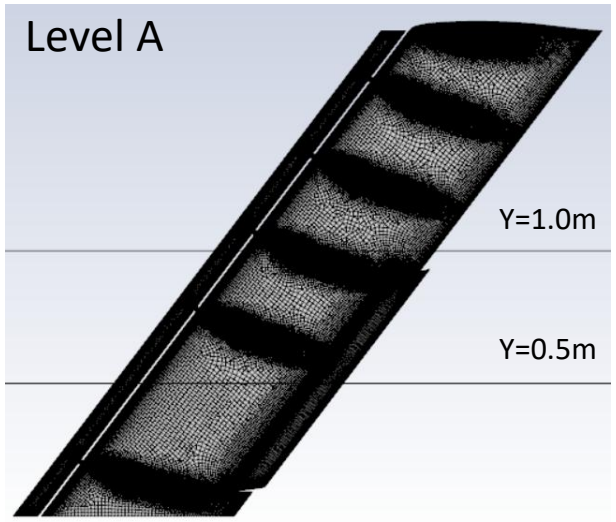


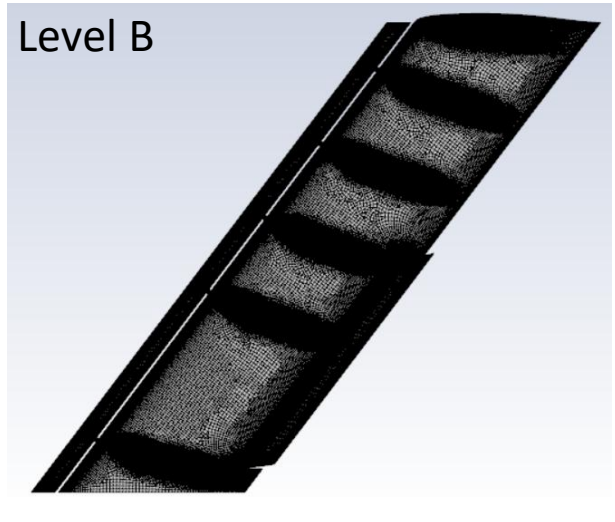


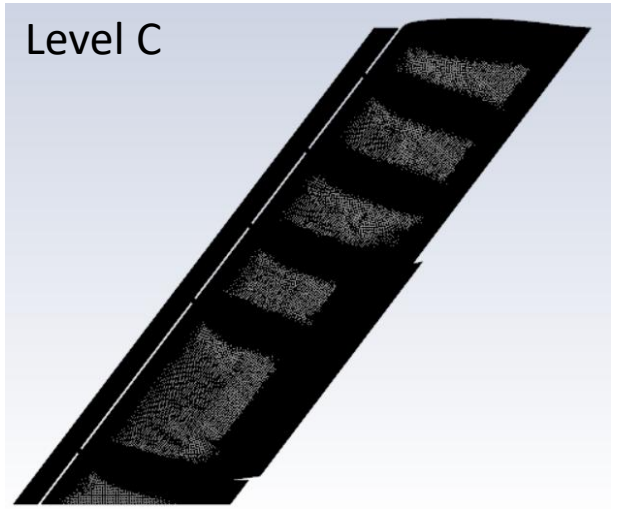


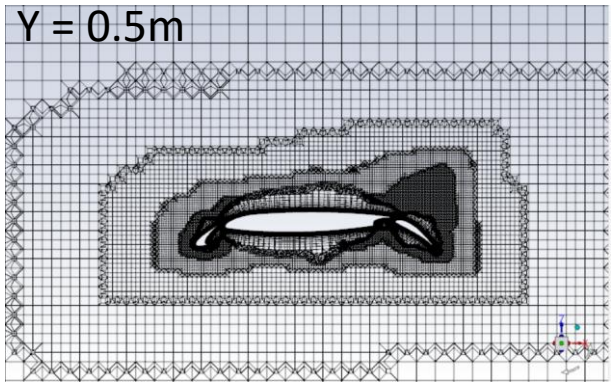
Fixed Grid

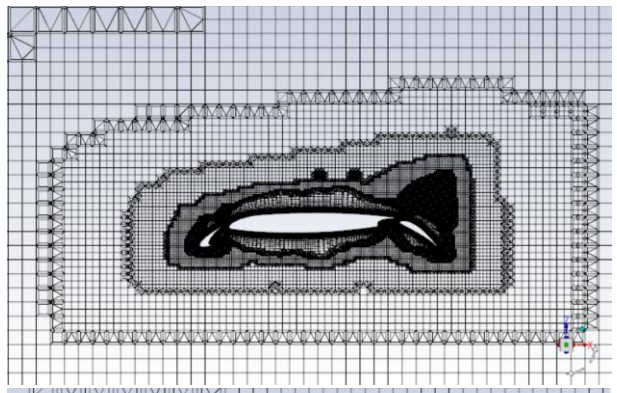
Pointwise Hex Dominant Mesh (R.1.TC1.03 Grid Family)

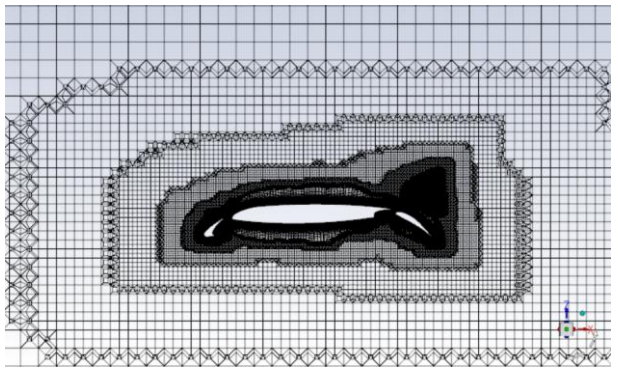


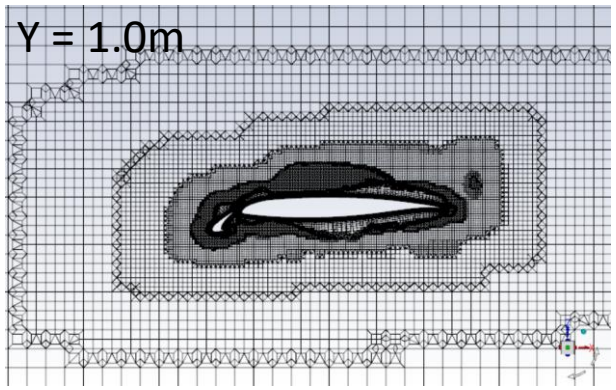


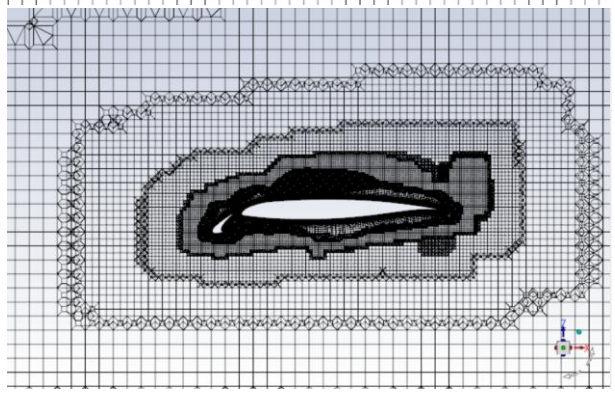


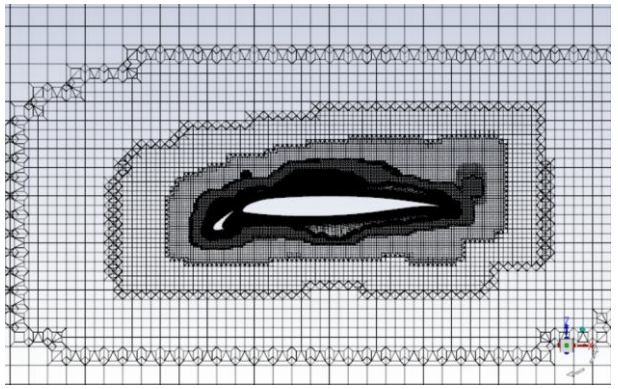












Pointwise – HexVol (F1) – Quad dominant

Grid Level	Cell Count	Node Count	Refinement Factor	Target y+
A	25,435,031	15,520,444	0.75	4/3
B	43,517,347	28,289,287	1.0	1.0
C	106,410,939	75,726,976	1.5	2/3
D	237,759,230	180,918,004	2.0	0.5
E	568,667,444	457,688,006	3.0	1/3

Ansys
part of SYNOPSYS®

Fluent-Aero Settings

Properties - Geometric Properties

Domain Type	Freestream
Domain Dimension	3D
Lift Direction at AoA = 0 Degrees	Z+
Drag Direction at AoA = 0 Degrees	X+
Pitching Moment Direction	Y+
Moment Center: X Position [m]	0.884128
Moment Center: Y Position [m]	0
Moment Center: Z Position [m]	0
Reference Length [m]	0.762
Reference Area [m^2]	1.39355
Compute Projected Area	☐

Properties - Airflow Physics

Solver	
Type	Density based
Time	Steady
Models	
Viscous	Spalart-Allmaras
Corner Flow Correction	Disabled
Curvature Correction	Disabled
Reactions	Disabled
Two Temperature	Disabled
Knudsen Number Criterion	Disabled
Materials	
Air Properties	Air default

Properties - Simulation Conditions

Design Points	
Number of Design Points	6
Flight Conditions	
Flow Speed	
Parameter	Mach
Distribution	Constant
Mach Number	0.2
Flow Direction	
Parameter	AoA
Distribution: Angle of Attack	Custom
Pressure and Temperature	
Parameter	Reynolds
Distribution: Reynolds Number	Constant
Reynolds Number	3.55e+06
Atmospheric Static Pressure [Pa]	101355
Distribution: Temperature	Constant
Atmospheric Static Temperature [K]	288.15
Turbulence	
Parameter	Intensity and Viscosity R
Distribution: Turbulent Viscosity Ratio	Constant
Turbulent Viscosity Ratio	1e-05
Wall Conditions	
Apply to All Walls	☑

Properties - Solve

Iterations	5000
Convergence Settings	Default
Convergence Criteria	Default

Max CFL of 100 for AoAs = [10°, 25°]
Max CFL of 20 for AoA = 30° and 35 °

Geometry Reference Quantities

Mean Aerodynamic Chord (MAC)	30 inches
Reference semi-span	72 inches
Moment Reference Center (MRC)	x = 34.8082 inches, y = 0.0 inches, z = 0 inches
Semi-span model reference area (Sref)	2,160 in^2
Leading Edge Deflection (reference)	30°
Trailing Edge Deflection (reference)	37°

Case Parameters and Requirements

Mach Number	0.20
Chord Reynolds Number	3.55 x 10^6
Angles of Attack	10°, 15°, 20°, 25°, 30°, 35°
Reference Static Temperature	518.67 °R
Reference Static Pressure	14.696 psi
Important Details	• Geometry is provided in full-scale inches • When using a dimensional code, it is recommended to adjust viscosity to match requested Reynolds number, this should result in reference quantities of SSL air. • All simulations are run Free-Air with no tunnel or support systems included • Symmetry boundary condition is typically applied at y = 0.0 inches.

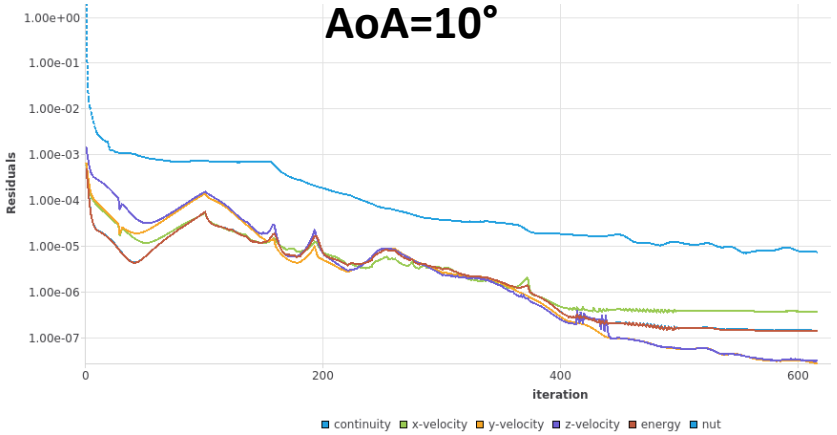
Input:Design Points

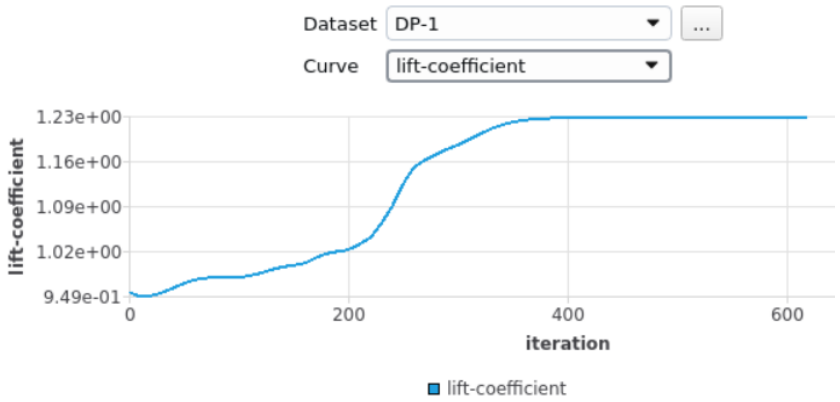
Filter | Filter Text

DP	Angle of Attack [deg]	Status
1	10	Needs Update
2	15	Needs Update
3	20	Needs Update
4	25	Needs Update
5	30	Needs Update
6	35	Needs Update

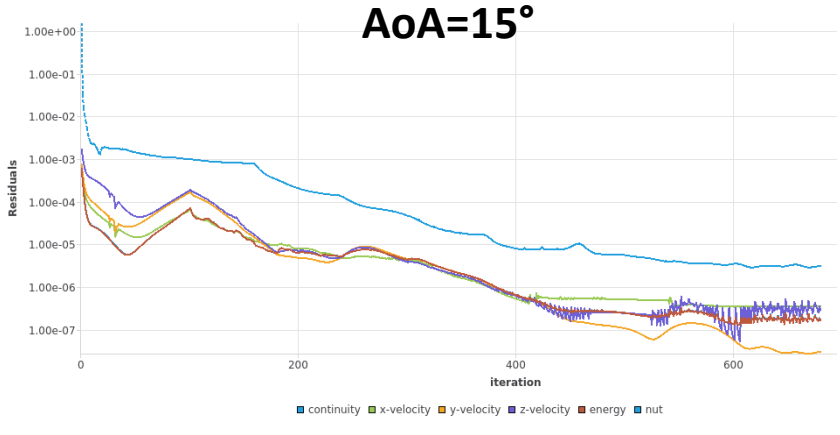
Level A Mesh: Convergence Plots

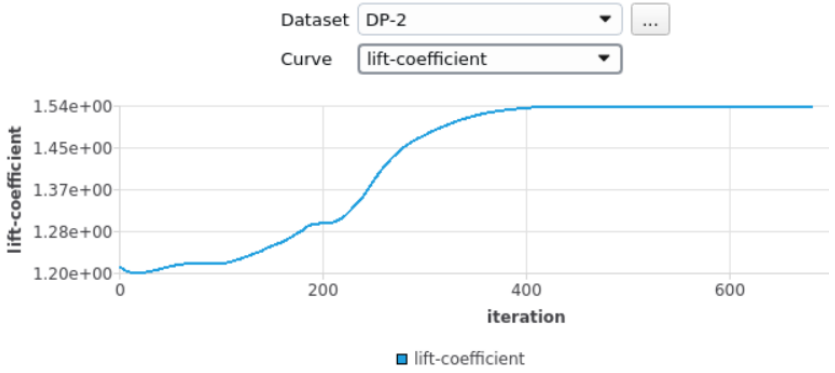
AoA=10°



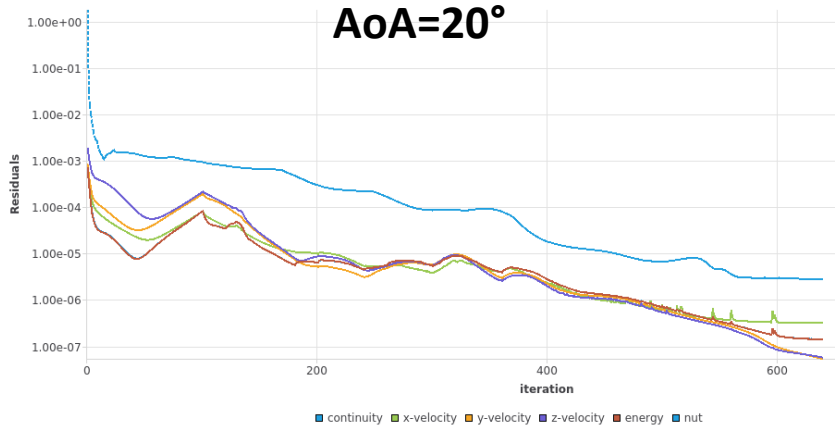


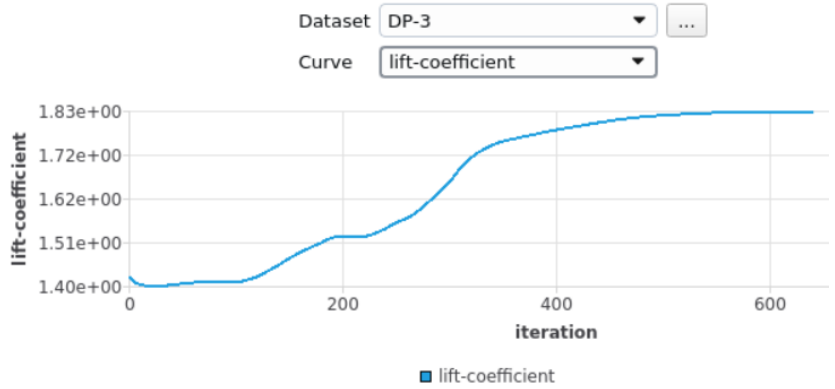
AoA=15°



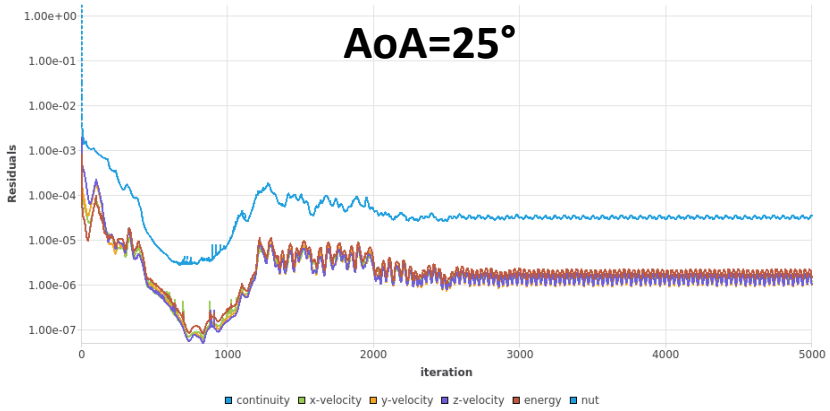


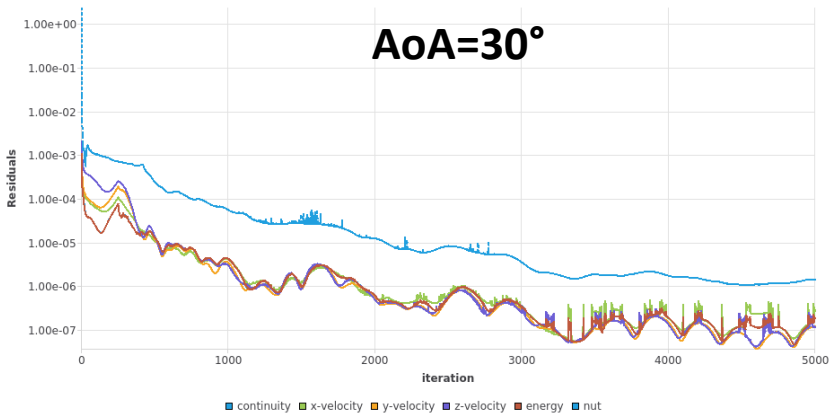
AoA=20°

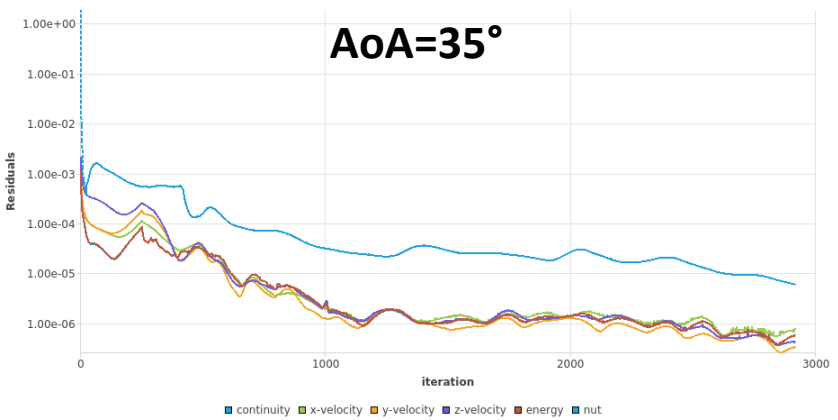


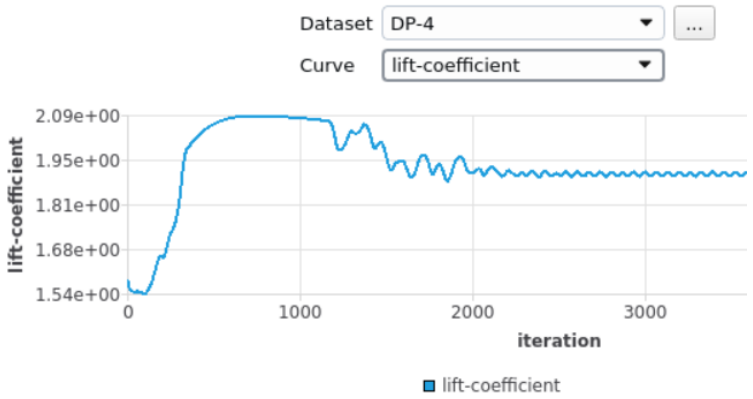


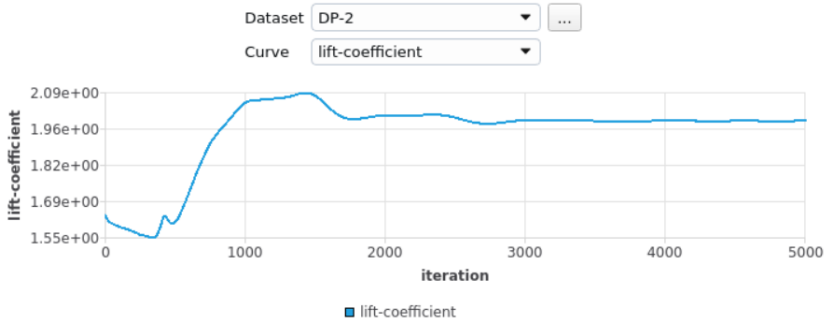
Level A Mesh: Convergence Plots

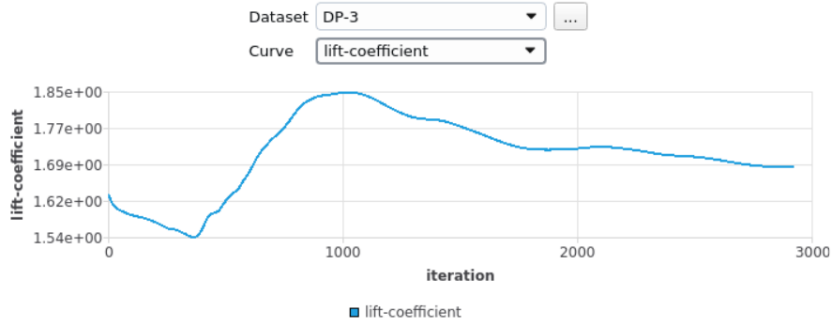






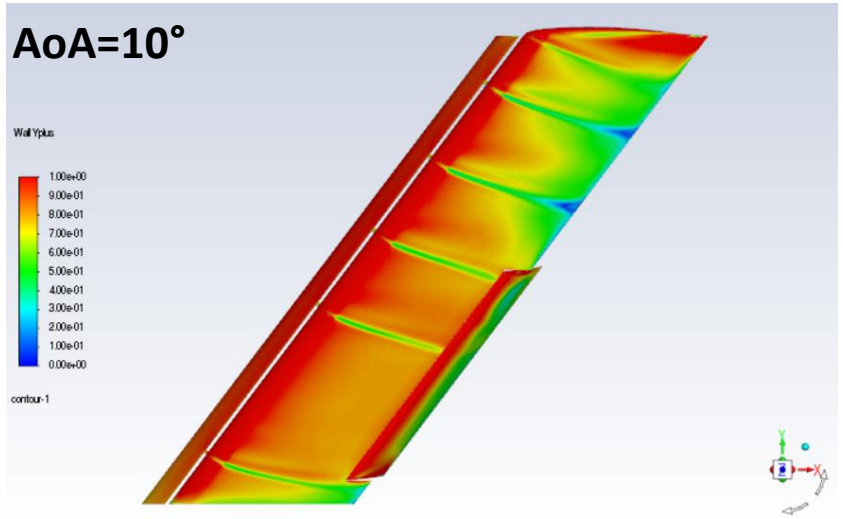


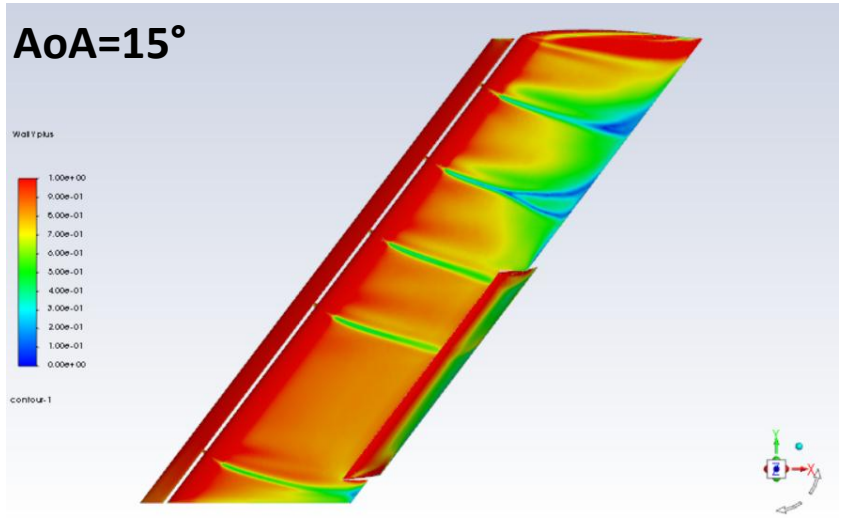


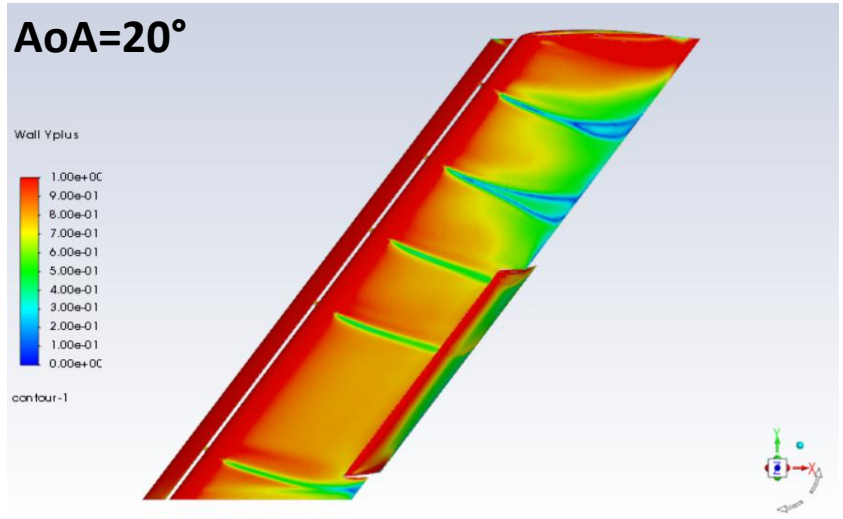


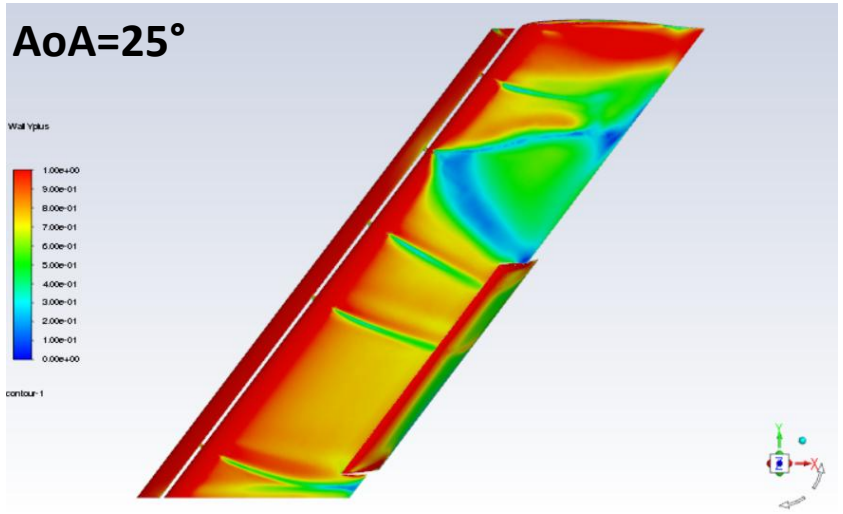
Level A Mesh: Wall Y+ Contours

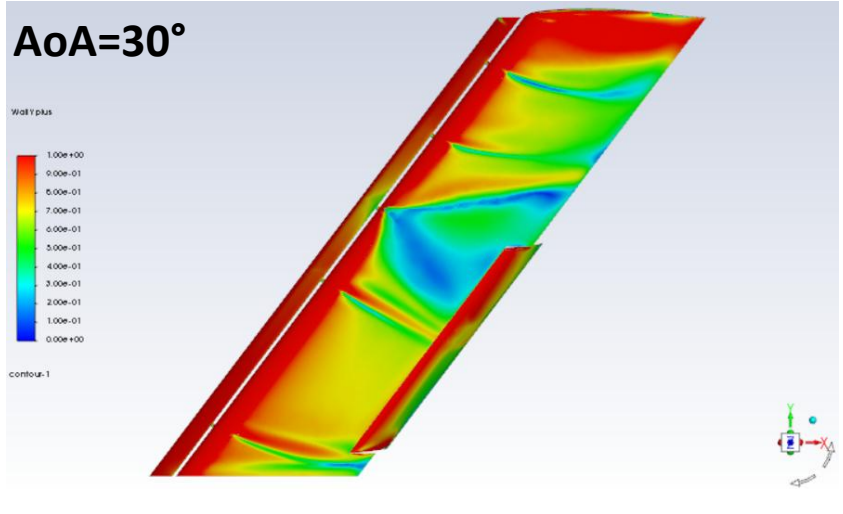
$y^+_{max} = \sim 3.0$

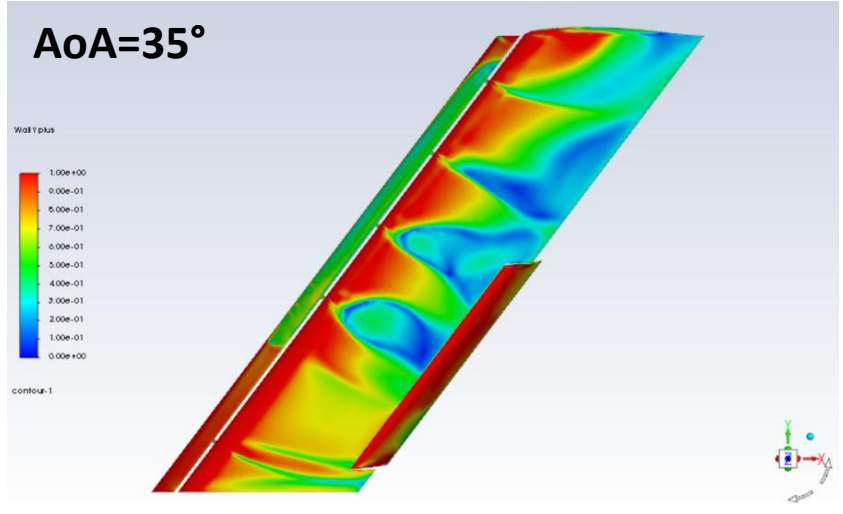






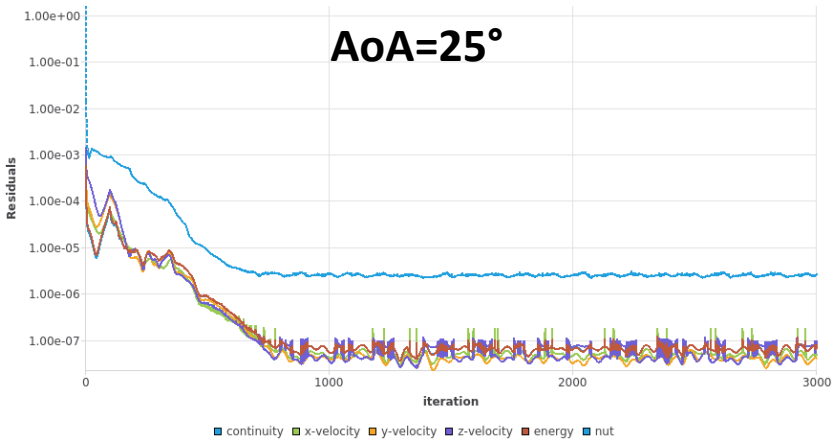


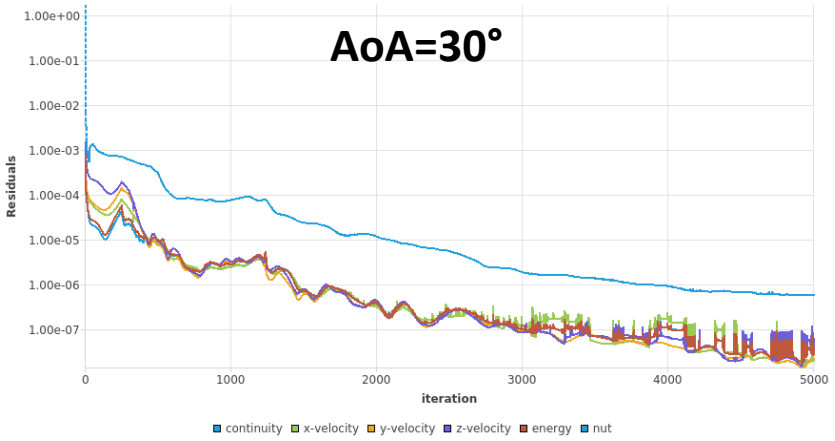


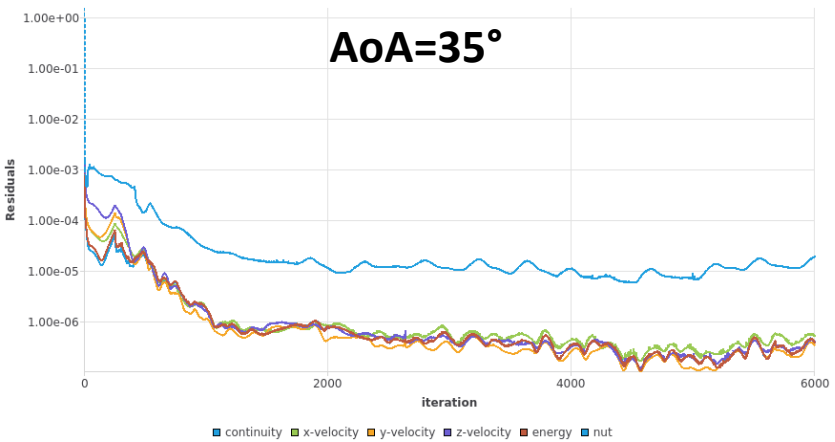


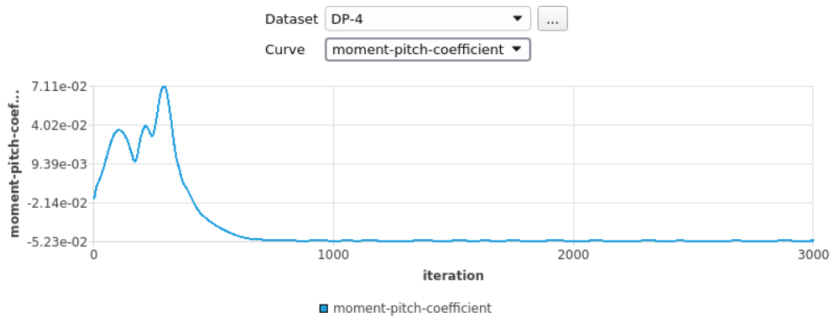
Ansys part of SYNOPSYS®

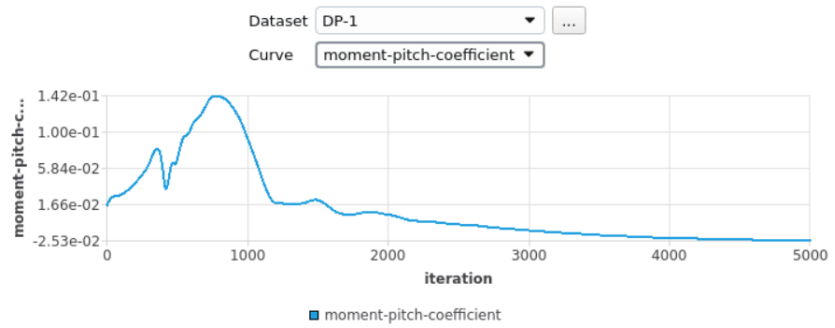
Level B Mesh: Convergence Plots

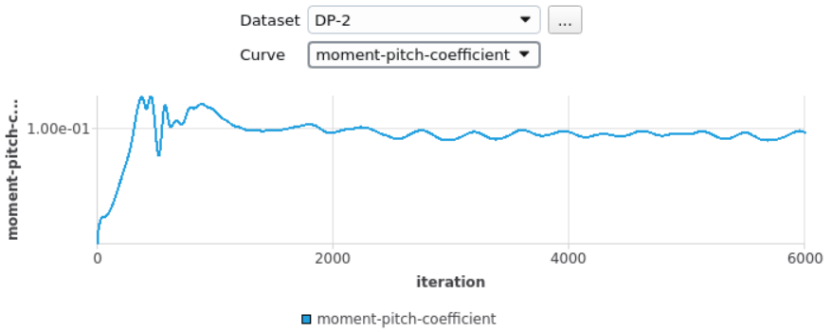






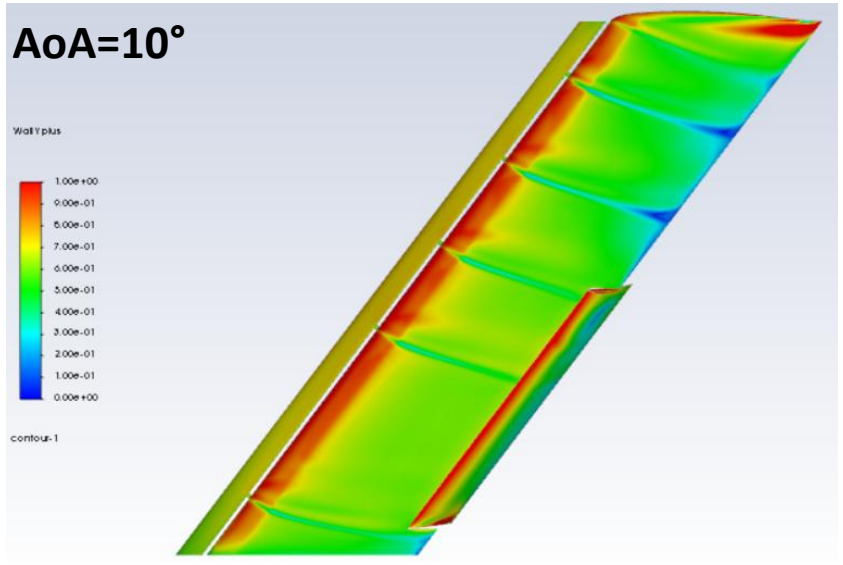


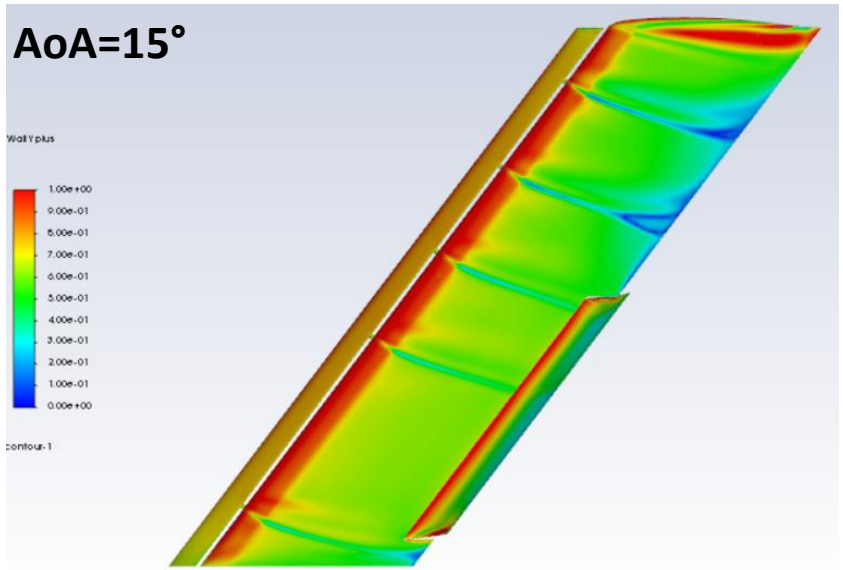


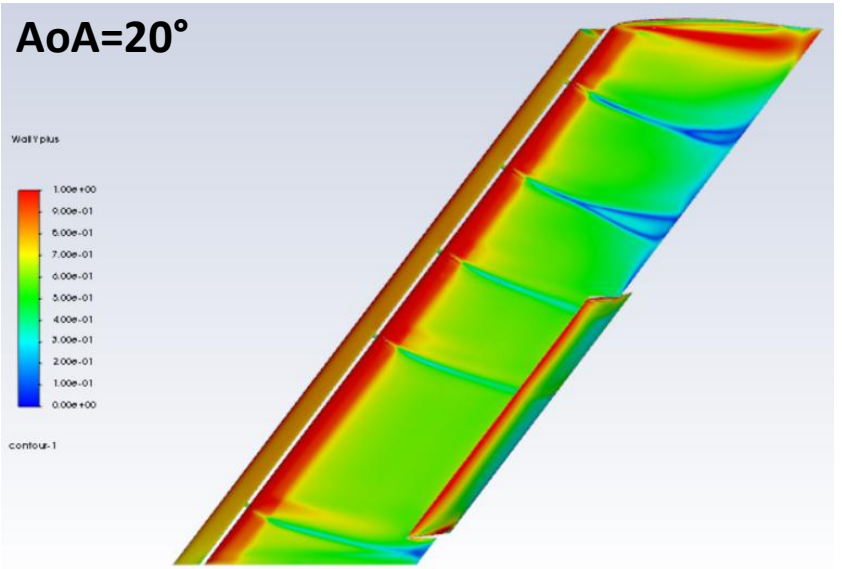


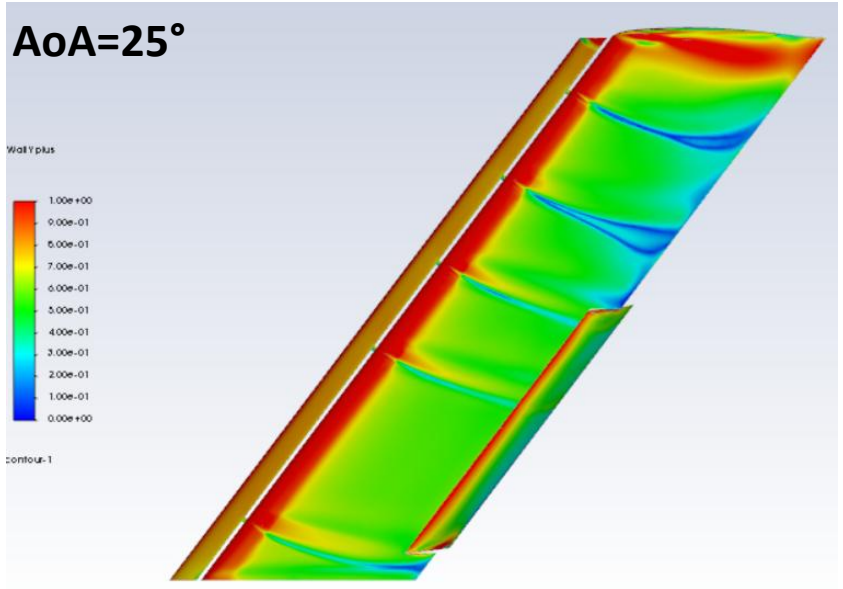
Level B Mesh: Wall Y+ Contours

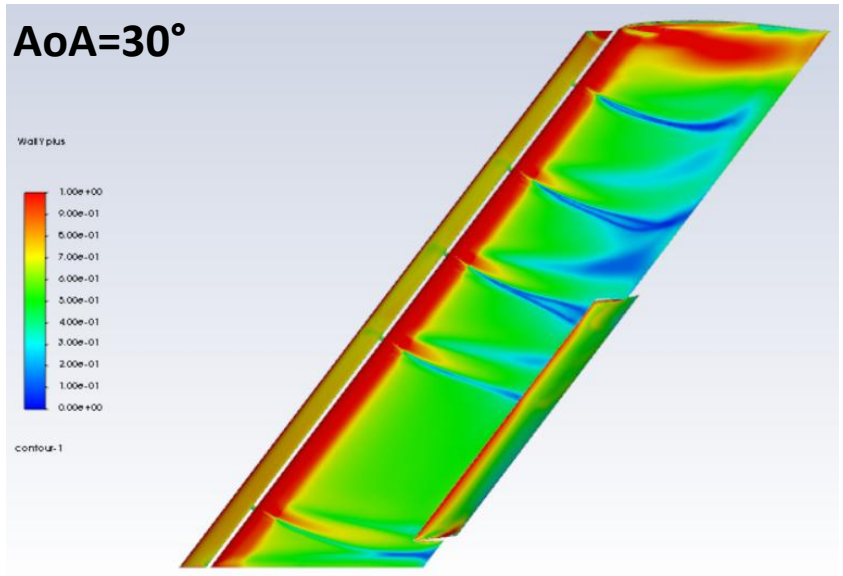
$y^+_{max} = \sim 2.4$

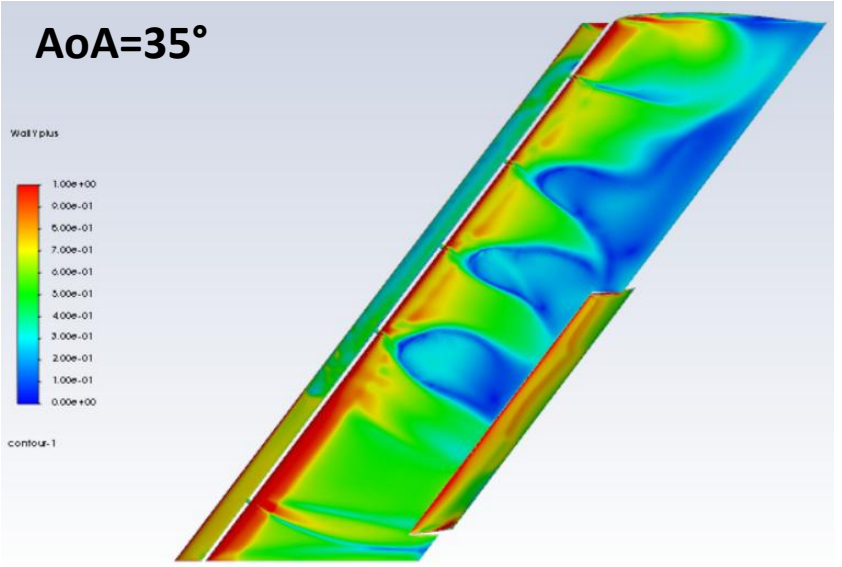






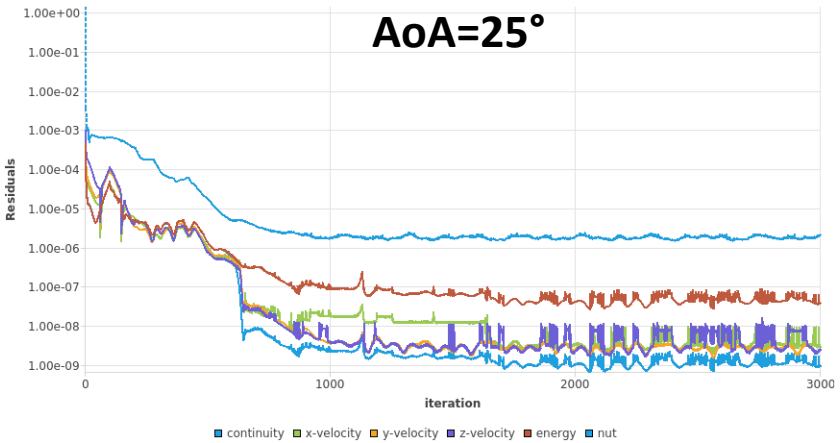


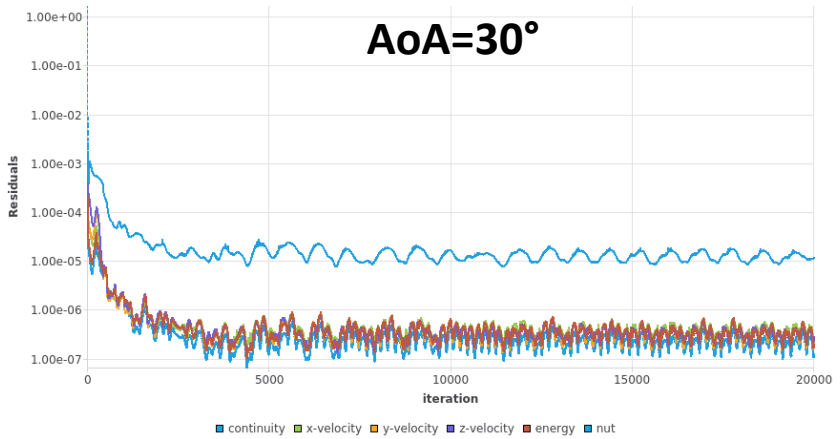


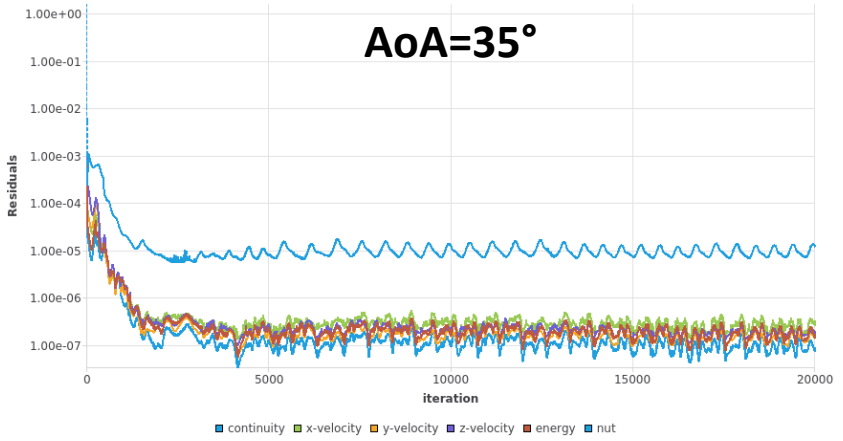


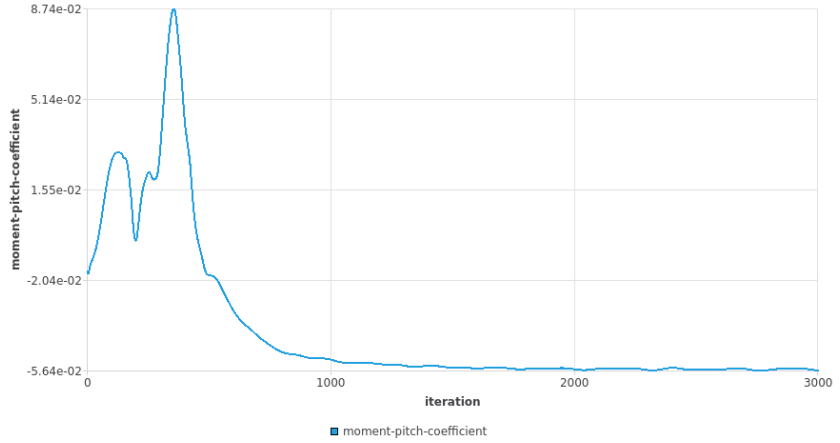
Ansys part of SYNOPSYS®

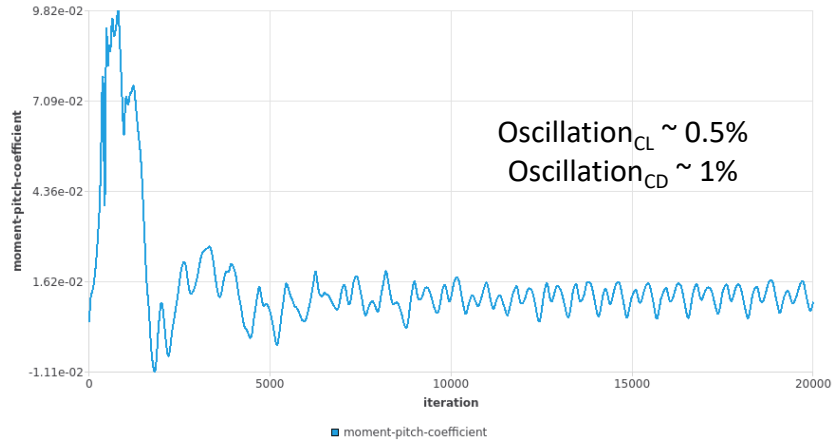
Level C Mesh: Convergence Plots

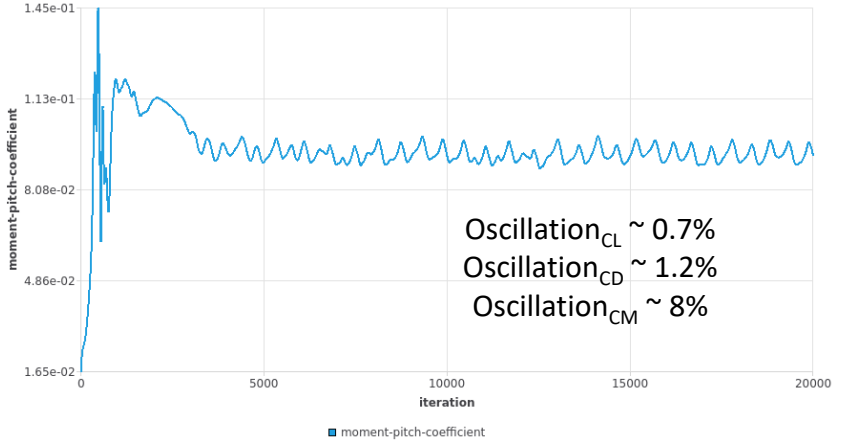






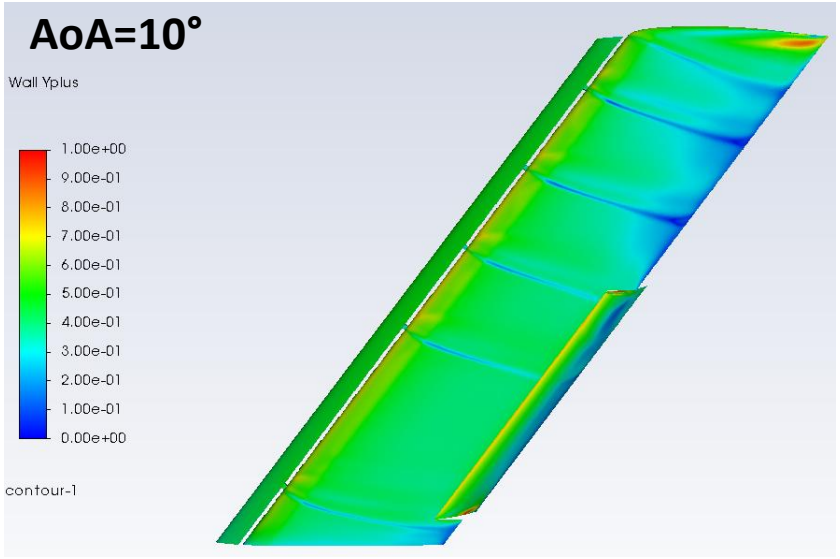


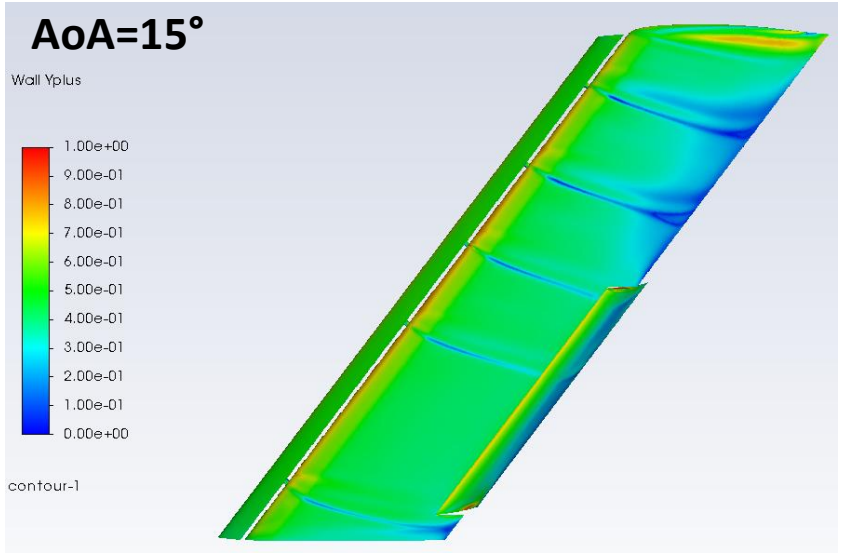


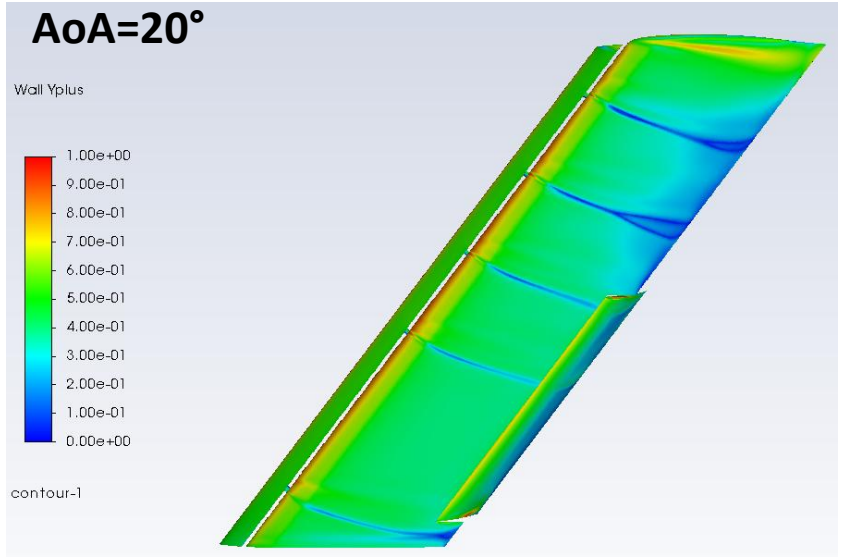


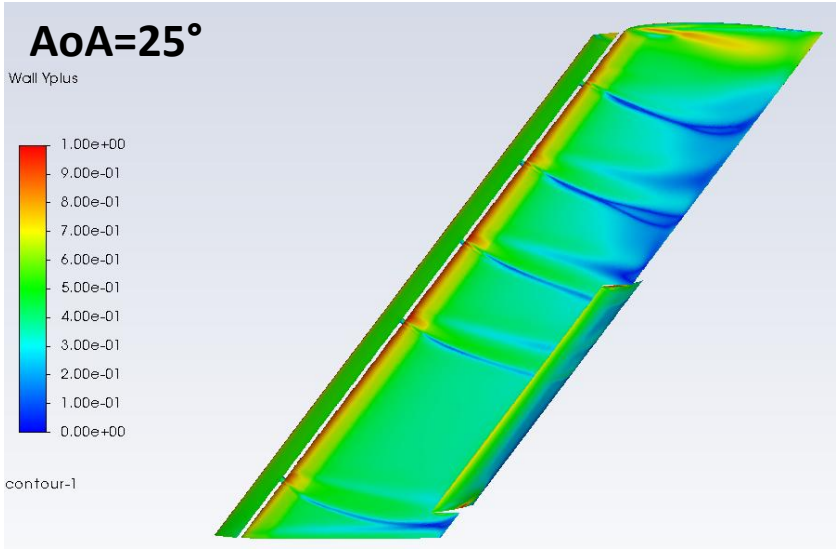
Level C Mesh: Wall Y+ Contours

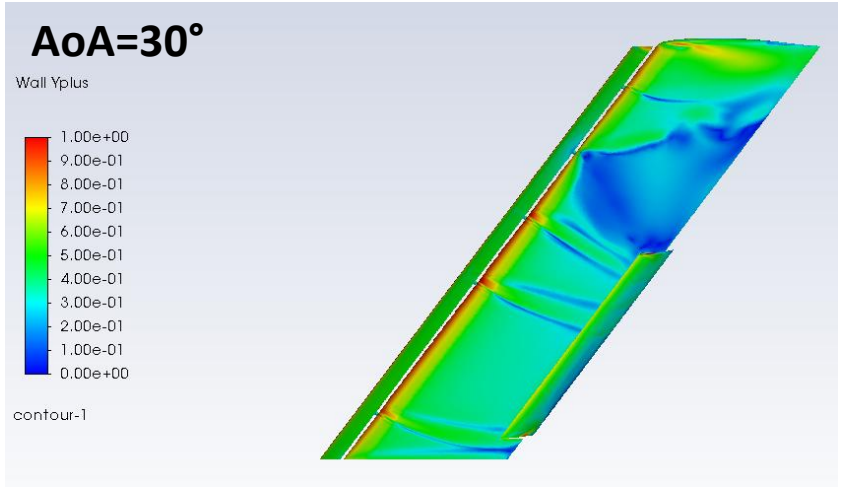
$y^+_{max} = \sim 1.8$

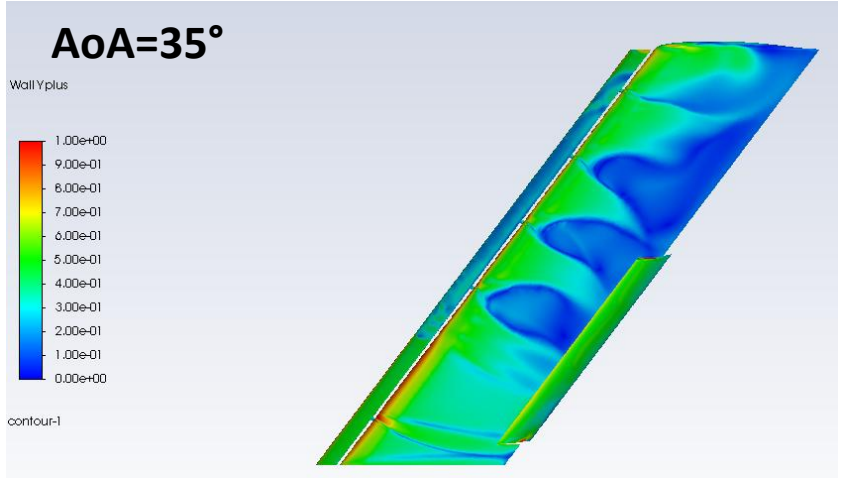






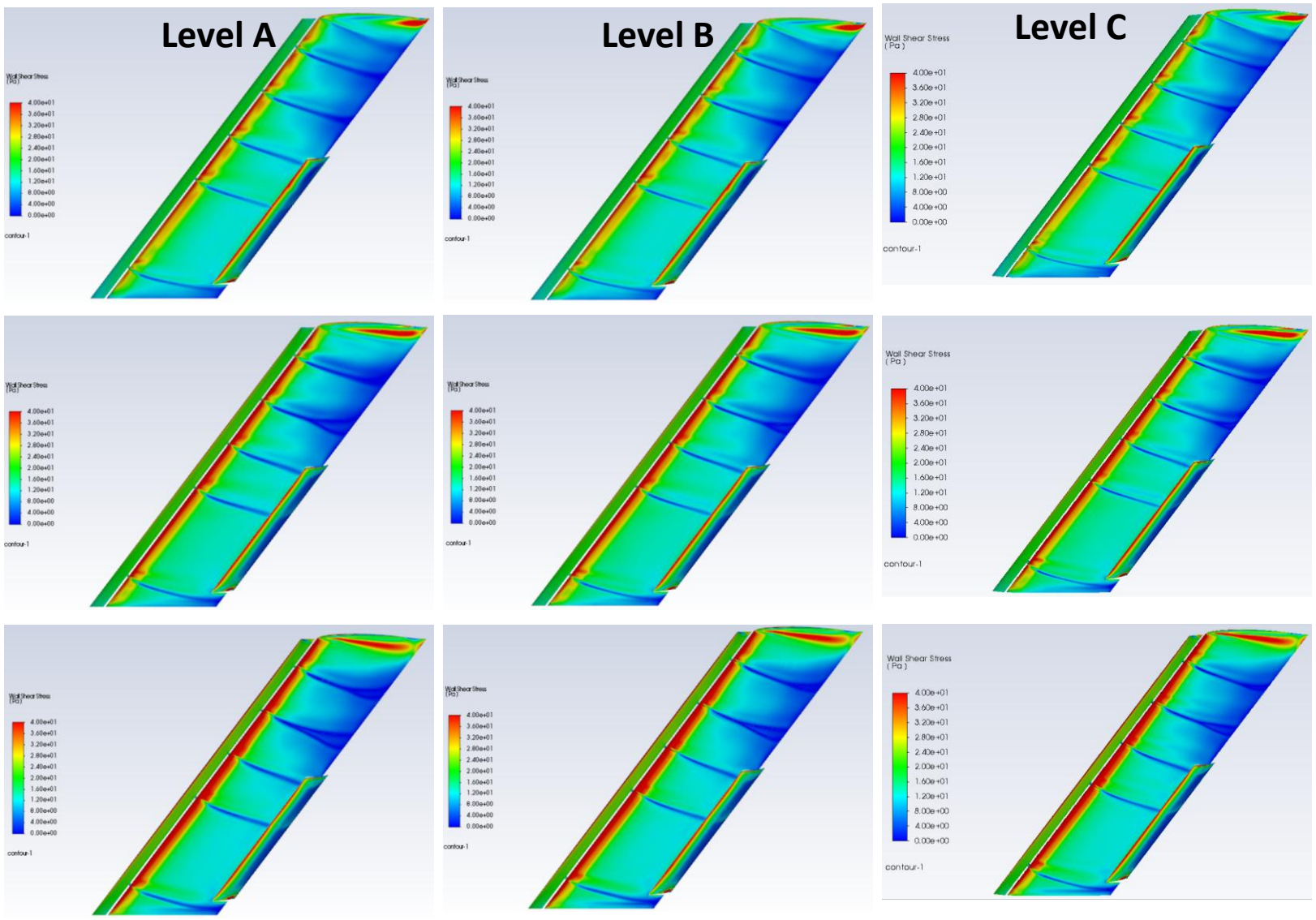






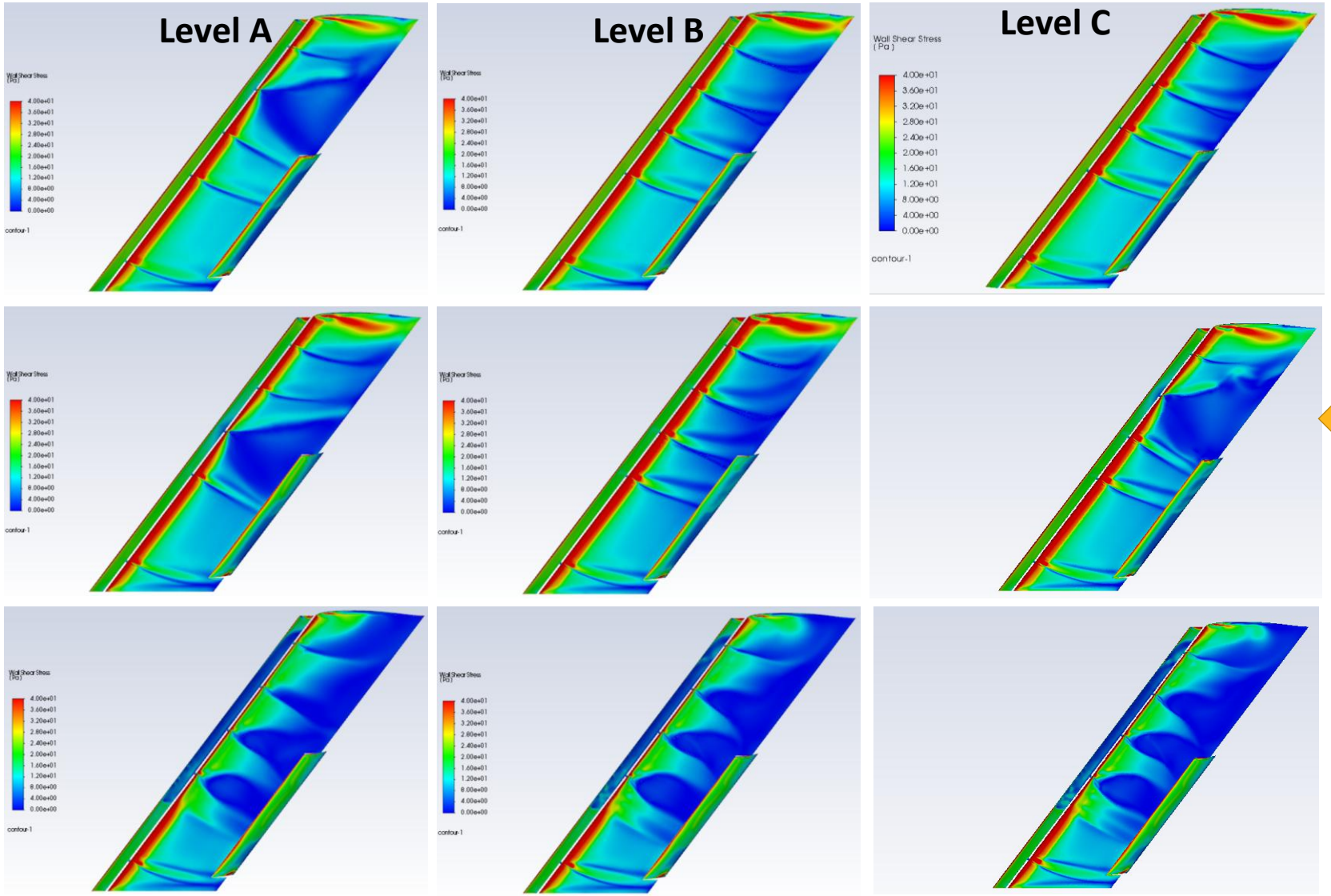
Ansys part of SYNOPSYS®

Shear Stress Contours – Level A to C



Legend Range: 0 – 40Pa

Shear Stress Contours – Level A to C

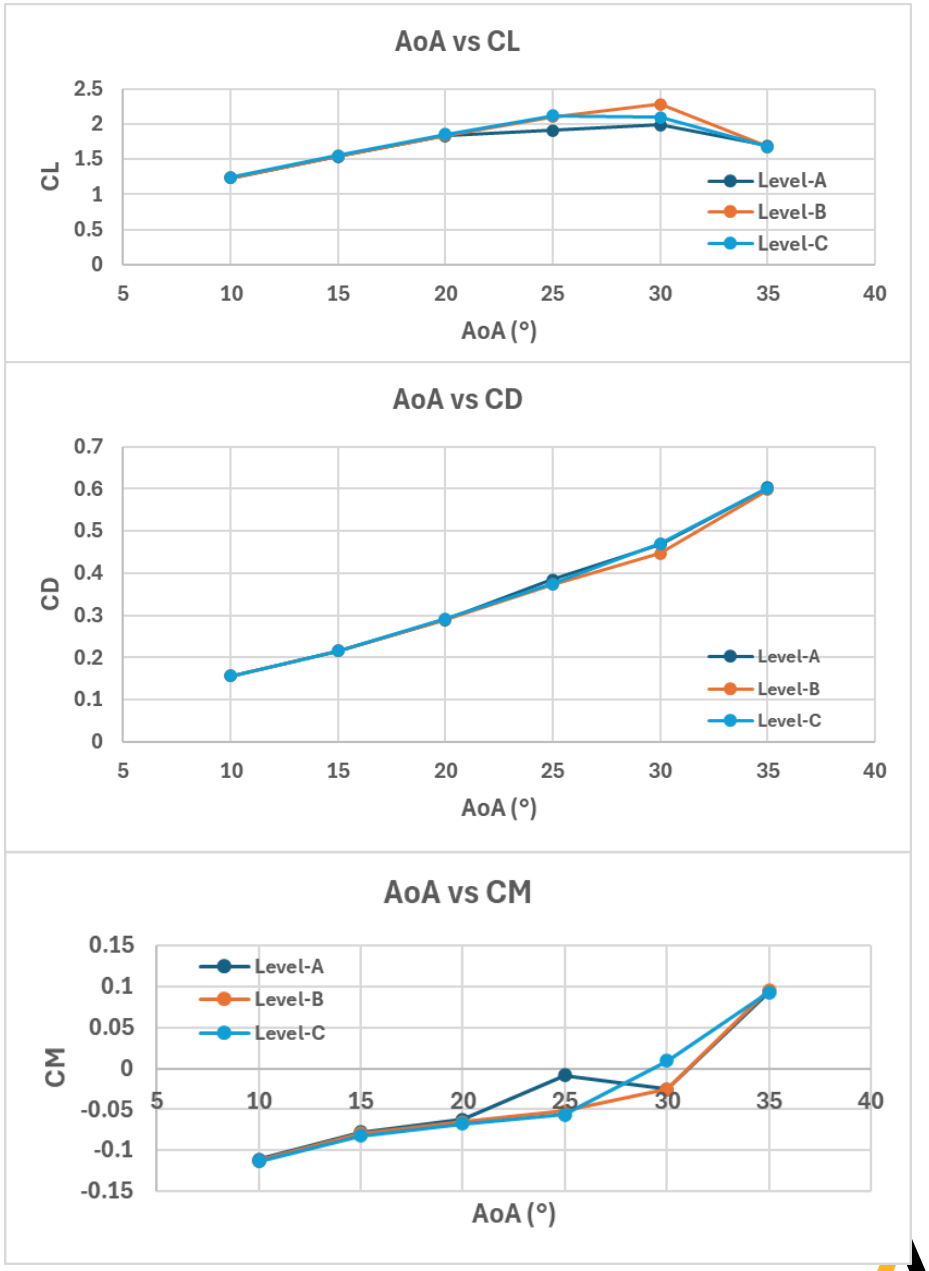


Study for Mesh Adaption

Ansys part of SYNOPSYS®

Observations

- Flow separation or pizza slices occur on the second to last and on the third slat bracket at high angles of attack: 25°, 30°, 35°.
- As the mesh gets finer, only separation at AoA = 30° & 35° persists. Effects of slat bracket rolling vortices on the suction side of the wing are less diffused.
- At low AoAs, simulations can be run with high CFL (100) while at high AoAs, the maximum CFL had to be reduced (CFL=20) to prevent divergence.
- Next, mesh adaption on AoA=30° using different mesh refinement levels.

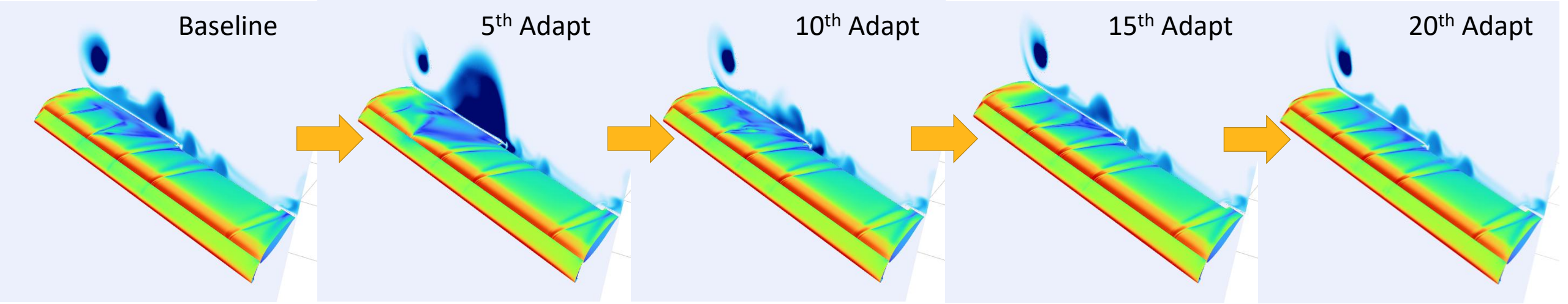


Mesh Adaption

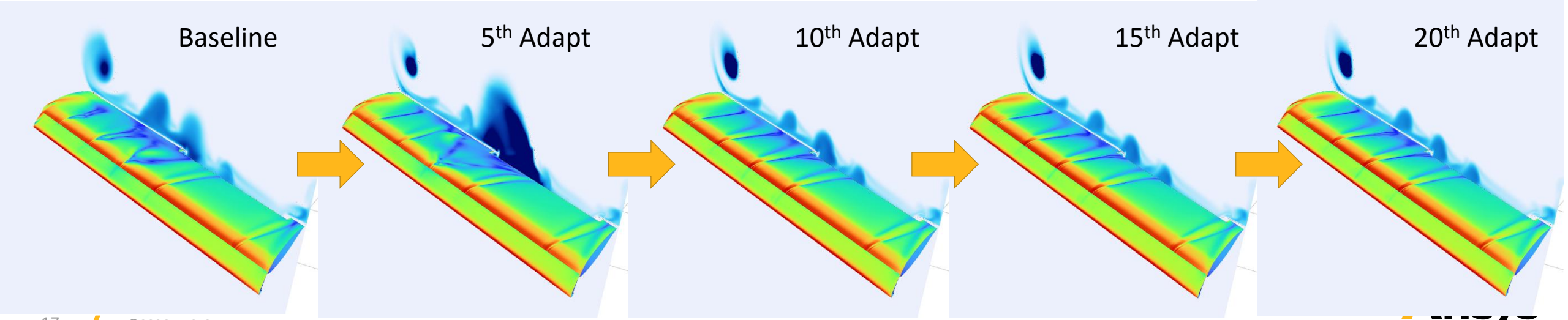
AoA = 30°

Mesh Adaption on Level A Mesh at AoA = 30°

CFL = 20

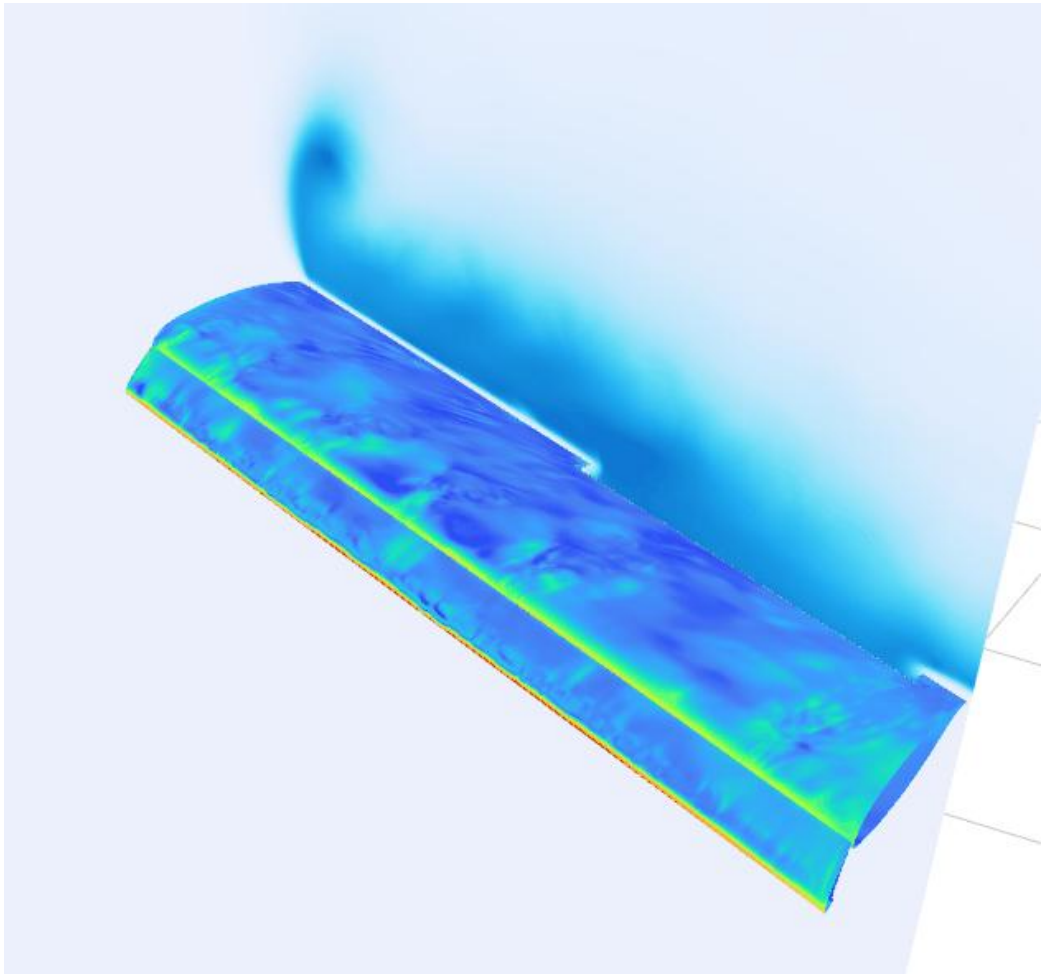


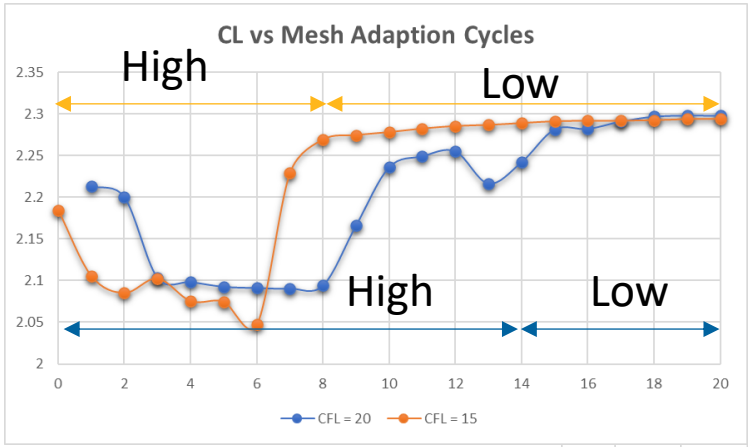
CFL = 15

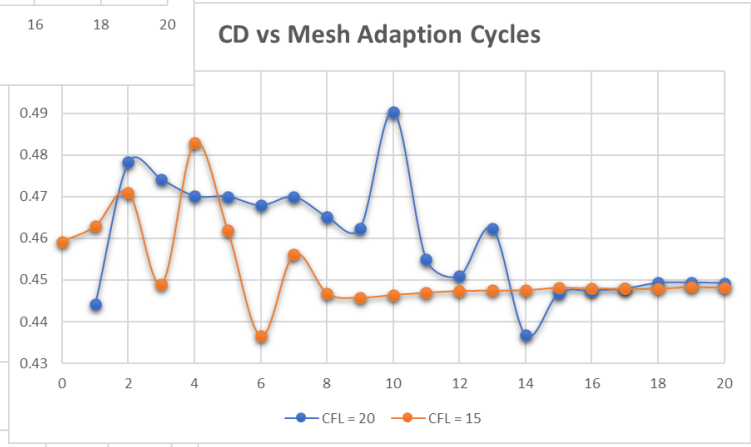


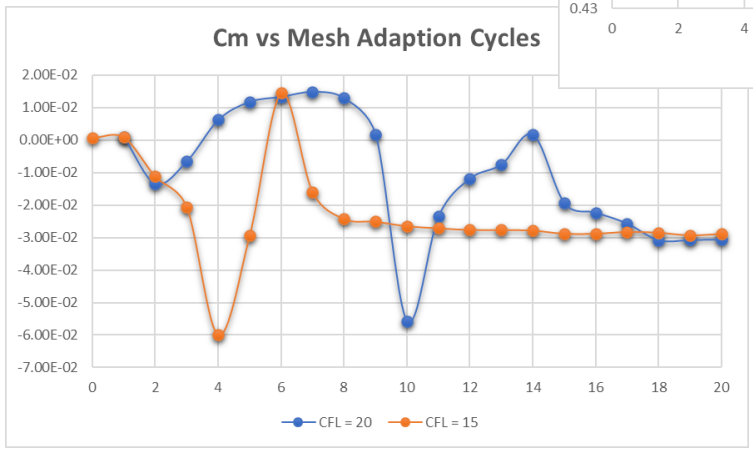
Mesh Adaption on Level A Mesh at AoA = 30°

CFL = 20



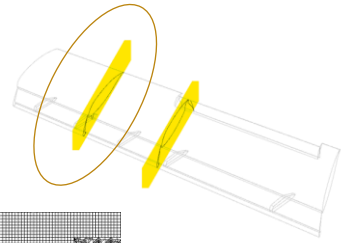




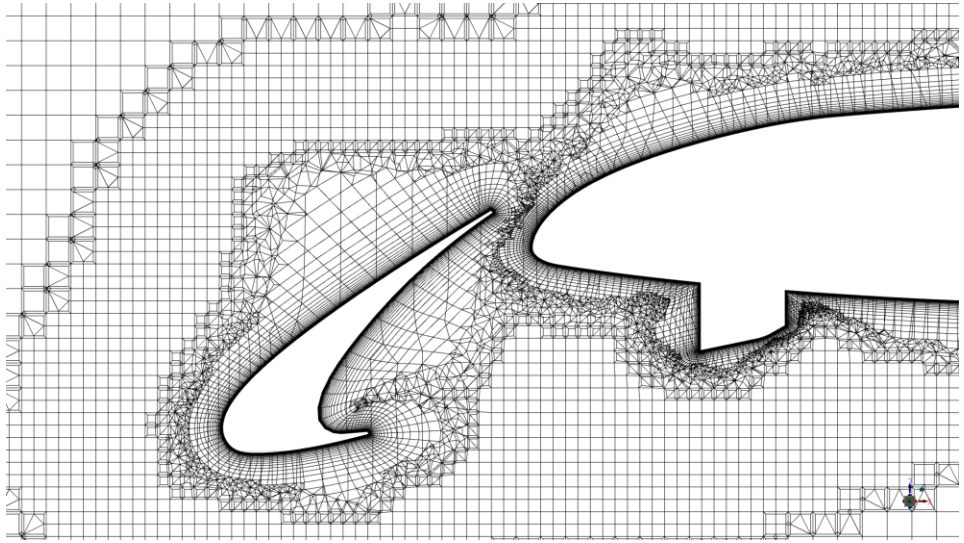


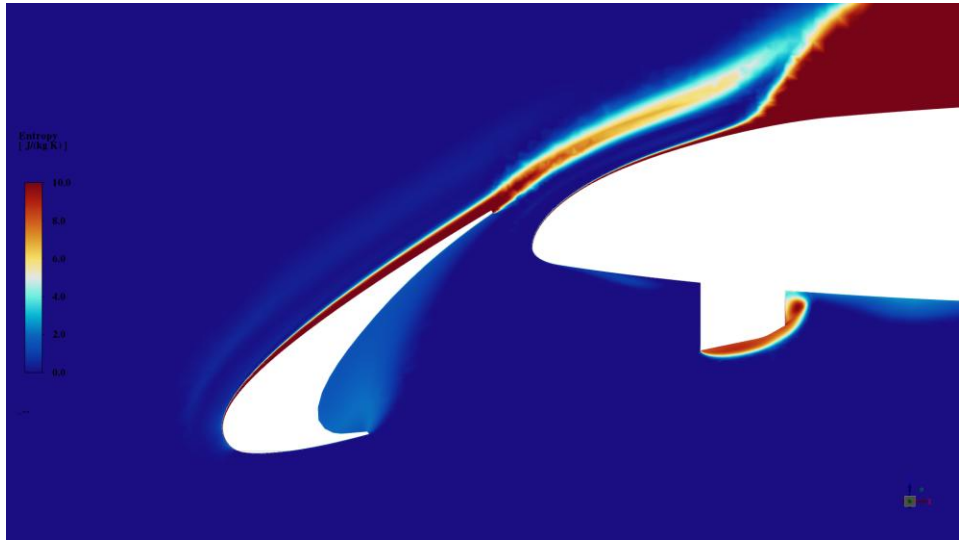
Difference in aerodynamic coefficients between the last 3 adaption cycles is below 0.7%

Mesh Adaption on Level A Mesh at AoA = 30° - CFL = 20

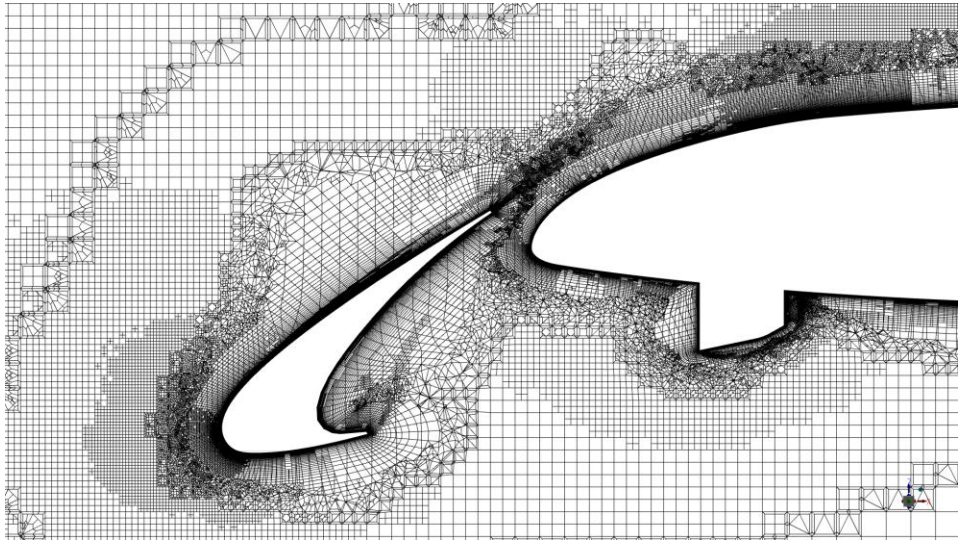


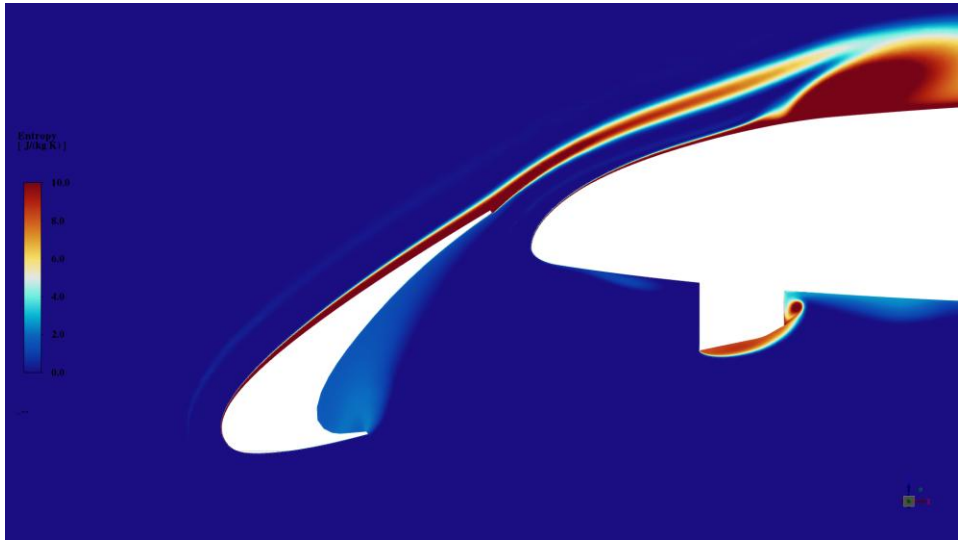
Baseline



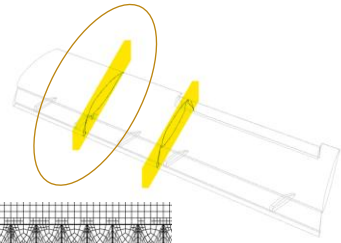


20th Adapt

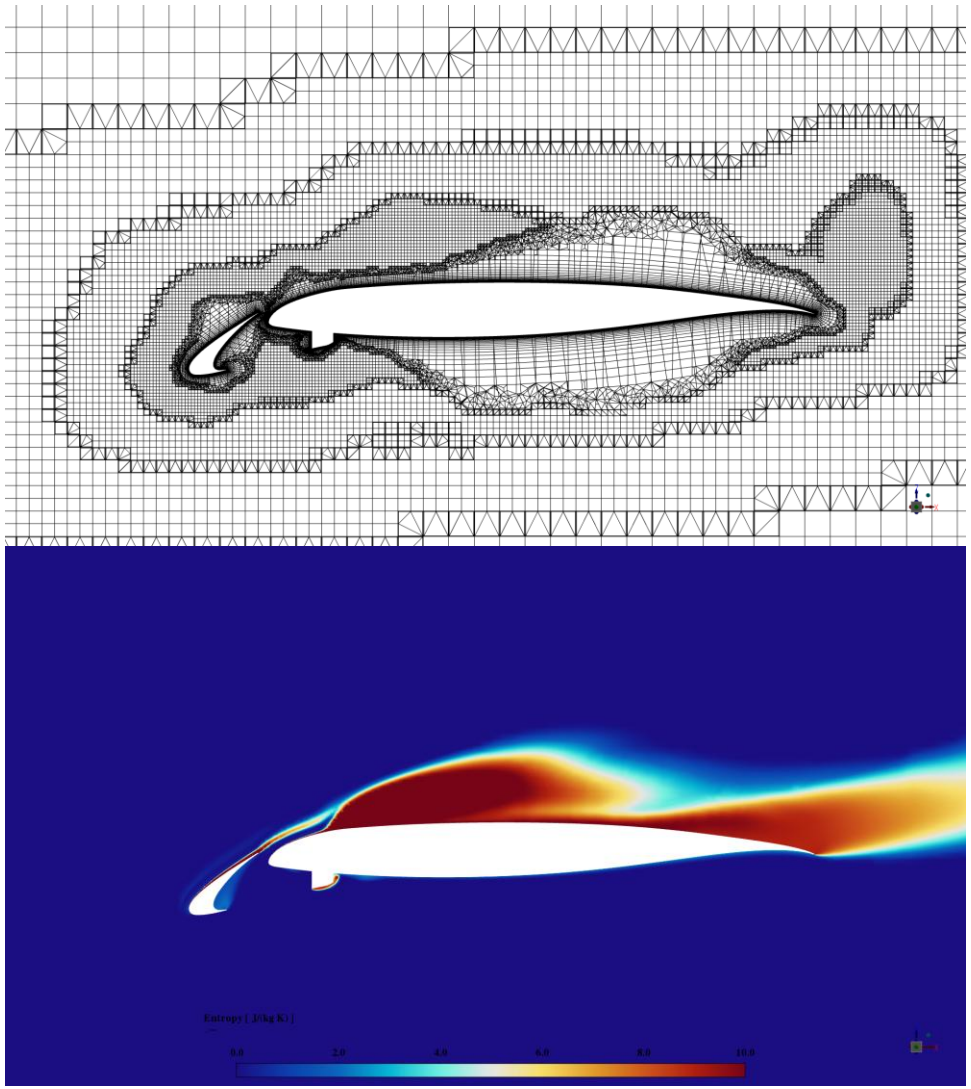




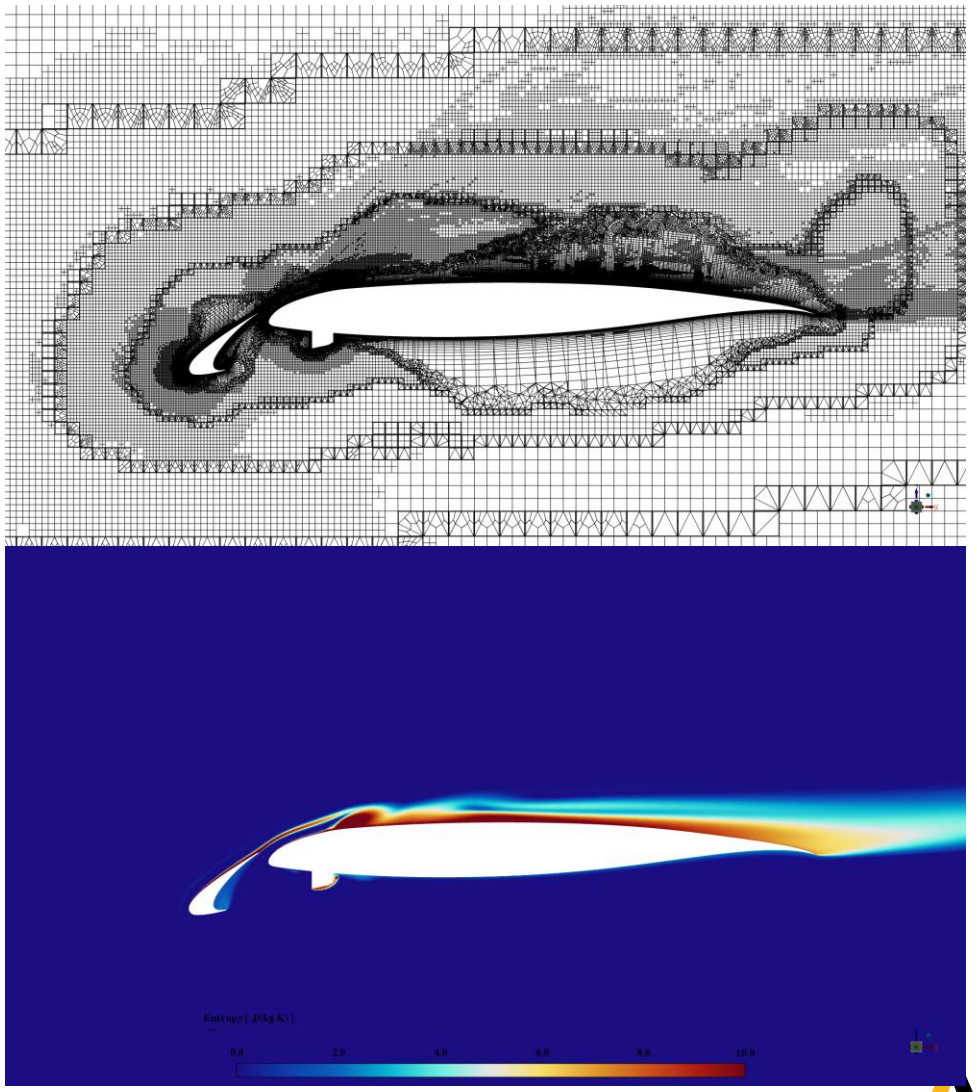
Mesh Adaption on Level A Mesh at AoA = 30° - CFL = 20



Baseline



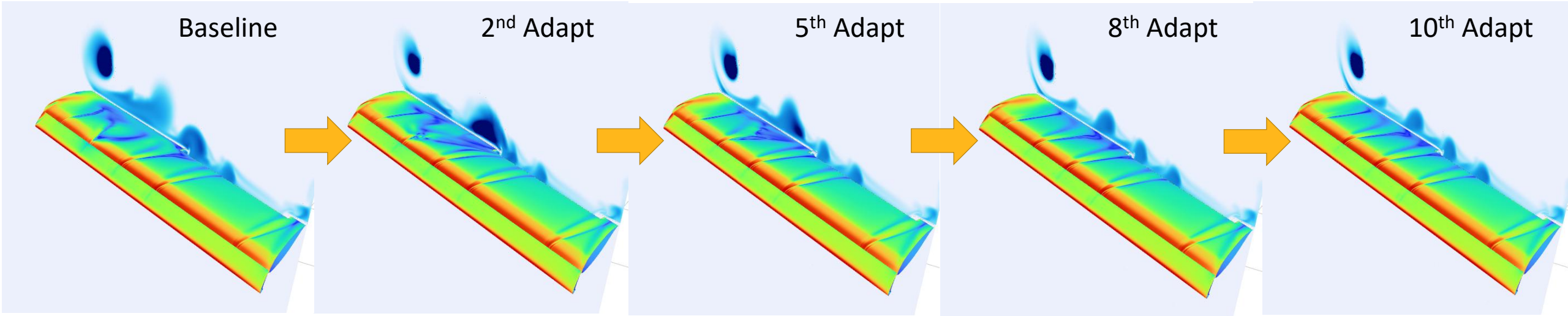
20th Adapt



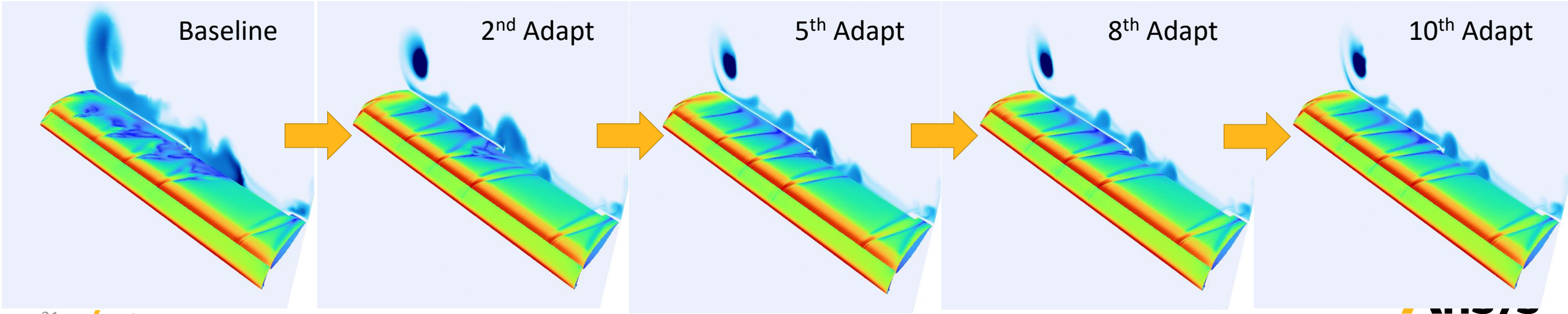
Ansys part of SYNOPSYS®

Mesh Adaption on Level B & Level C Mesh at AoA = 30°

Level B - CFL = 20

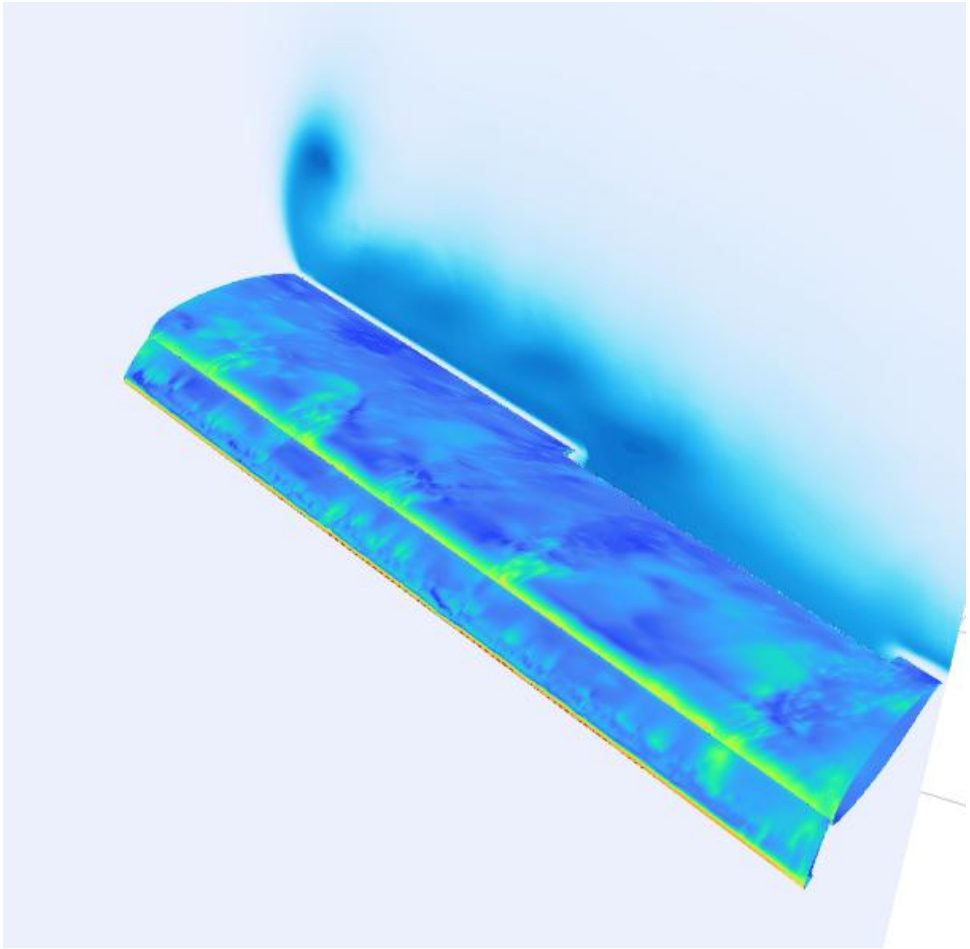


Level C - CFL = 15

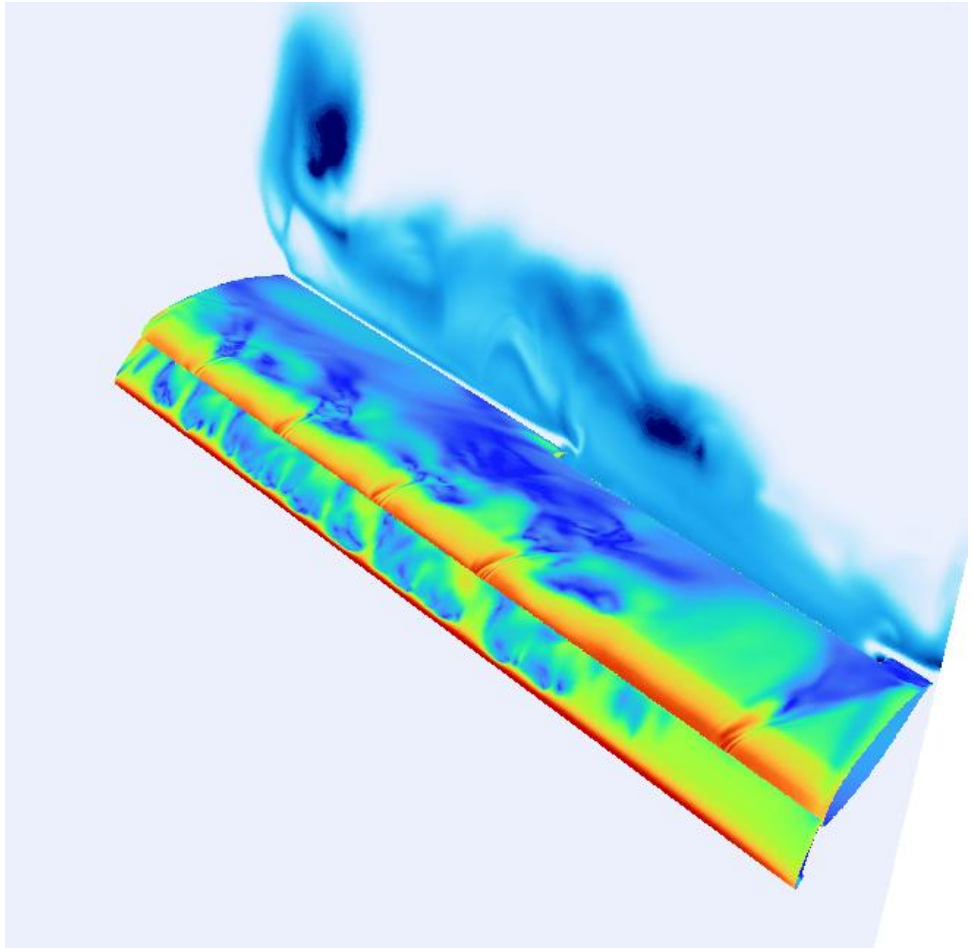


Mesh Adaption on Level B and C Mesh at AoA = 30°

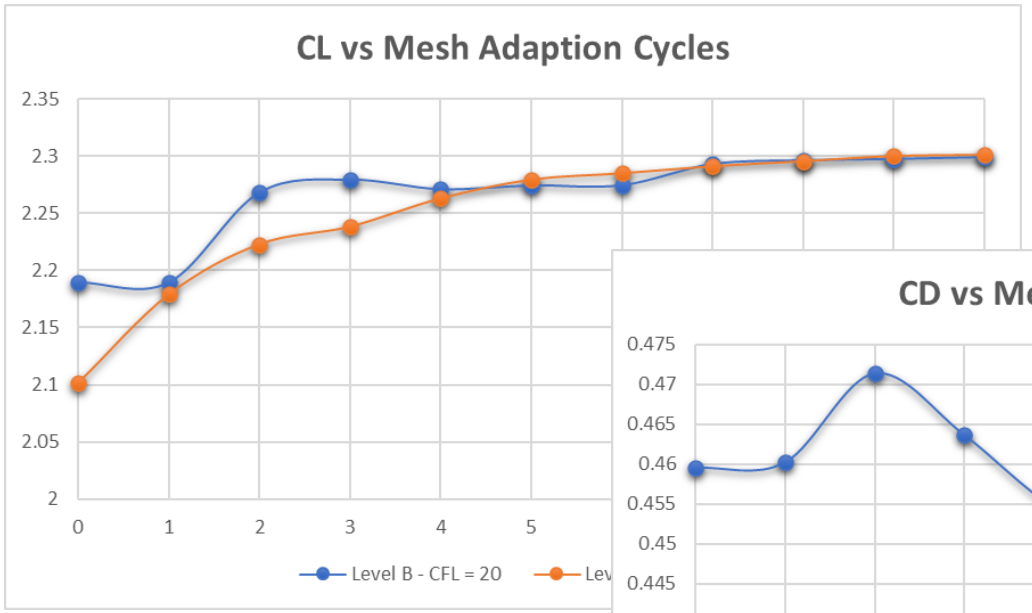
Level B - CFL = 20

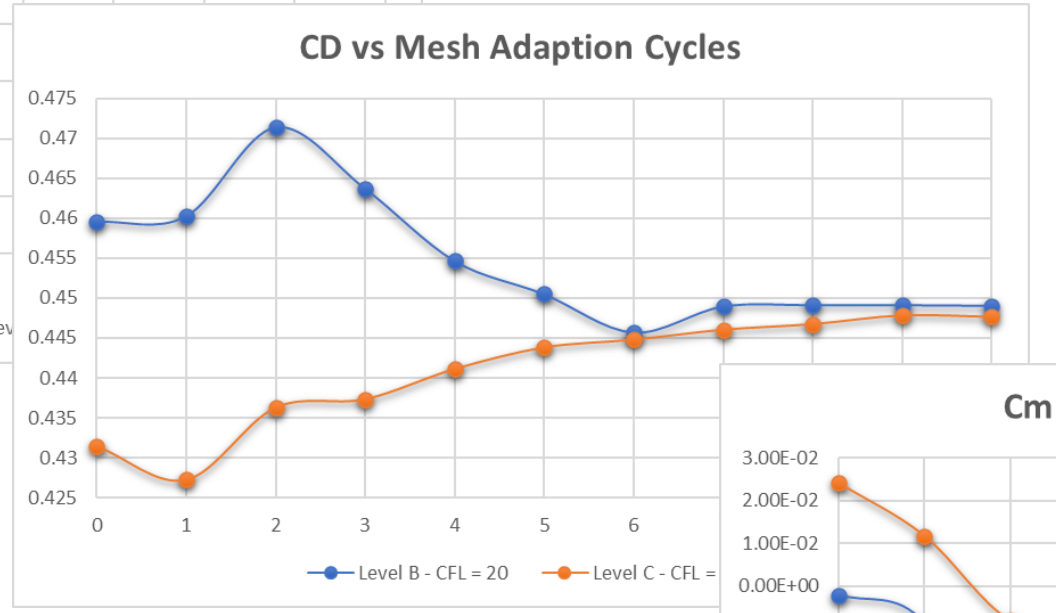


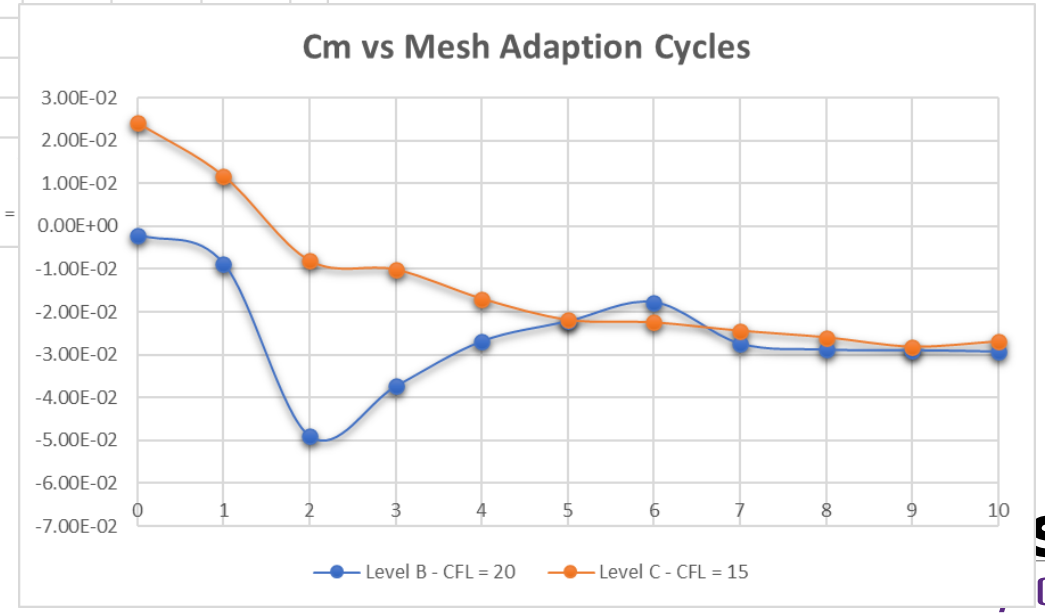
Level C - CFL = 15



Mesh Adaption on Level B and C Mesh at AoA = 30°



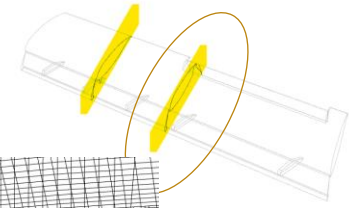




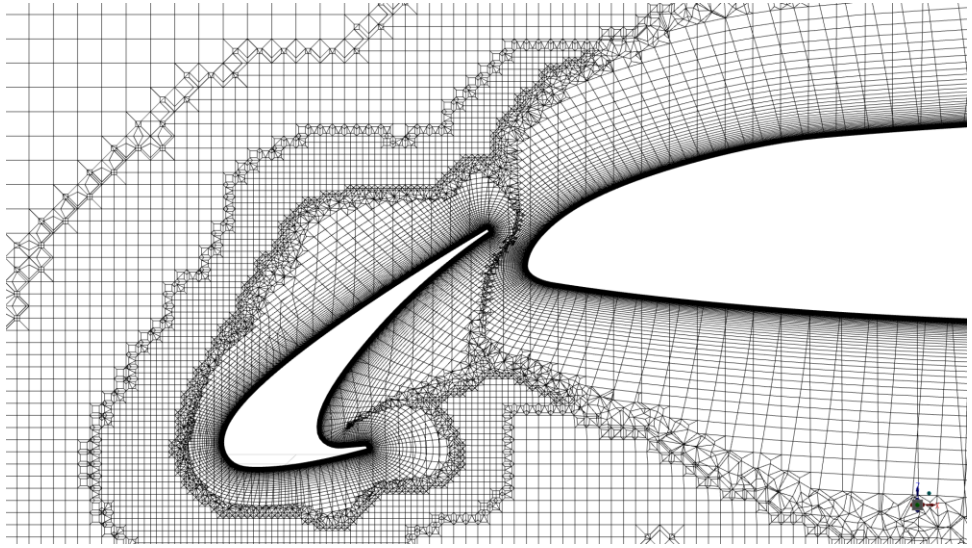
Difference in CL and CD between the last 3 adaption cycles is below 0.3%. Pitching moment still see differences of around 4%.

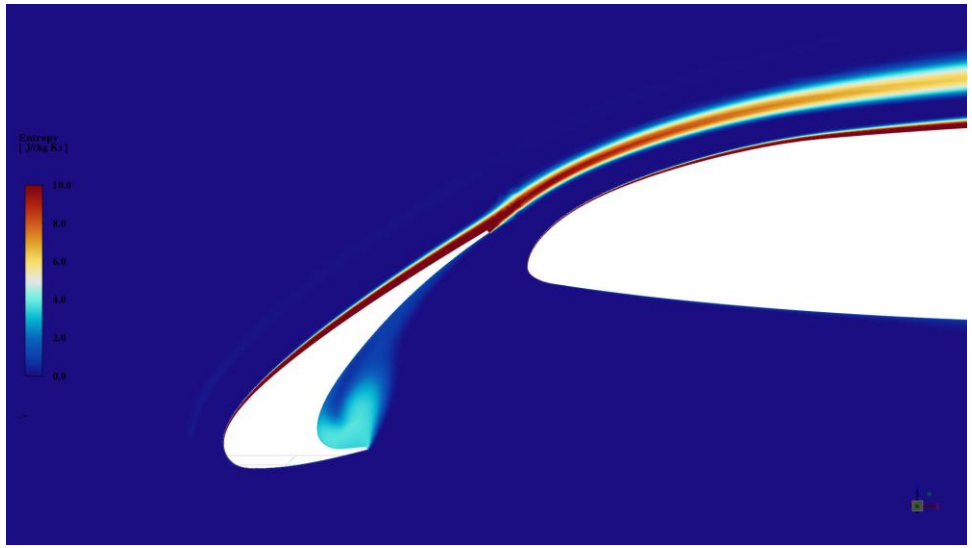
Need more adaption cycles to reduce pitching moment difference between adaption cycles.

Mesh Adaption on Level C Mesh at AoA = 30° - CFL = 15

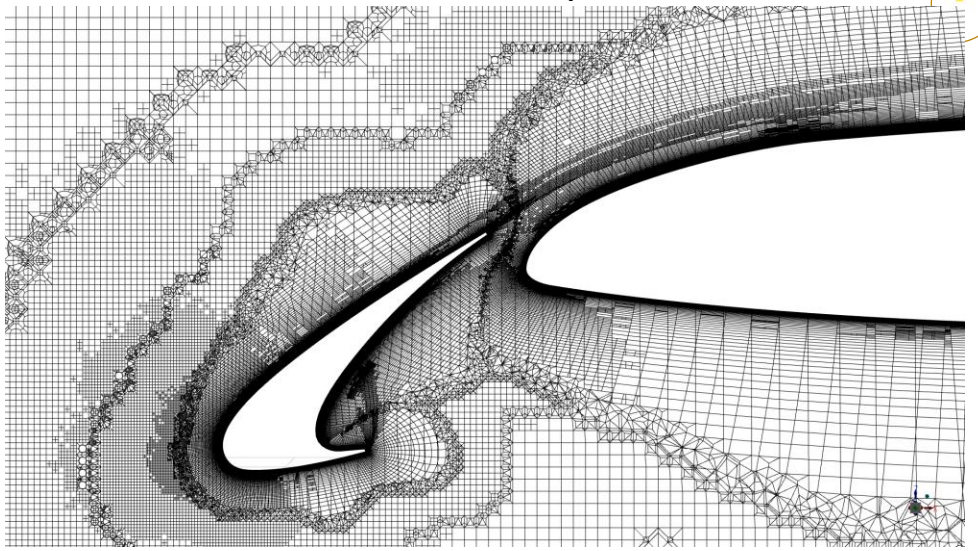


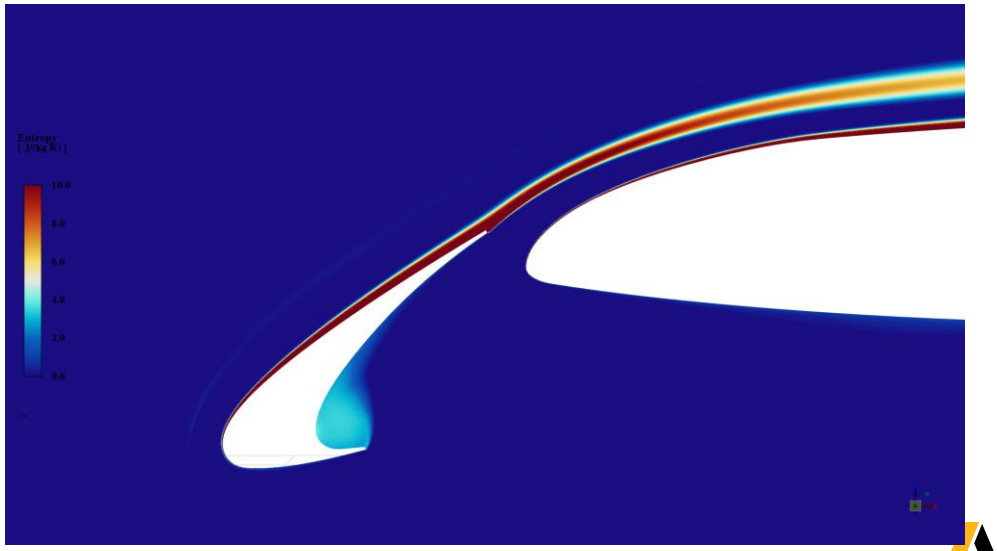
Baseline



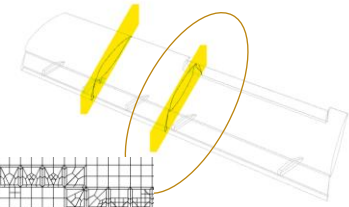


10th Adapt

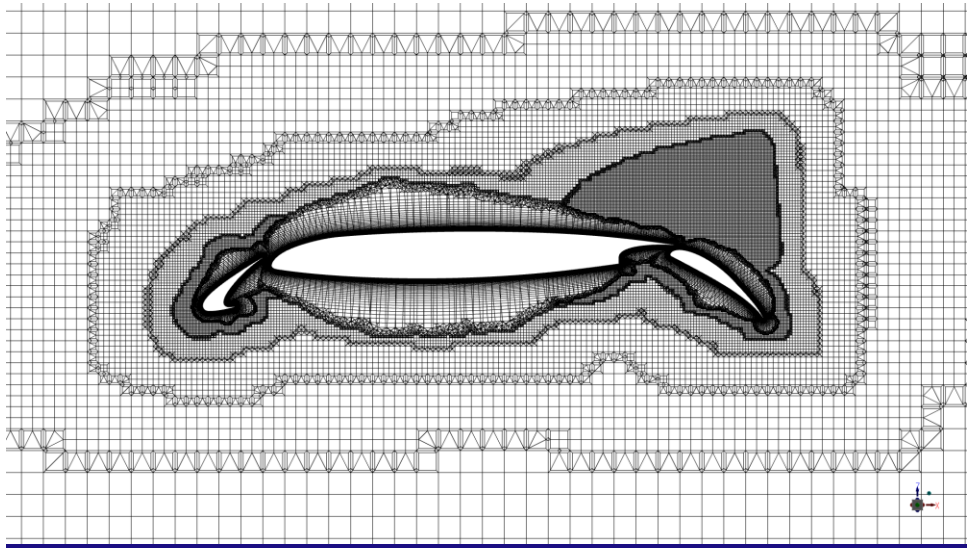


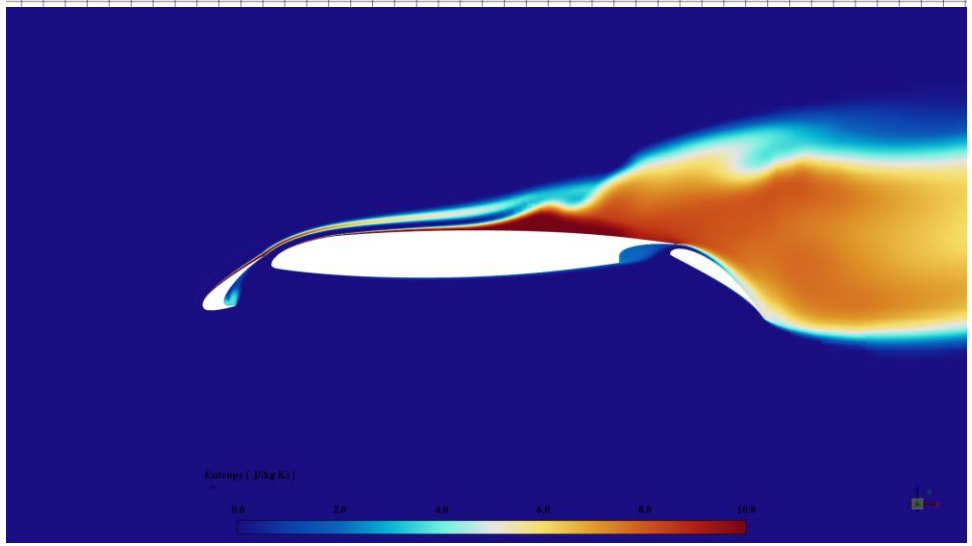


Mesh Adaption on Level C Mesh at AoA = 30° - CFL = 15

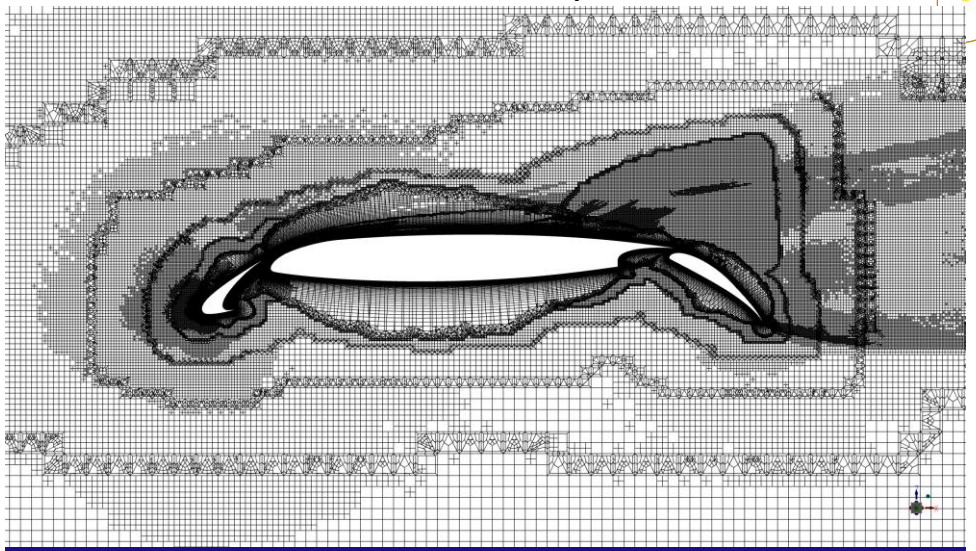


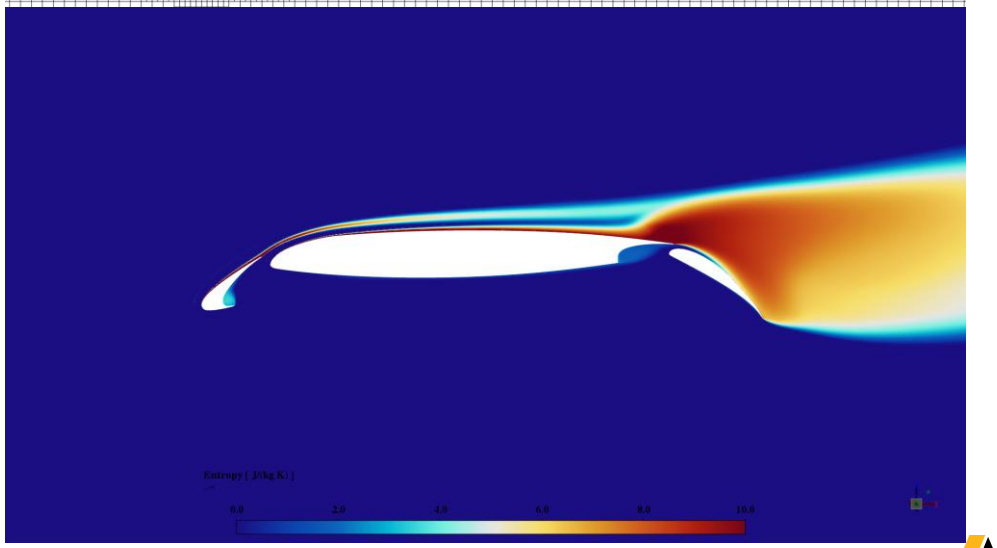
Baseline





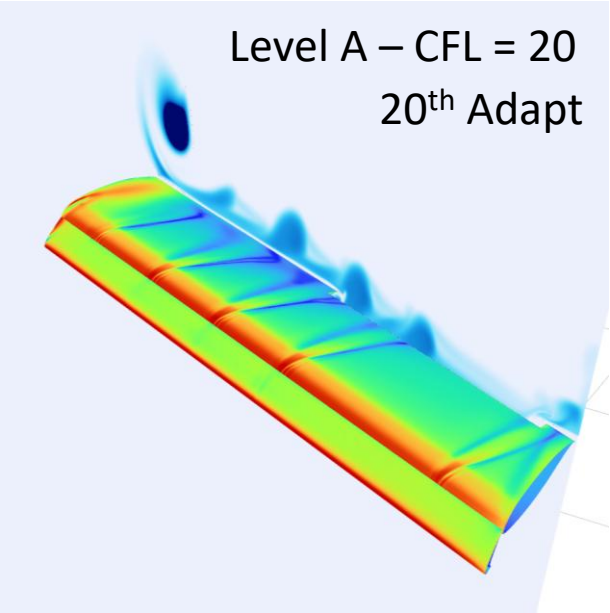
10^{th} Adapt



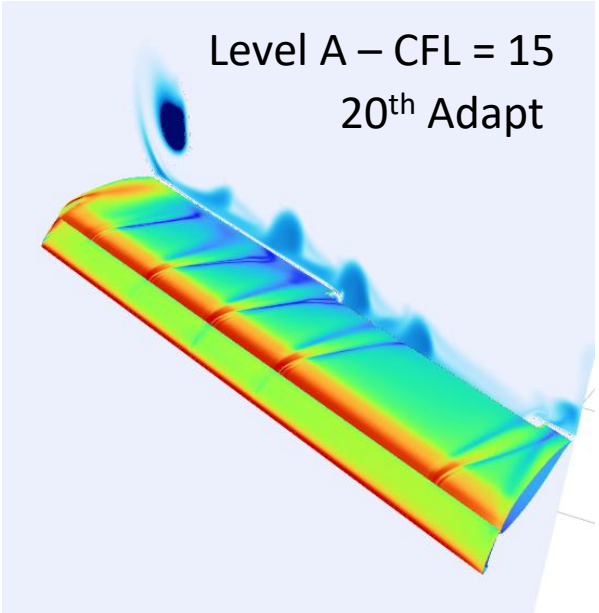


Ansys part of SYNOPSYS®

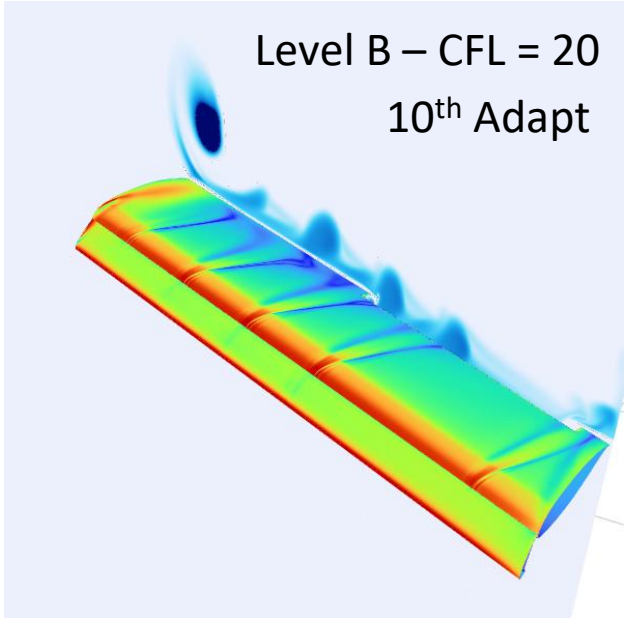
Mesh Adaption on Level A, B & C Mesh at AoA = 30°



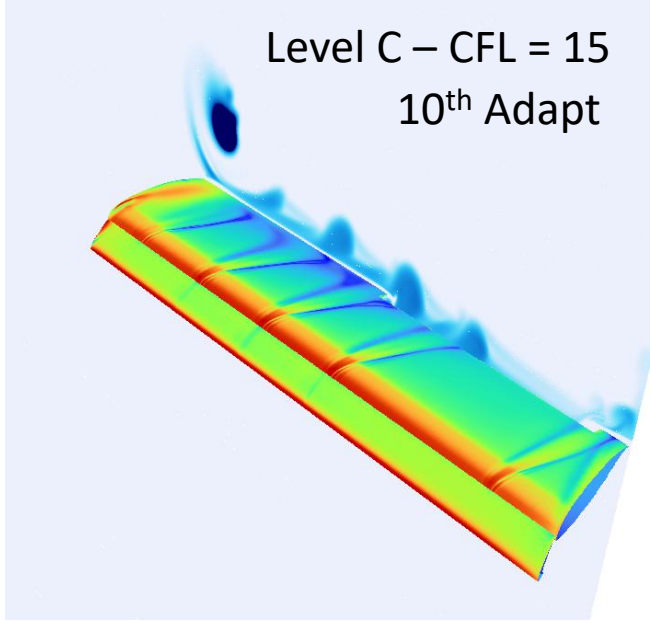
C_L = 2.298
C_D = 0.4491
C_m = -0.03080
Cell Size = 245 M



C_L = 2.294
C_D = 0.4481
C_m = -0.02881
Cell Size = 215 M



C_L = 2.301
C_D = 0.4493
C_m = -0.03019
Cell Size = 184 M



C_L = 2.301
C_D = 0.4477
C_m = -0.02690
Cell Size = 444 M

Observation

- Baseline Mesh Separation zone varies based on CFL number -> Convergence Settings
  - For CFL=20; second to last slat bracket
  - For CFL=15; bracket in front of the last portion of the flap along the span from root to tip
- Regardless of the wall Y+, PUMA with Combined Hessian – Entropy provides a solution that is free of a pizza slice at AoA=30°. Since the first layer of elements above the suction side is not adapted, this seems to indicate that refinement of the volumetric mesh is sufficient to prevent separation.
- Surface mesh refinement even on the coarsest level is sufficient to prevent flow separation
- Less mesh adaption cycles are required to achieve convergence on CL with less oscillations when finer baseline meshes are used.
- After adaption, all baseline meshes (Level A to C) solutions qualitatively provide similar solutions with similar aerodynamic coefficients except for pitching moment. Level B and Level C meshes will require more than 10 mesh adaption cycles to properly converge these coefficients.


Ansys
part of SYNOPSYS®