DPW-6 and HiLiftPW-3 using the Stanford University Unstructured (SU2)

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EMBRAER

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Outline

Objective

Description of SU2

Summary of cases

DPW-6

HiLiftPW-3

Summary

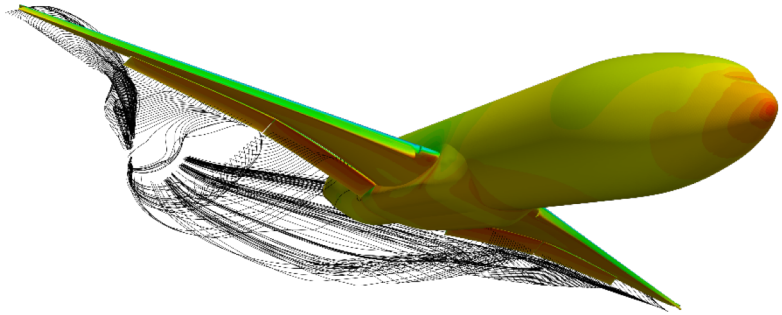
Next Steps

Objective

- Aerodynamic shape optimization
  - Accuracy
    - Transonic
    - High-lift configuration
  - Robustness
    - Mesh
    - Conditions/Restart
  - Speed
    - CPU hours
  - Baseline setup

Summary of SU2

- Versions 4.3, 5.0 and 6.0
- Unstructured Finite-Volume (Vertex-based, Dual-Grid with edge-based data structured)
- Spatial Integration
  - Upwind Schemes (Roe, HLLC, etc …)
  - Central Schemes (JST)
- Time Integration
  - Dual-Time Stepping
  - Explicit and Implicit
- Turbulence Models :
  - Differents Spalart-Allmaras (SA) variants
  - Menter's SST
- Also available: Adjoints, Hybrid RANS/LES, FSI, High-Order DG, Uncertainty Estimation, Turbomachinery, etc…



Numerics used

- Based on Transonic Case: TestCases - OneraM6 (V4.3)
- Tested: CRM Wing-body configuration (DPW6)

- Convective numerical method:
  - JST, **ROE**, AUSM and HLLC
- Multi-grid: 1 or 2 cycle V and **no multi-grid**
- Turbulence models:
  - Transonic: SA and SST
  - High-Lift: SA and SA-QCR
- Adaptive CFL number:
  - initial 10, maximum 50 (mesh depended)

Summary of cases :

6th AIAA CFD Drag Prediction Workshop

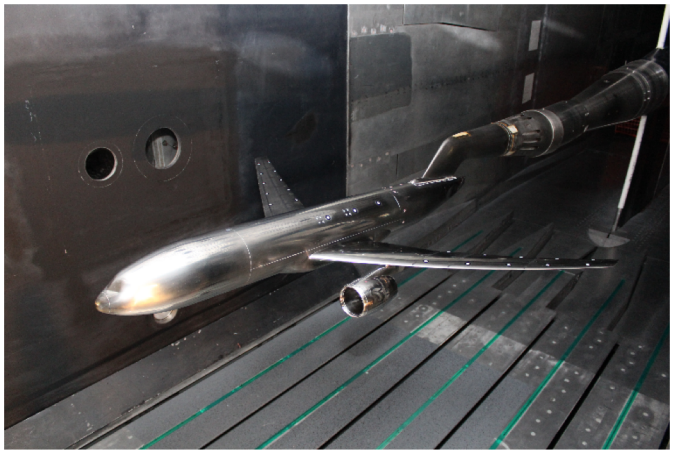
CASE	GEOM	Grid	Origin	Refinement Level
2	CRM WB [2.75]	CustomHexa	Embraer	Tiny
2	CRM WB[2.75]	CustomHybrid-I	Embraer	Tiny
2	CRM WB [2.75]	CustomHybrid-A	Embraer	T,C,M,F
2	CRM WBPN [2.75]	CustomHybrid-A	Embraer	T,C,M,F

3rd High Lift Prediction Workshop

CASE	GEOM	Grid	Origin	Element types	Refinement Level
1(a)	CRM-WB-fully-gapped	B3	Committee	Hex/Pri/Pyr/Tet	Coarse
1(a)	CRM-WB-fully-gapped	B3	Committee	Hex/Pri/Pyr/Tet	Medium
1(a)	CRM-WB-fully-gapped	B3	Committee	Hex/Pri/Pyr/Tet	Fine
2(a)	JAXA-WB	C2	Committee	Mixed	Medium
2(c)	JAXA-WBPN	C2	Committee	Mixed	Medium

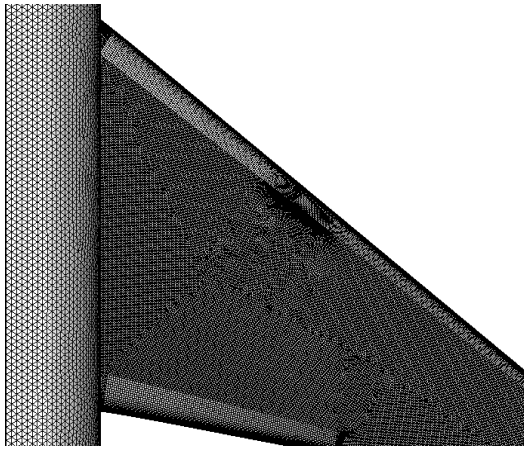
DPW-6

- Case 2 - CRM Nacelle-Pylon Drag Increment
  - Calculate the drag increment between the CRM-WBNP and the CRM-WB configurations.
  - Flow conditions: M = 0.85; Re = 5 million; fixed CL = 0.5
  - Aeroelastic deflections at the angle-of-attack 2.75 degrees geometry.
  - Grid convergence study on Baseline WB and WBNP grids.

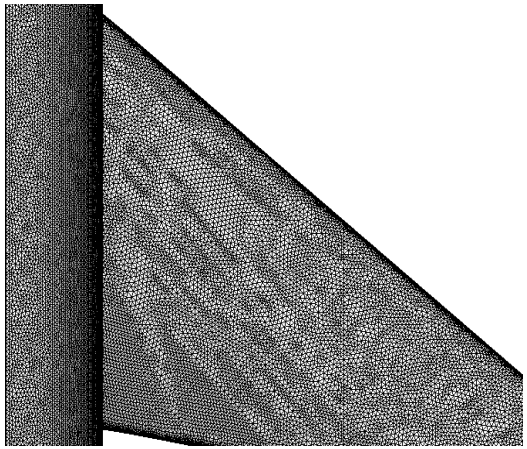


DPW-6 - mesh

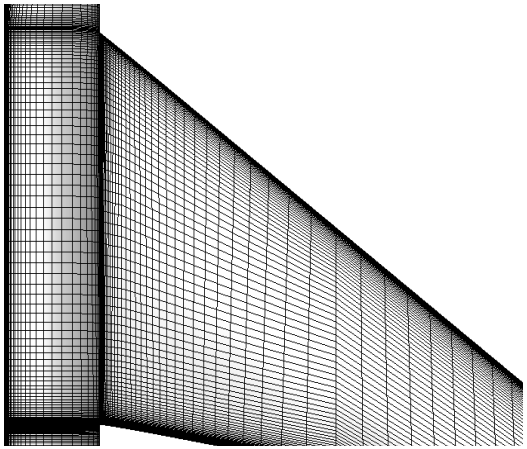
Embraer meshes



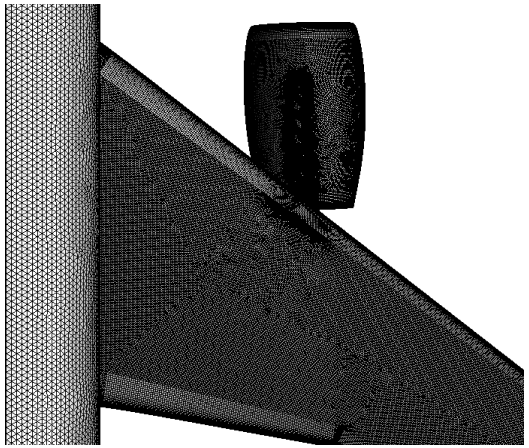
CustomHybrid-A

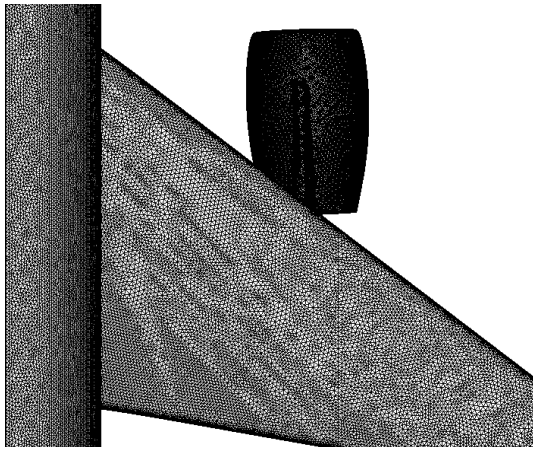


CustomHybrid-I

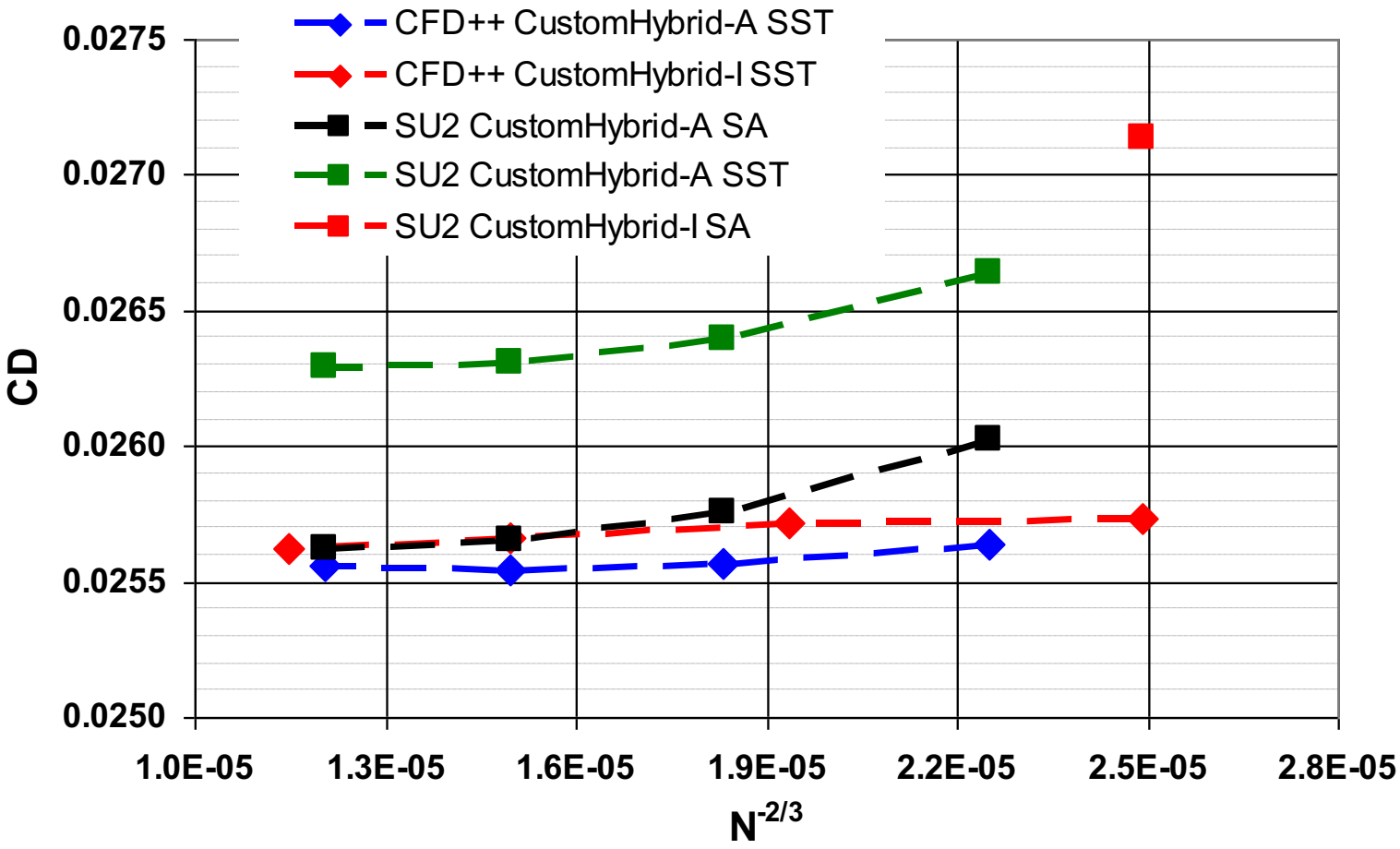


CustomHexa

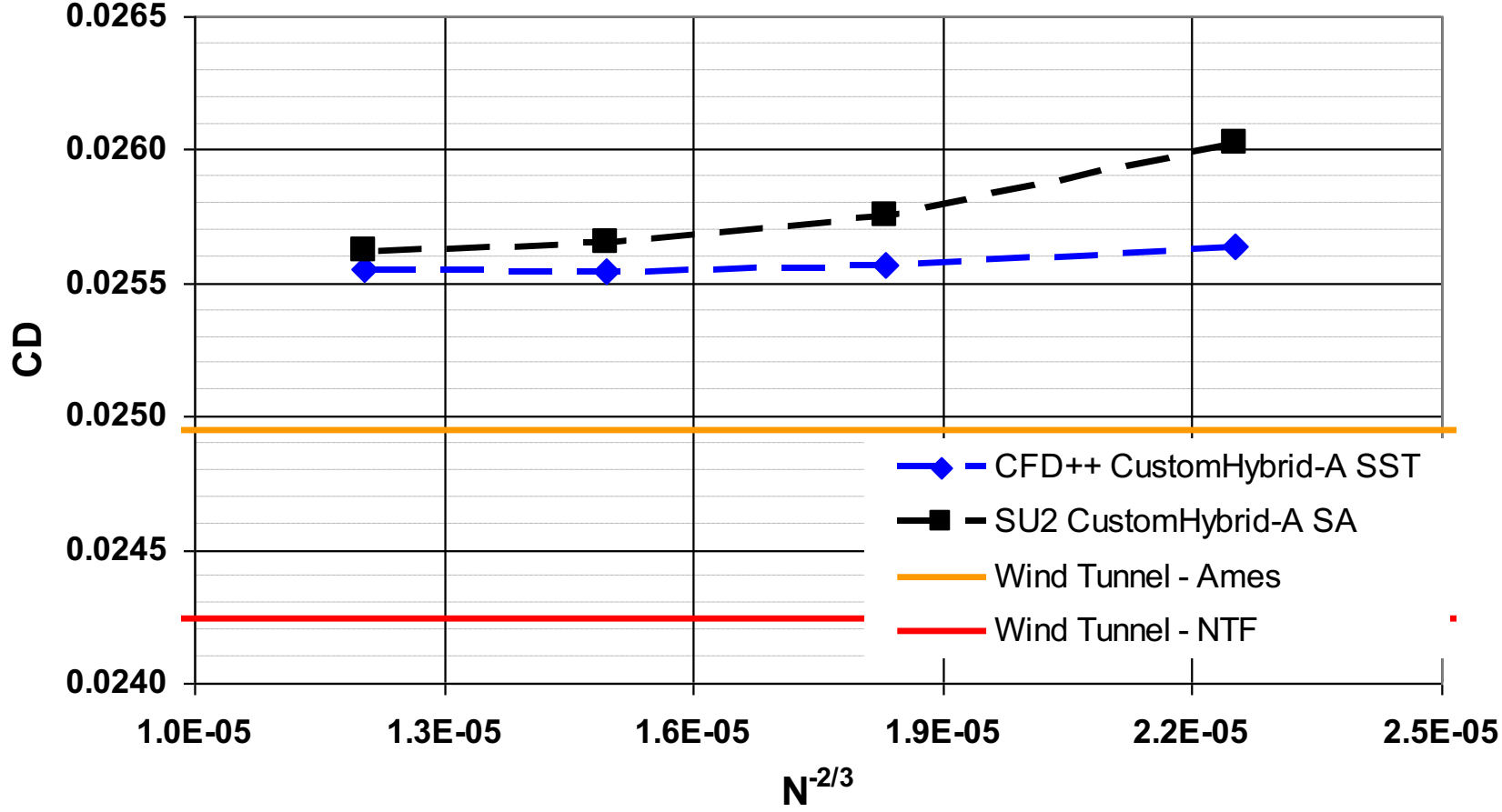




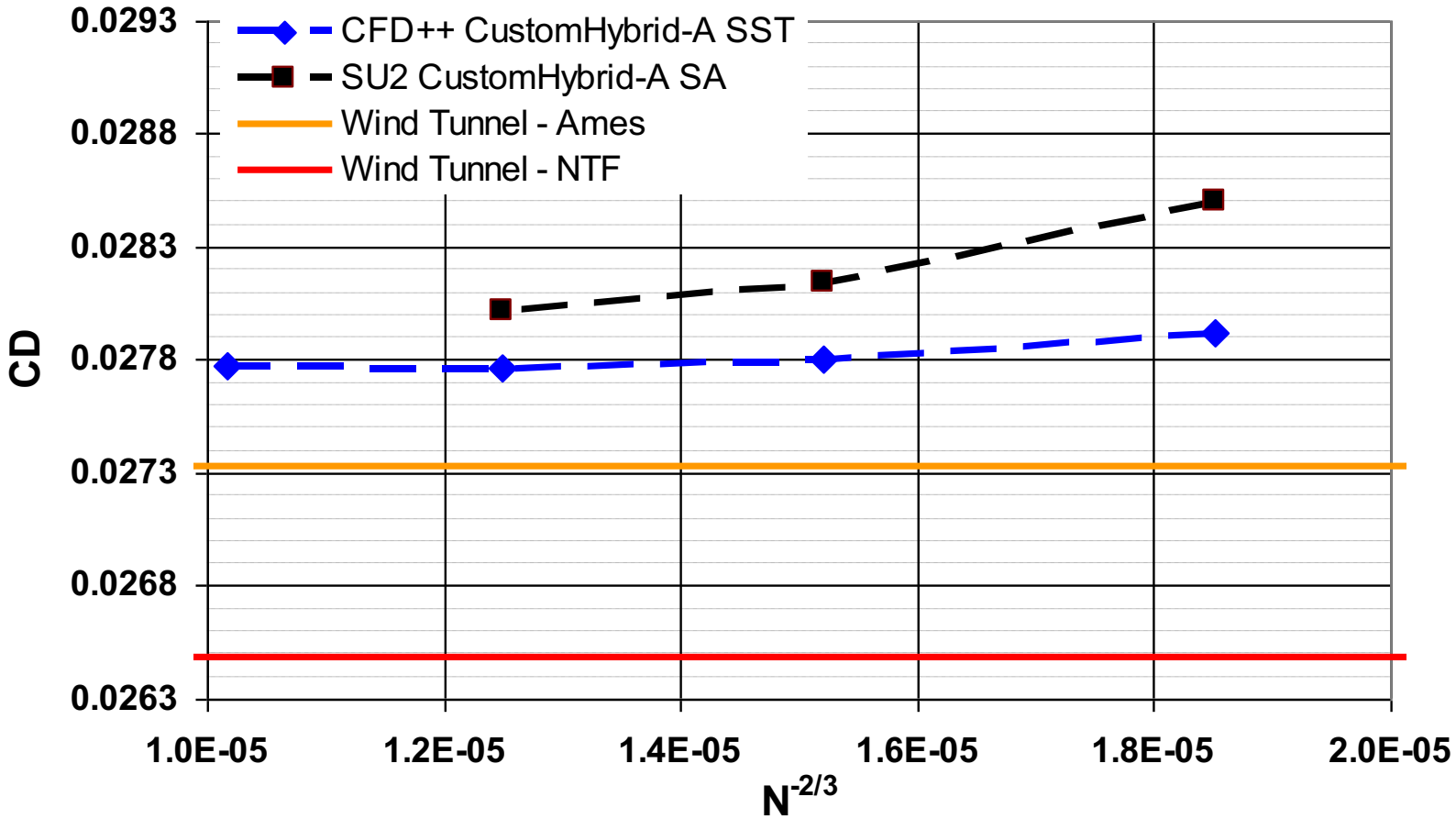
DPW-6 – Drag


CFD++ CustomHybrid-A SST
CFD++ CustomHybrid-I SST
SU2 CustomHybrid-A SA
SU2 CustomHybrid-A SST
SU2 CustomHybrid-I SA
0.0275
0.0270
0.0265
0.0260
0.0255
0.0250
CD
1.0E-05
1.3E-05
1.6E-05
1.9E-05
2.2E-05
2.5E-05
2.8E-05
N-2/3

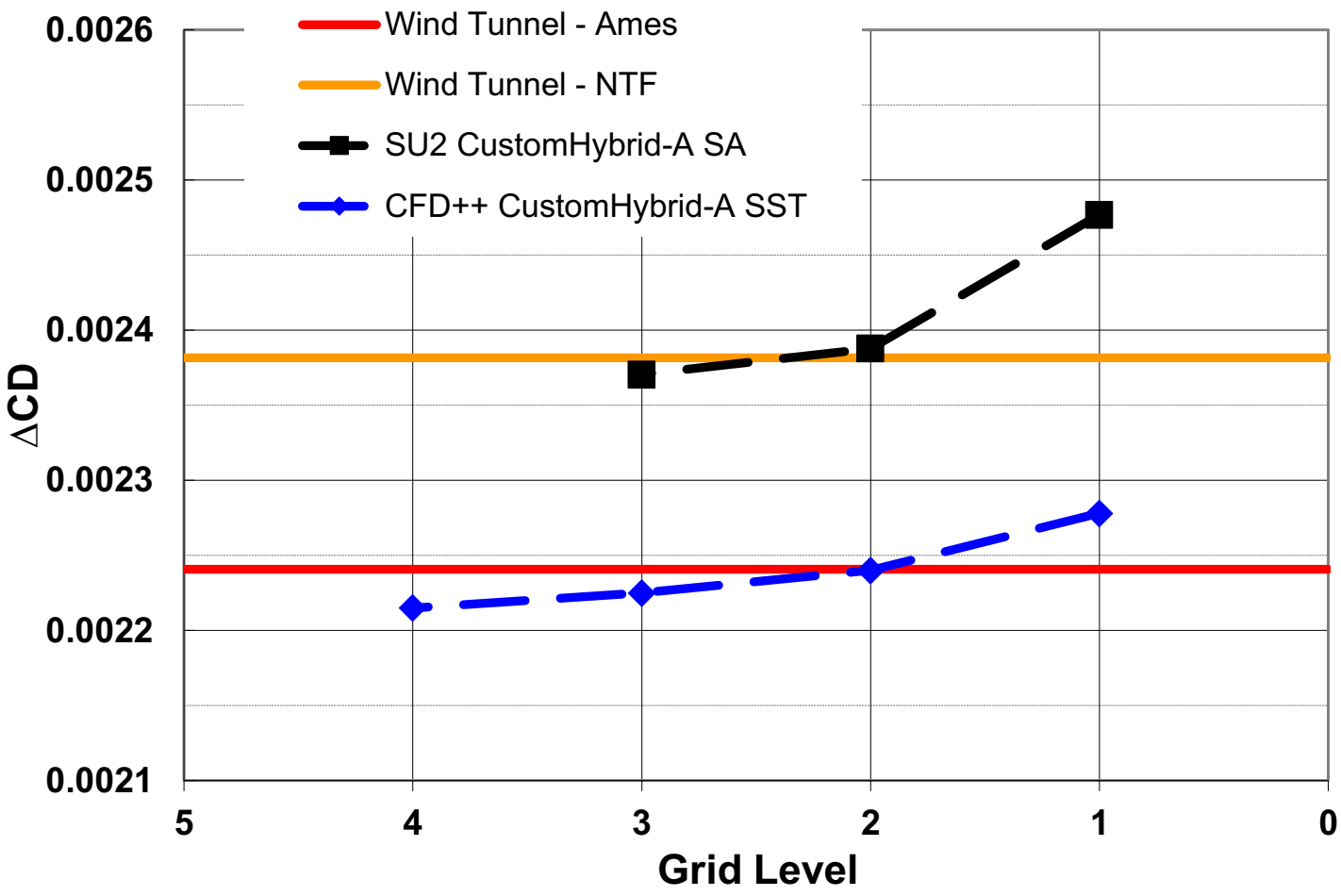
DPW-6 – WB – CFD and Wind Tunnel



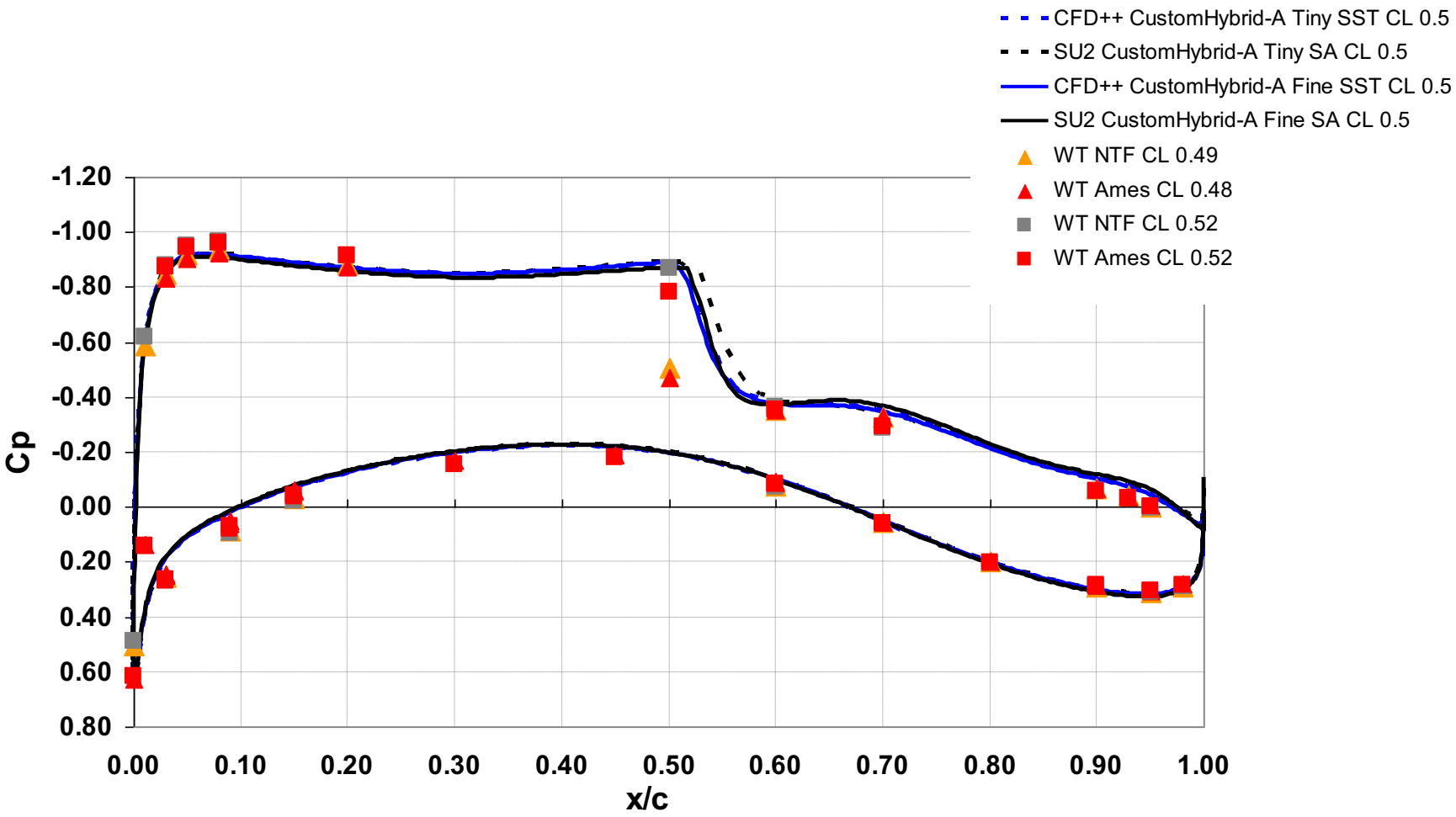
DPW-6 – WBPN - CFD and Wind Tunnel



DPW-6 – PN drag increment - CFD and Wind Tunnel

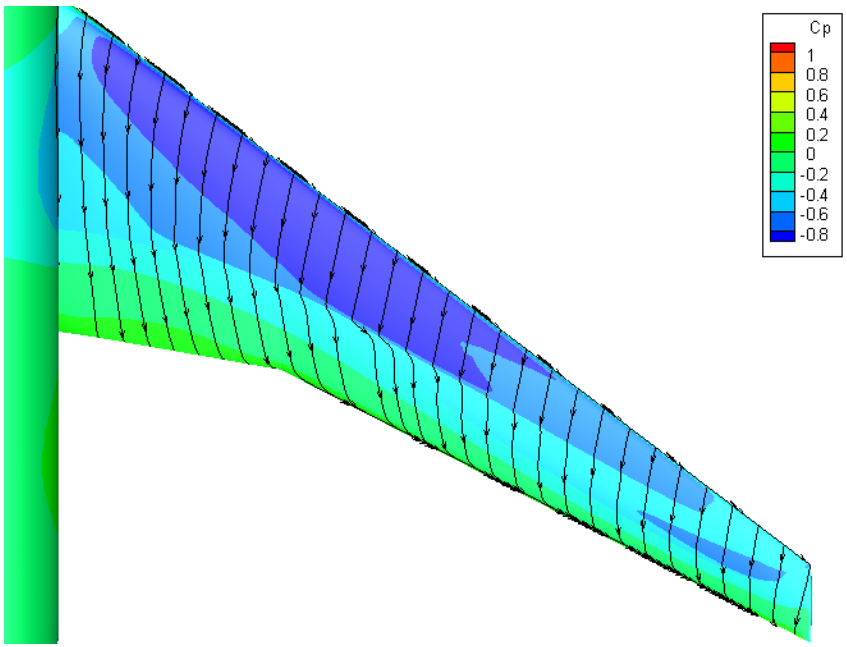


DPW-6 – Cp´s

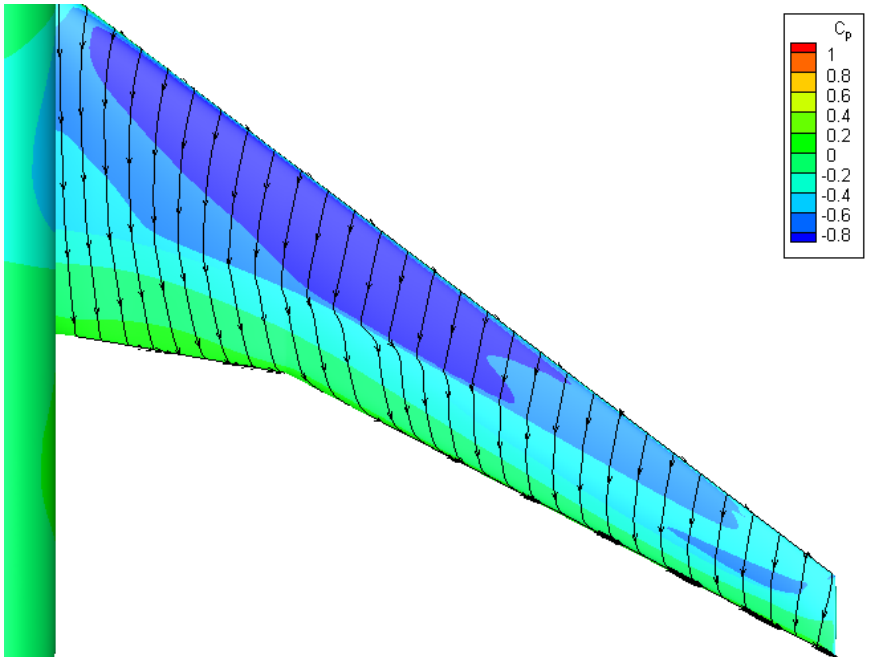


50% of span

DPW-6 – Streamlines



CFD++



SU2

CustomHybrid-A Tiny

Brief overview of CRM results

- Grid effect
  - SU2 have a grid dependence worse than CFD++
  - The high aspect ratio mesh, CustomHexa, take longer to converge and gives a worsted result
  - Results are reasonably converged for CL and CD
- Coefficients
  - Absolute drag with fine mesh was suitable
  - The PN drag increment matched with Wind Tunnel test
- Cp´s and streamlines
  - SU2 with fine mesh have excellent results

HiLiftPW-3

- Case 1: Grid Convergence Study
  - Flow solutions on a series of consistently refined fixed grids are requested to assess grid convergence.
  - The NASA High Lift Common Research Model (HL-CRM) is a wing-body high lift system that will be studied in a nominal landing configuration (slat and flaps deployed at 30° and 37°, respectively) without nacelle, pylon, tail, or support brackets.
  - Case 1a: Full Chord Flap Gap

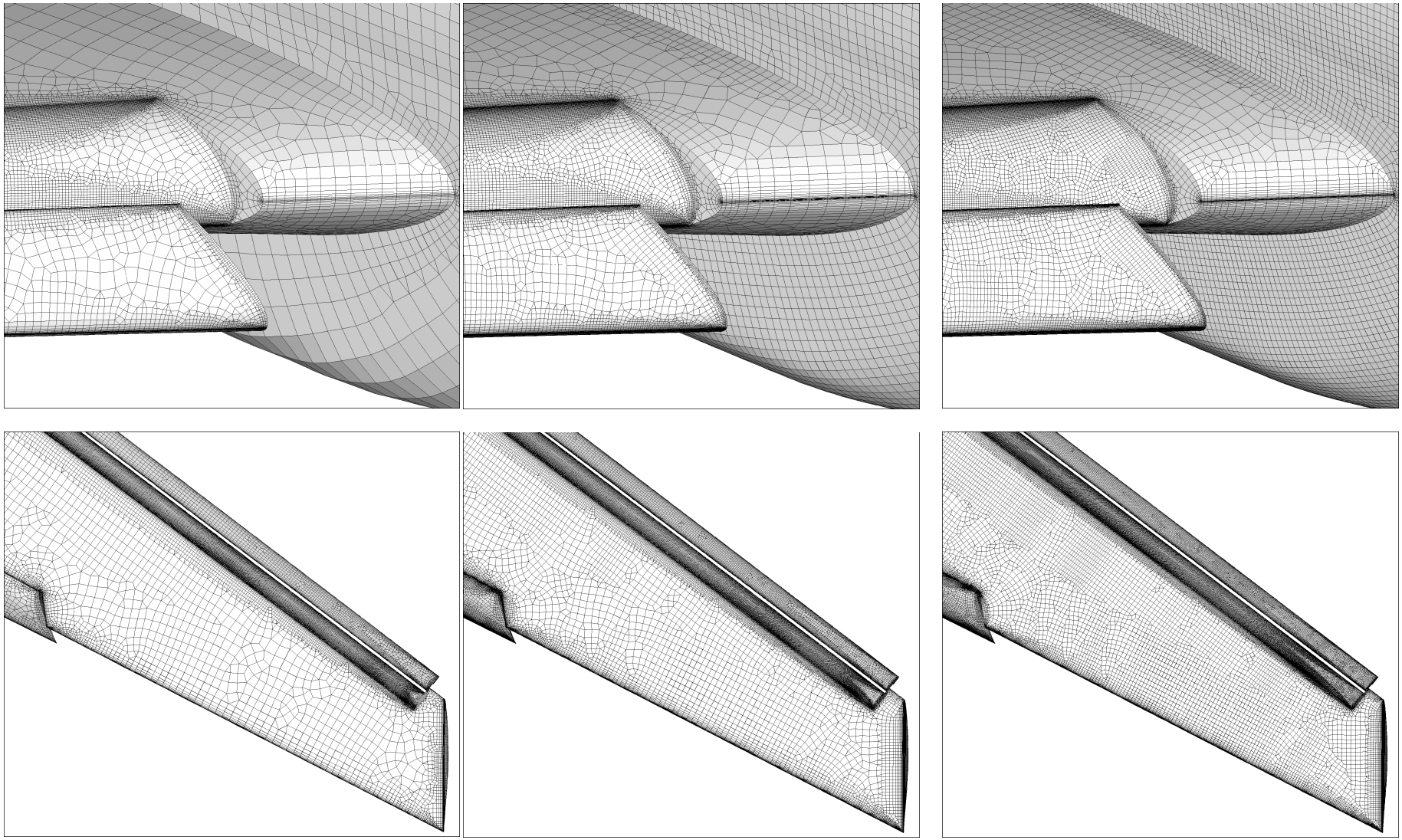
Blind Case – without any Wind Tunnel Result

HiLiftPW-3

- Case 2: Nacelle Installation Study
  - Medium grid.
  - The JAXA Standard Model (JSM) is a wing-body high lift system, landing configuration, brackets on and nacelle/pylon on/off.
  - The experiment used a semi-span model with a 60 mm peniche standoff, but requested computations are “free air.”

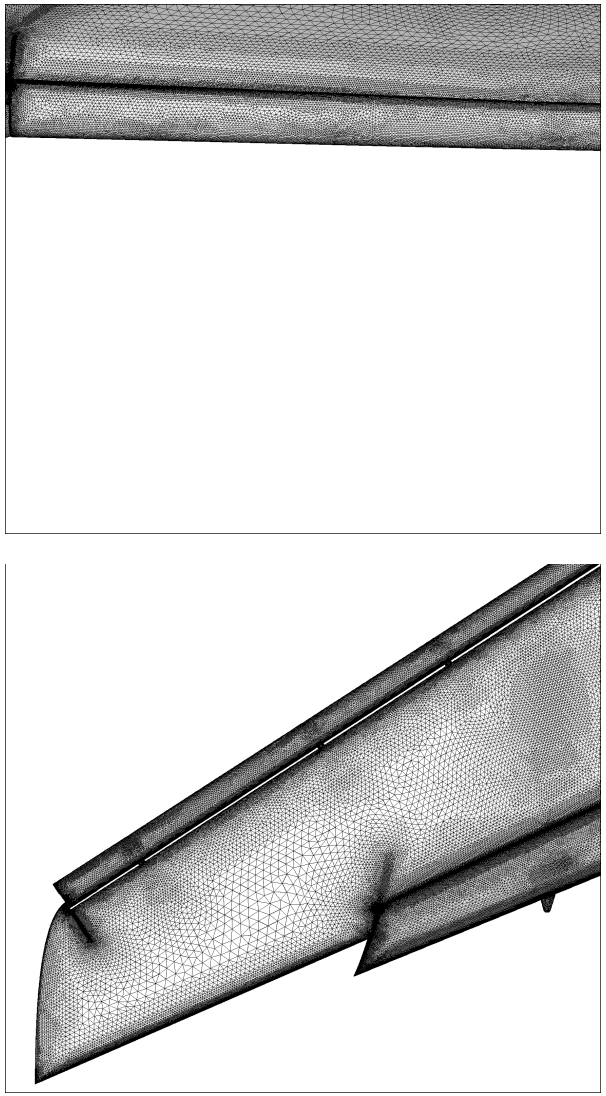
Grid comparison CRM-HL: B3

coarse | **medium** | **fine**

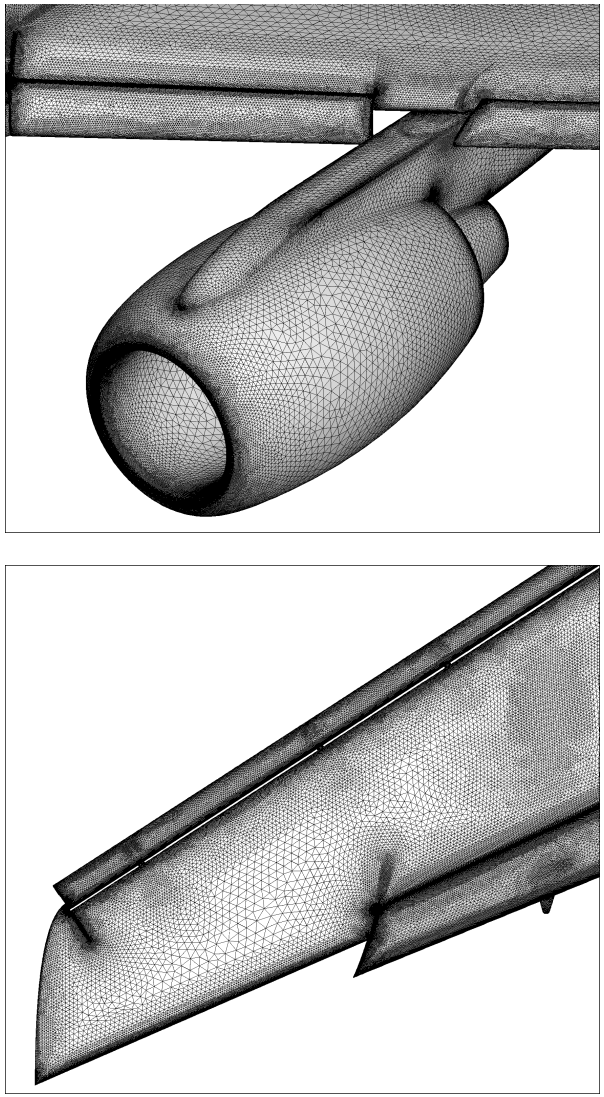


Grid comparison JSM: C2

PyNa Off



PyNa On



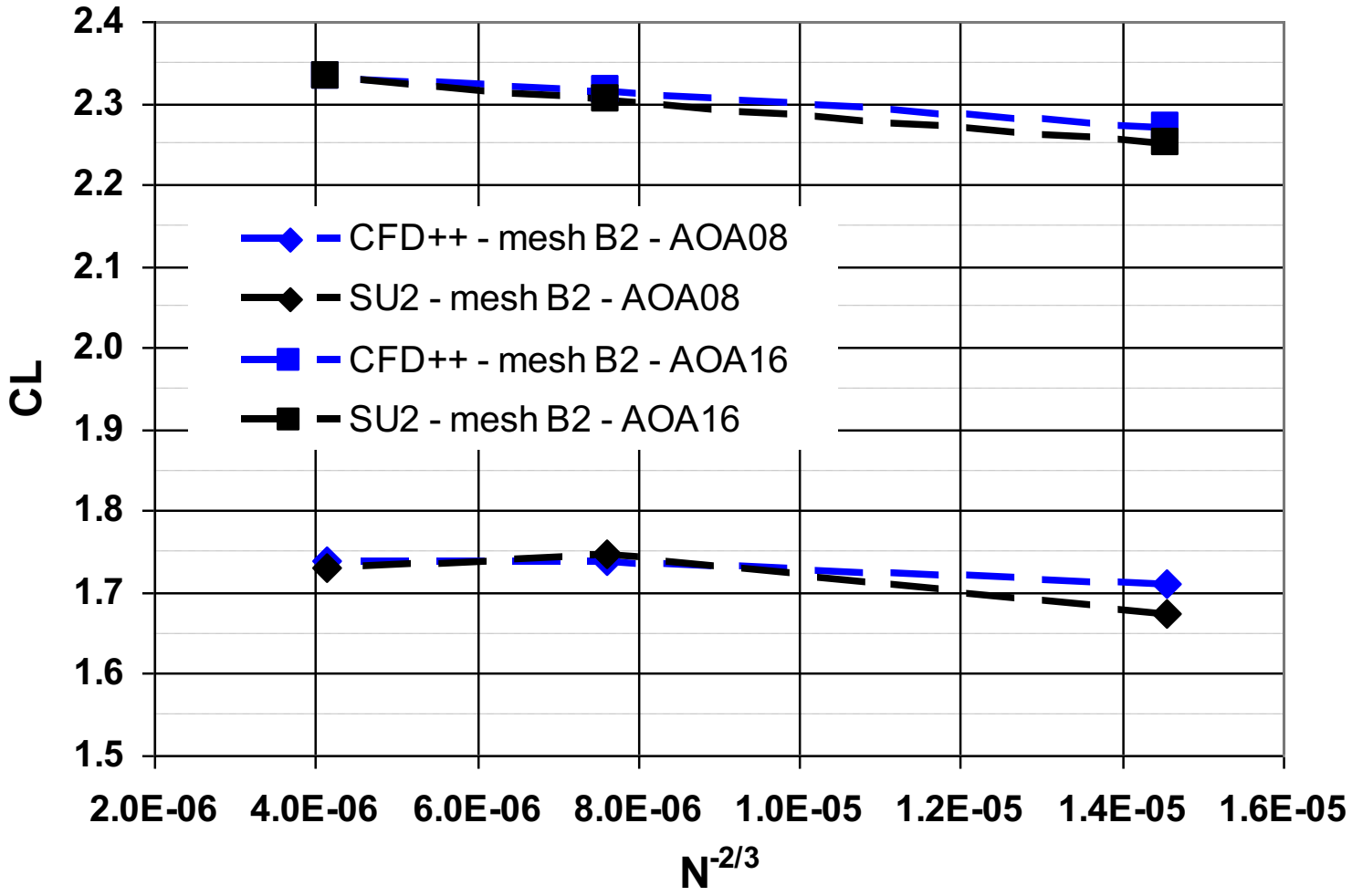
HL-CRM results

M=0.20

Rey=3.26E+06

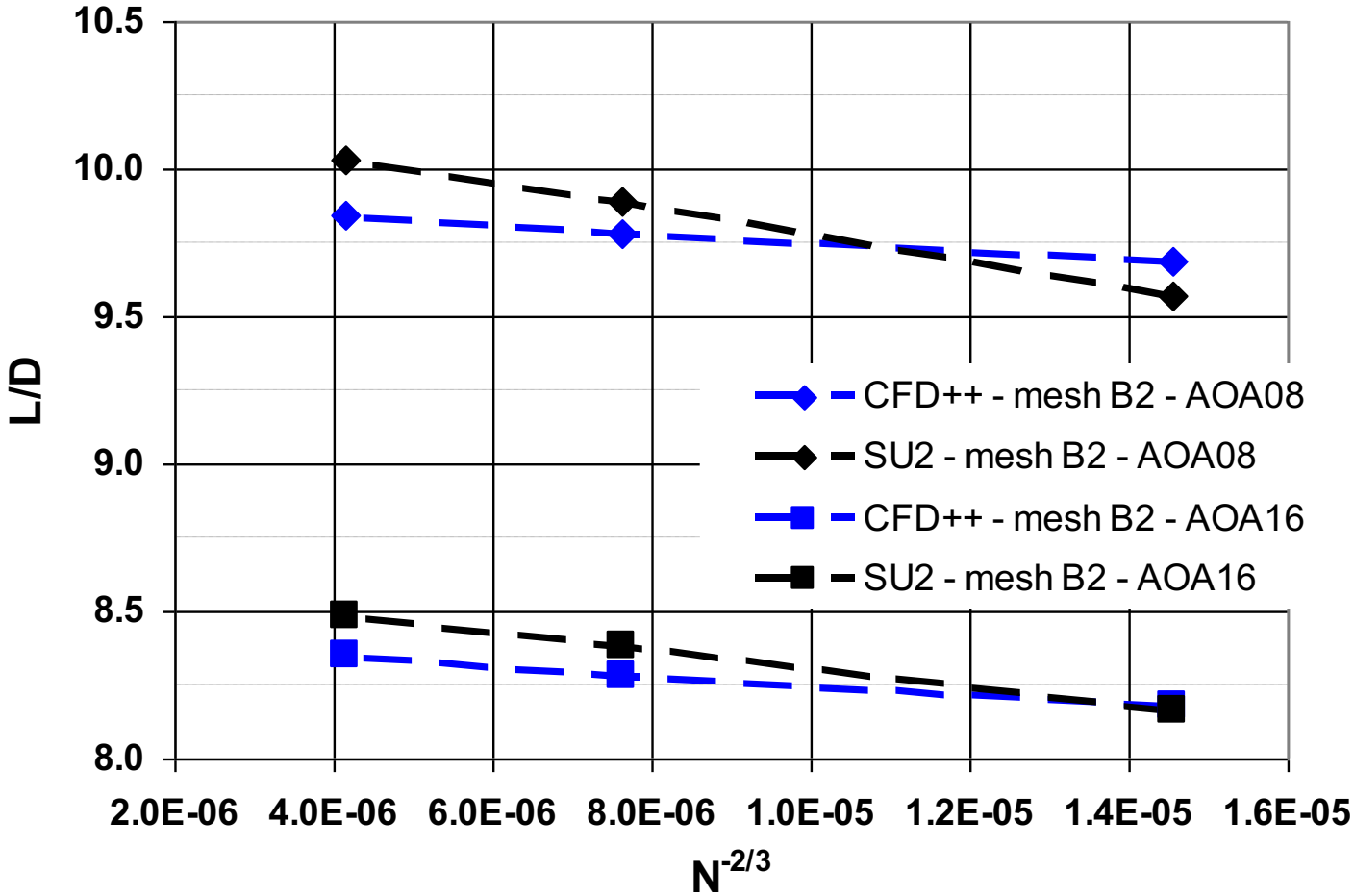
HL-CRM results – grid convergence

Grid B3



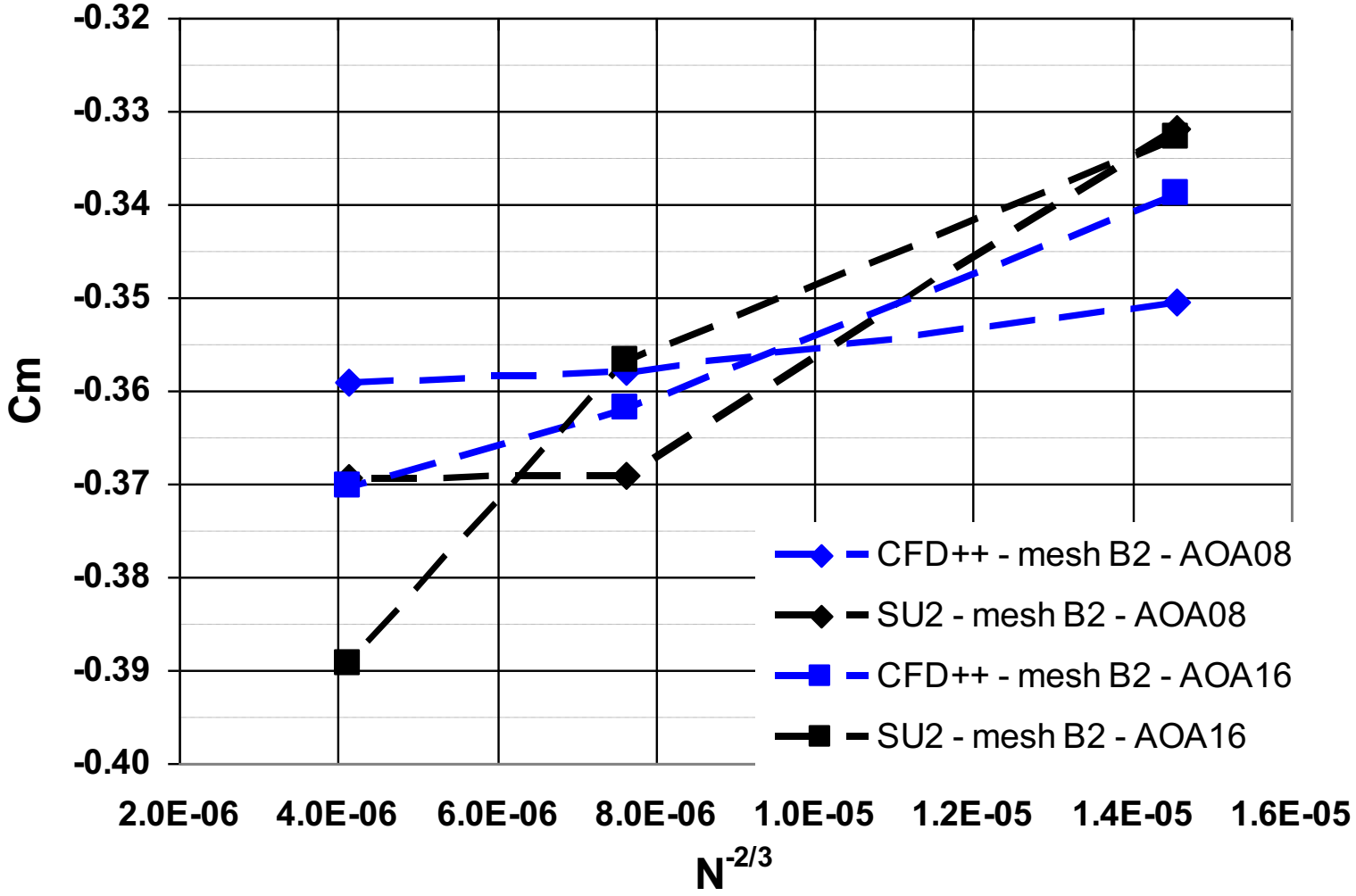
HL-CRM results – grid convergence

Grid B3



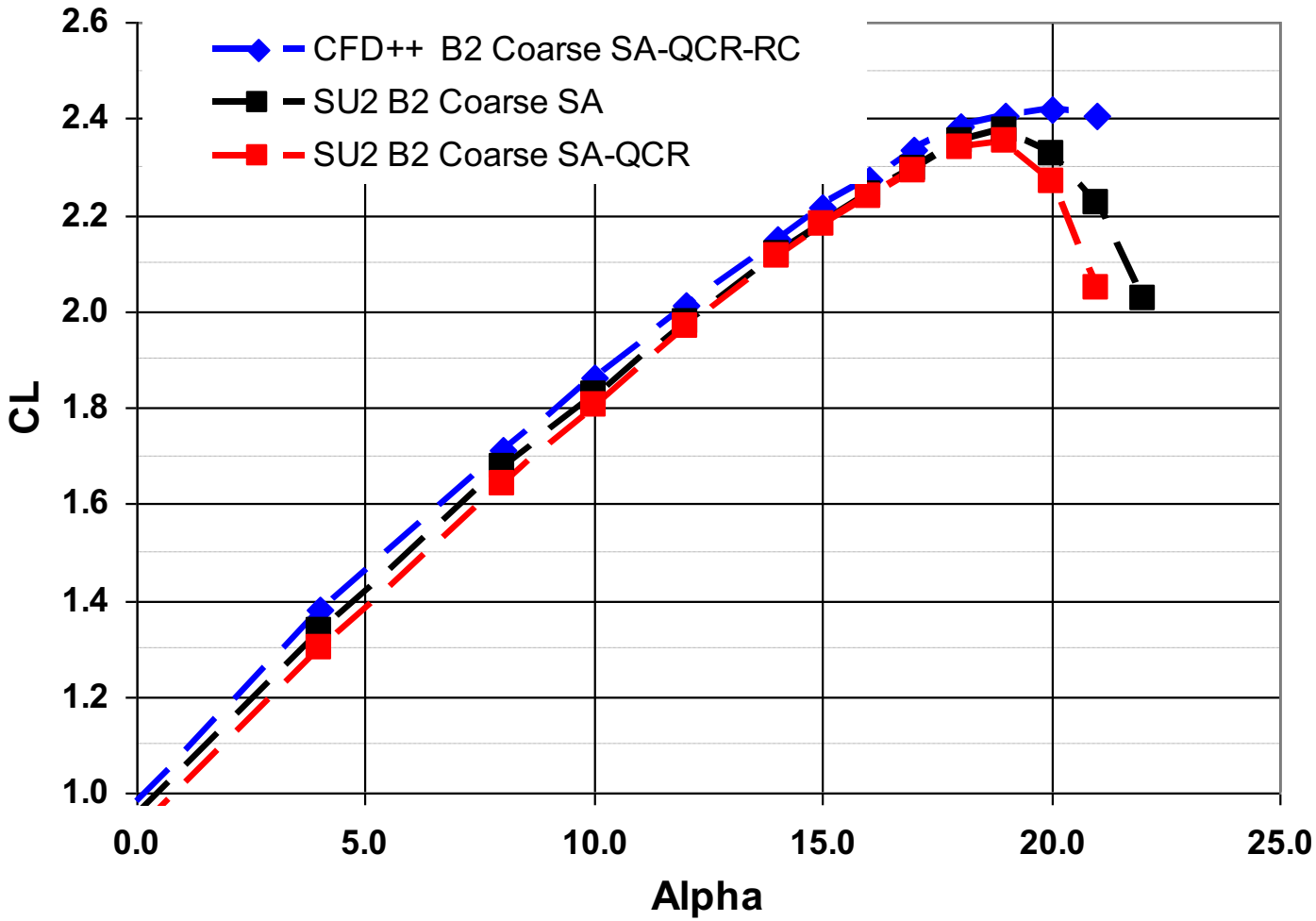
HL-CRM results – grid convergence

Grid B3



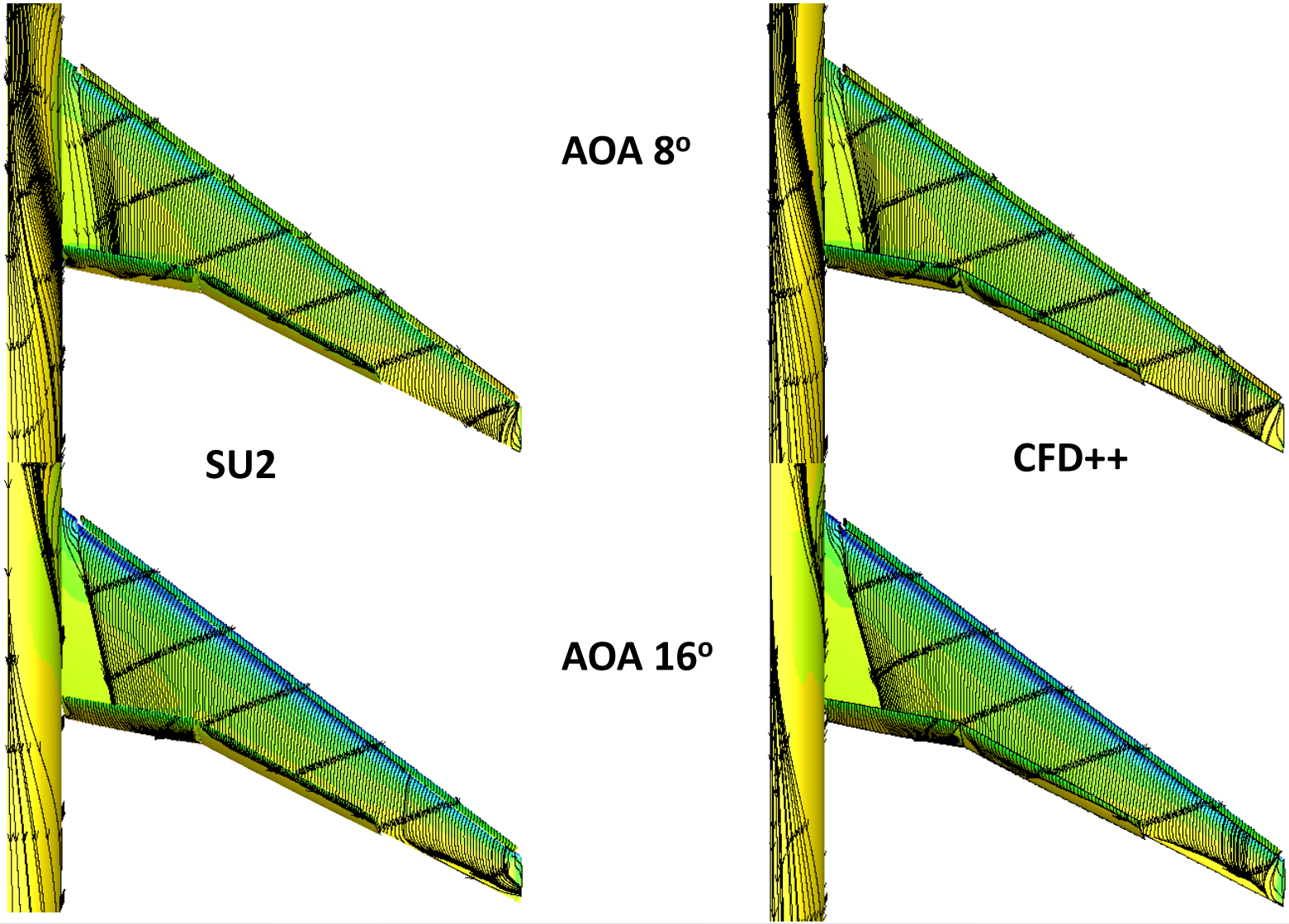
HL-CRM results – grid convergence

Grid B3



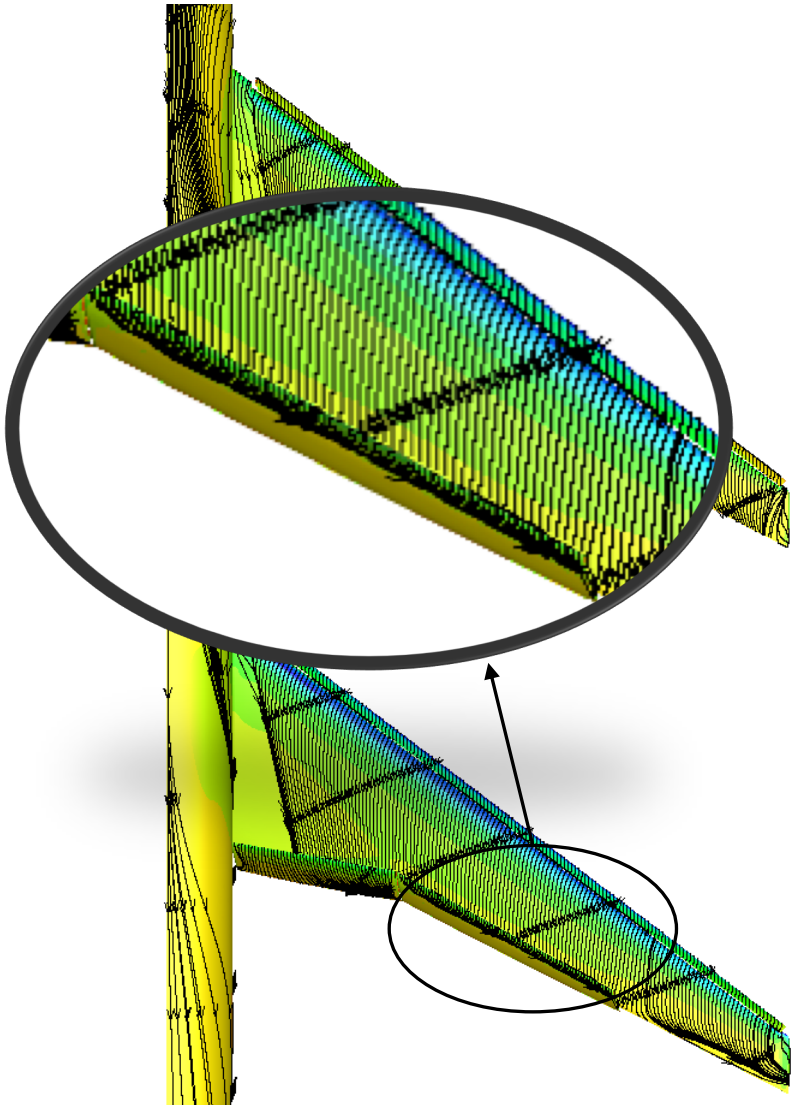
HL-CRM results – solvers

Grid B3 – Coarse



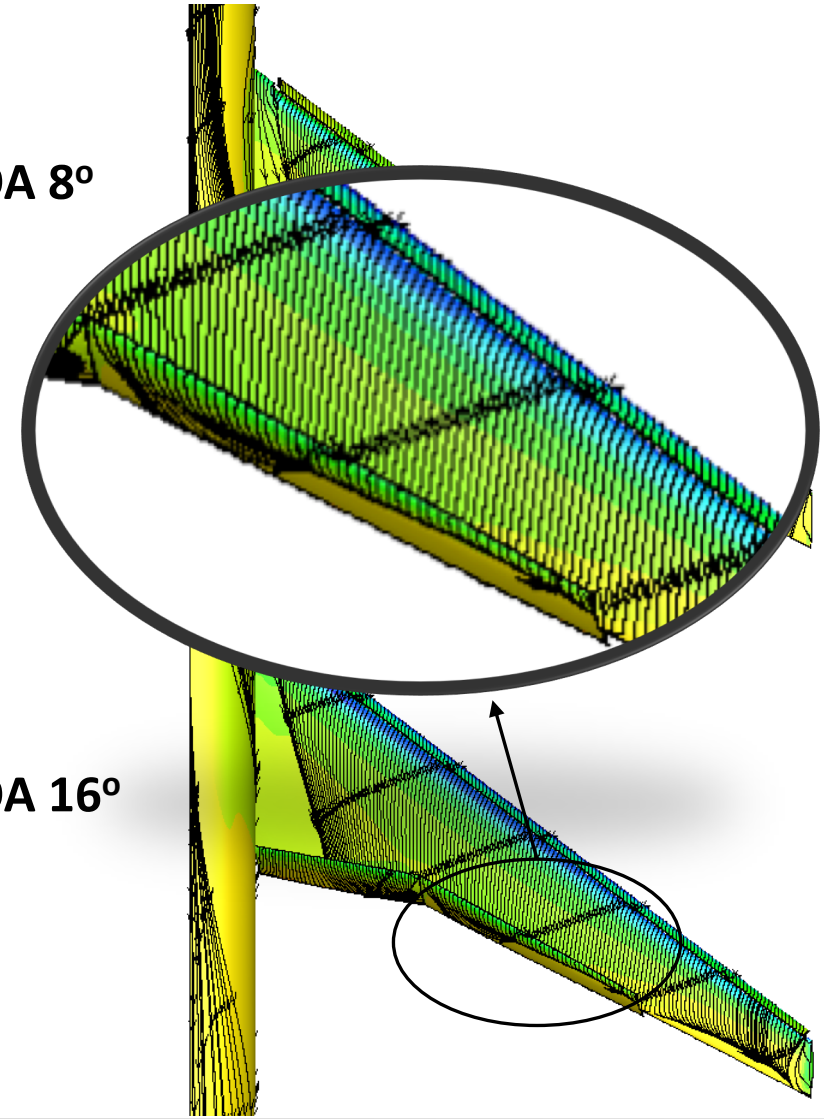
HL-CRM results – solvers

Grid B3 – Coarse



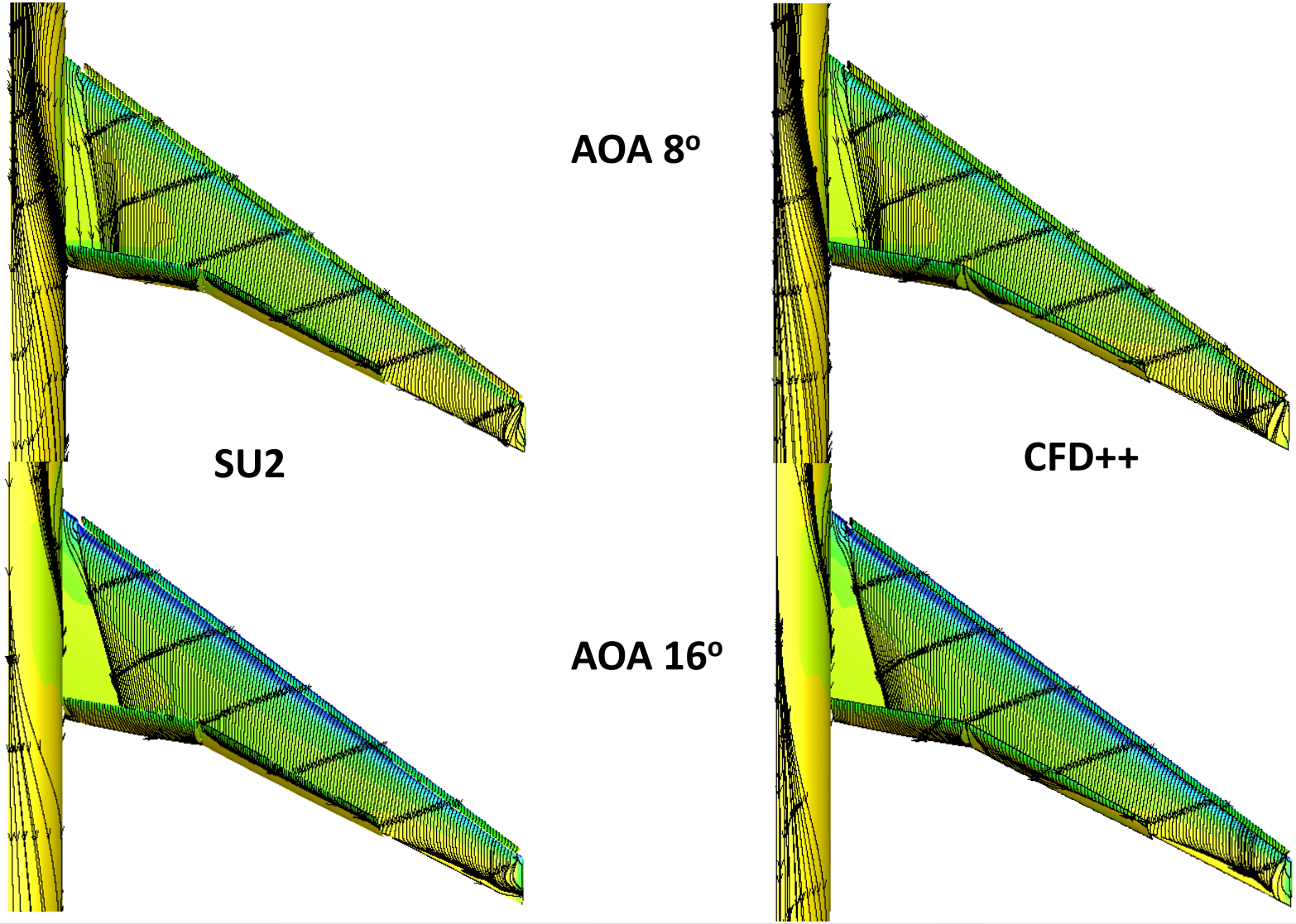
AOA 8º

AOA 16º



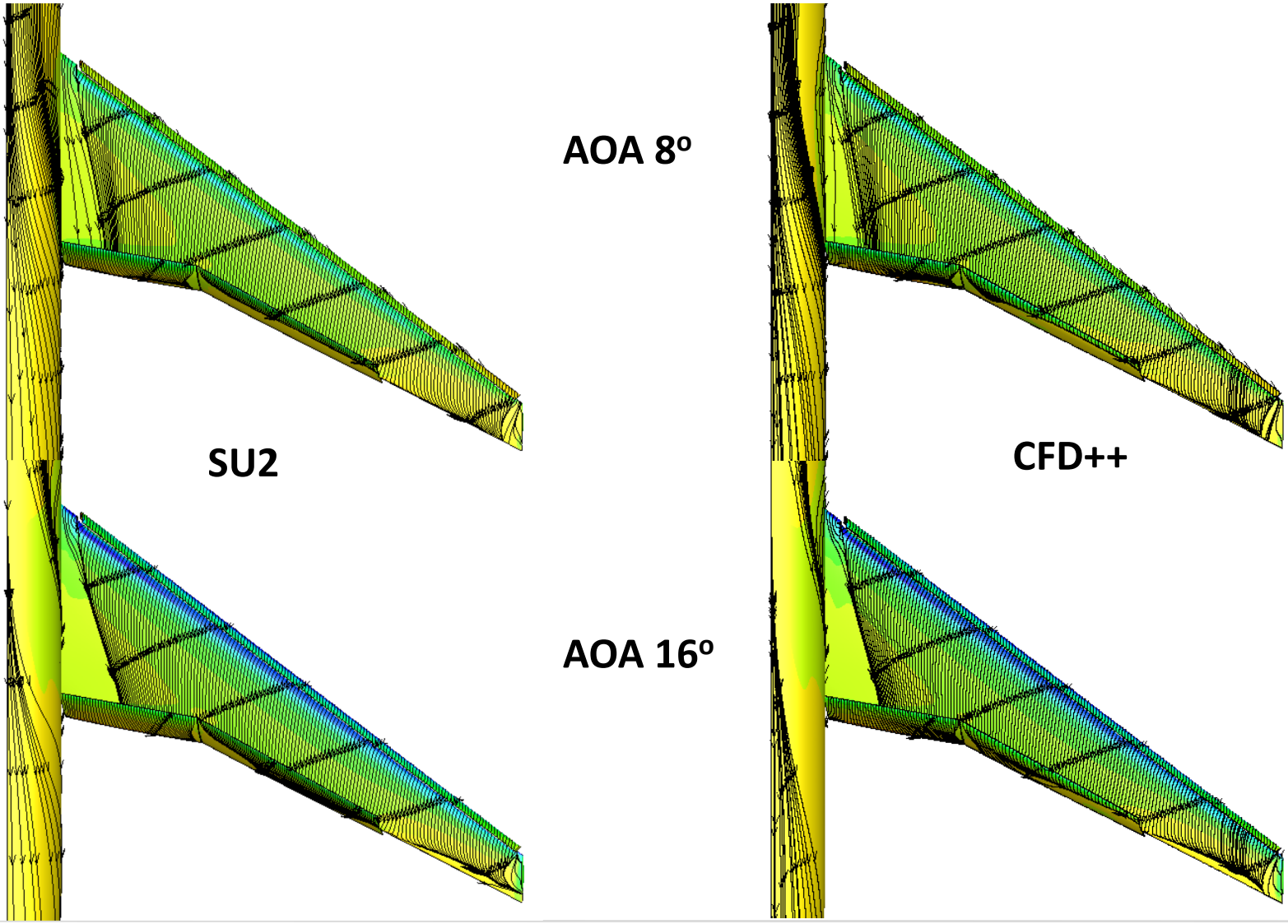
HL-CRM results – solvers

Grid B3 – Medium



HL-CRM results – solvers

Grid B3 – Fine



Brief overview of HL-CRM results

- Grid convergence
  - Results are reasonably converged for CL and CD but not for CM
- Coefficients
  - SU2 captured a stall at 19°, and CFD++ captured a stall at 20°
  - The QCR did not have a significant affect
- Streamlines
  - The flap have less flow separation with CFD++ in the outboard panel at Coarse mesh, but inverted at Medium and Fine mesh.

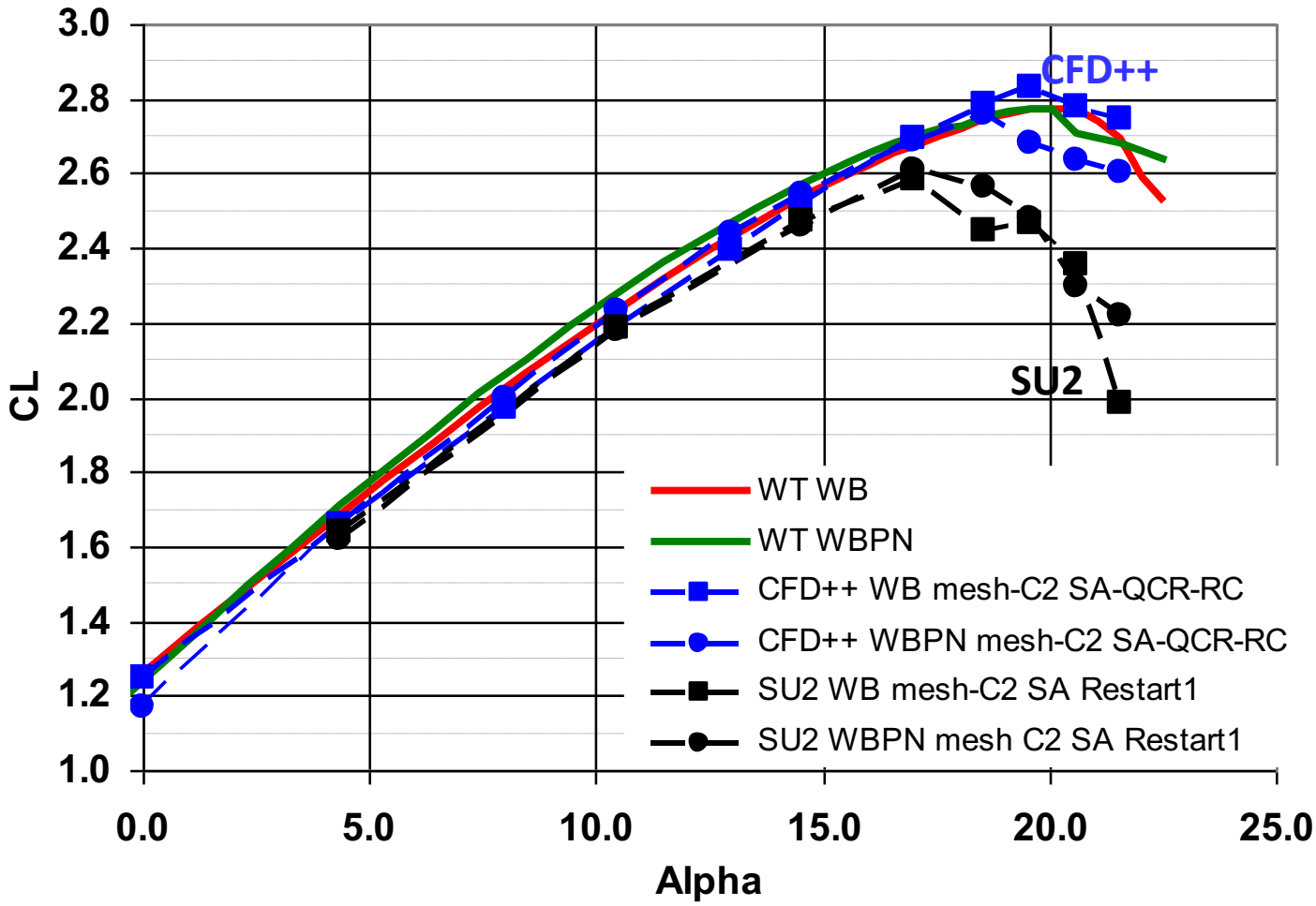
JSM results

M=0.17

Rey=1.93E+06

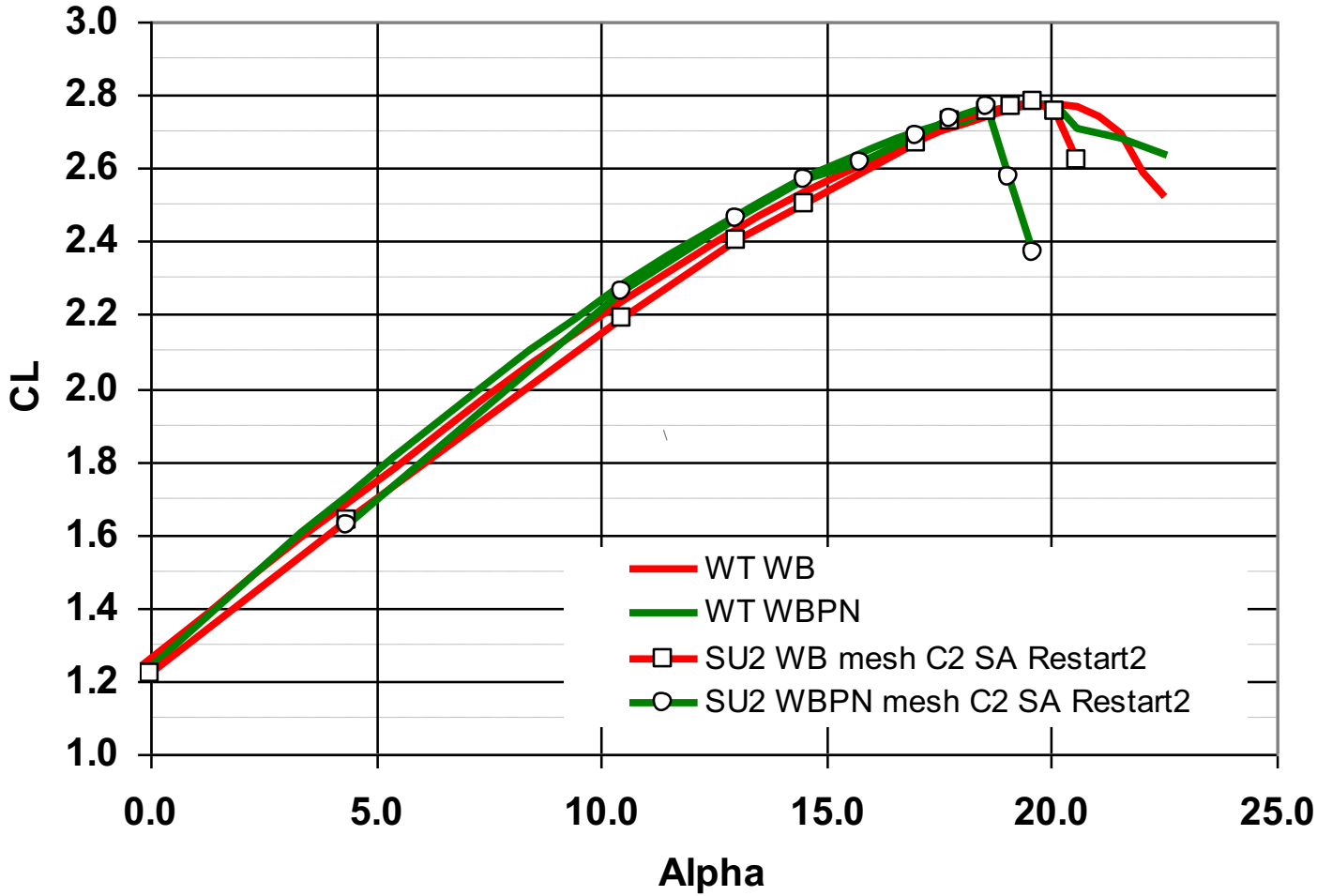
JSM results – CFD++ x SU2

SU2: SA
CFD++: SA
mesh family C2



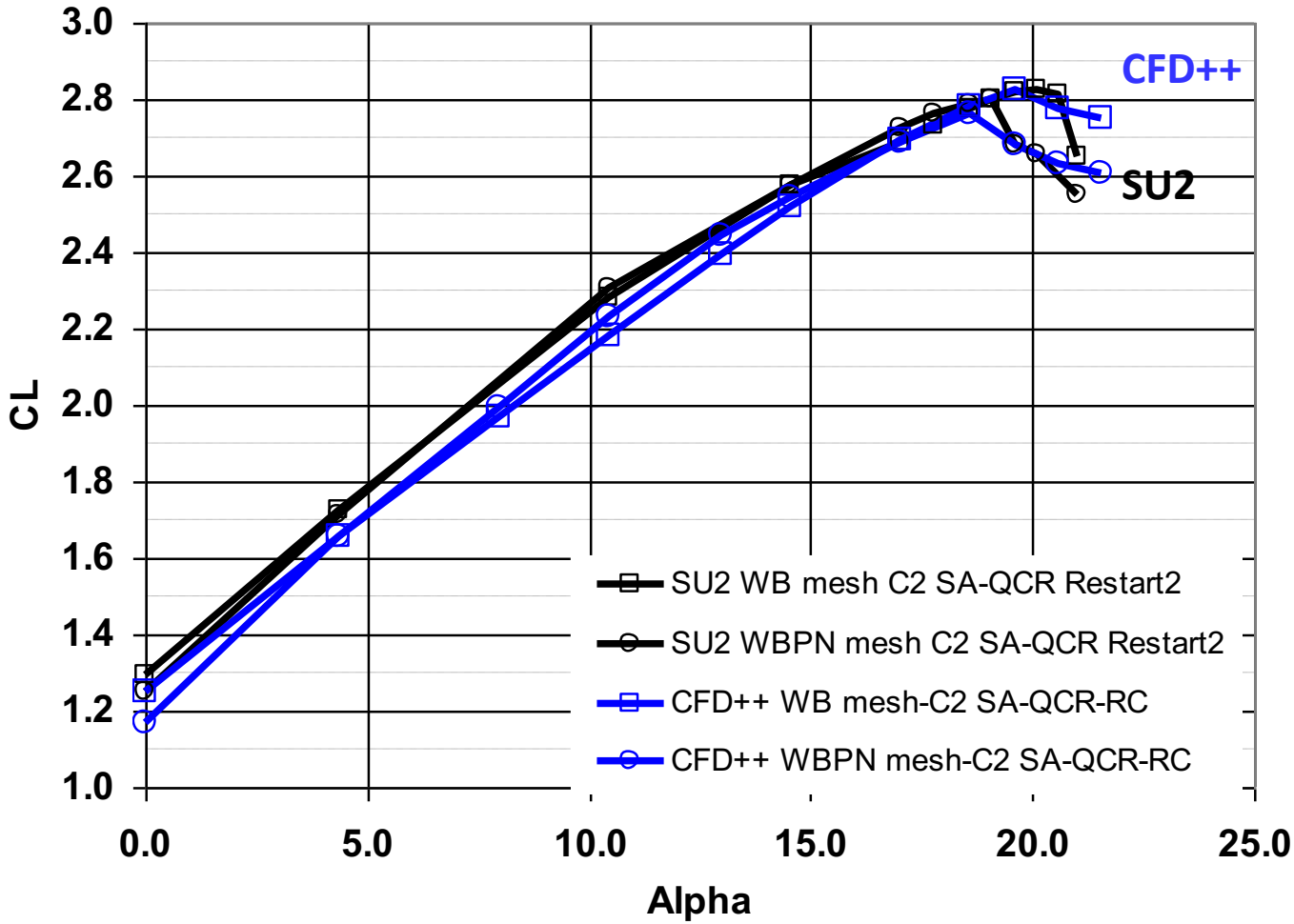
JSM results – SU2 – Restart2

SU2: SA
CFD++: SA
mesh family C2



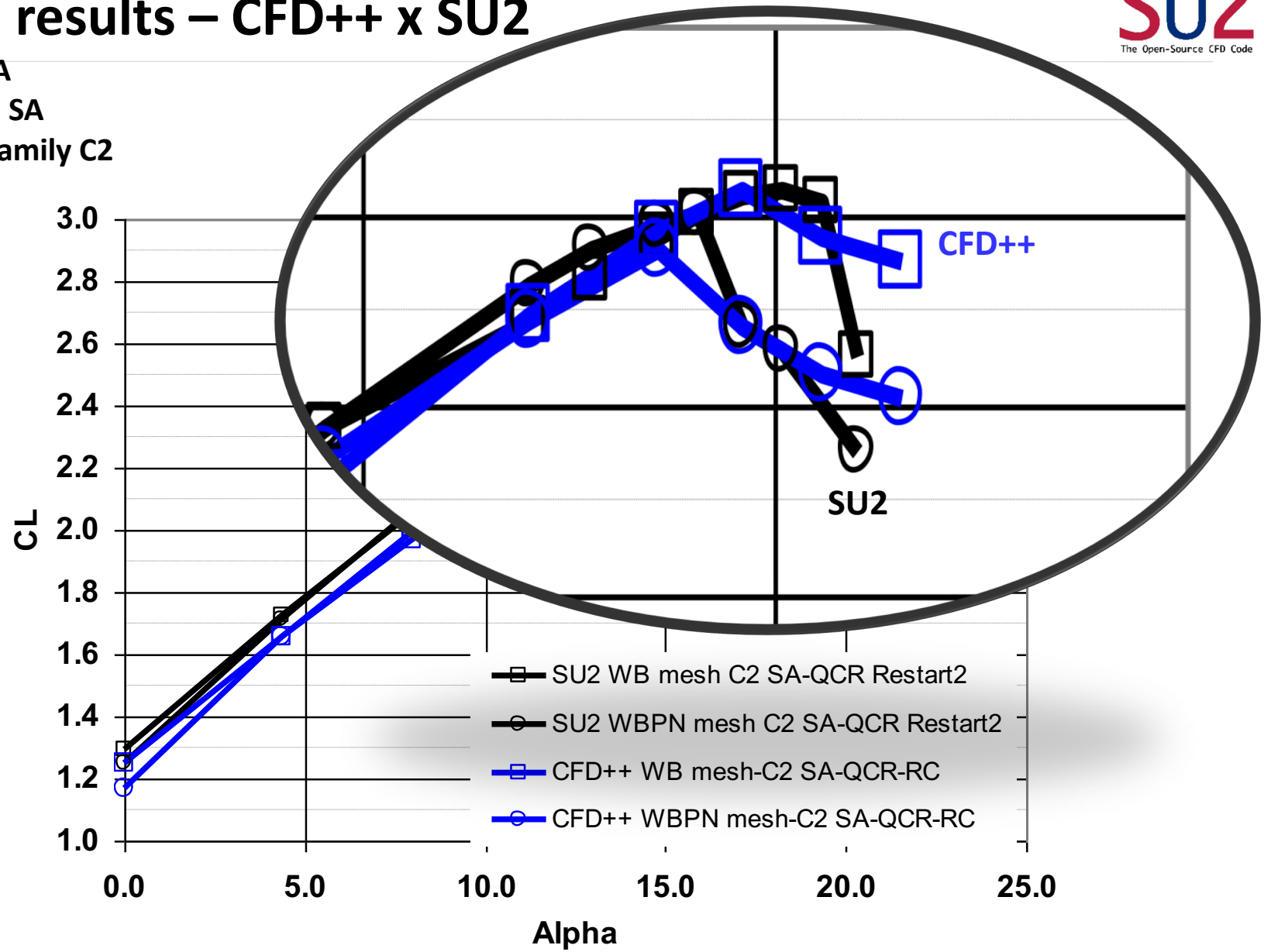
JSM results – CFD++ x SU2

SU2: SA
CFD++: SA
mesh family C2



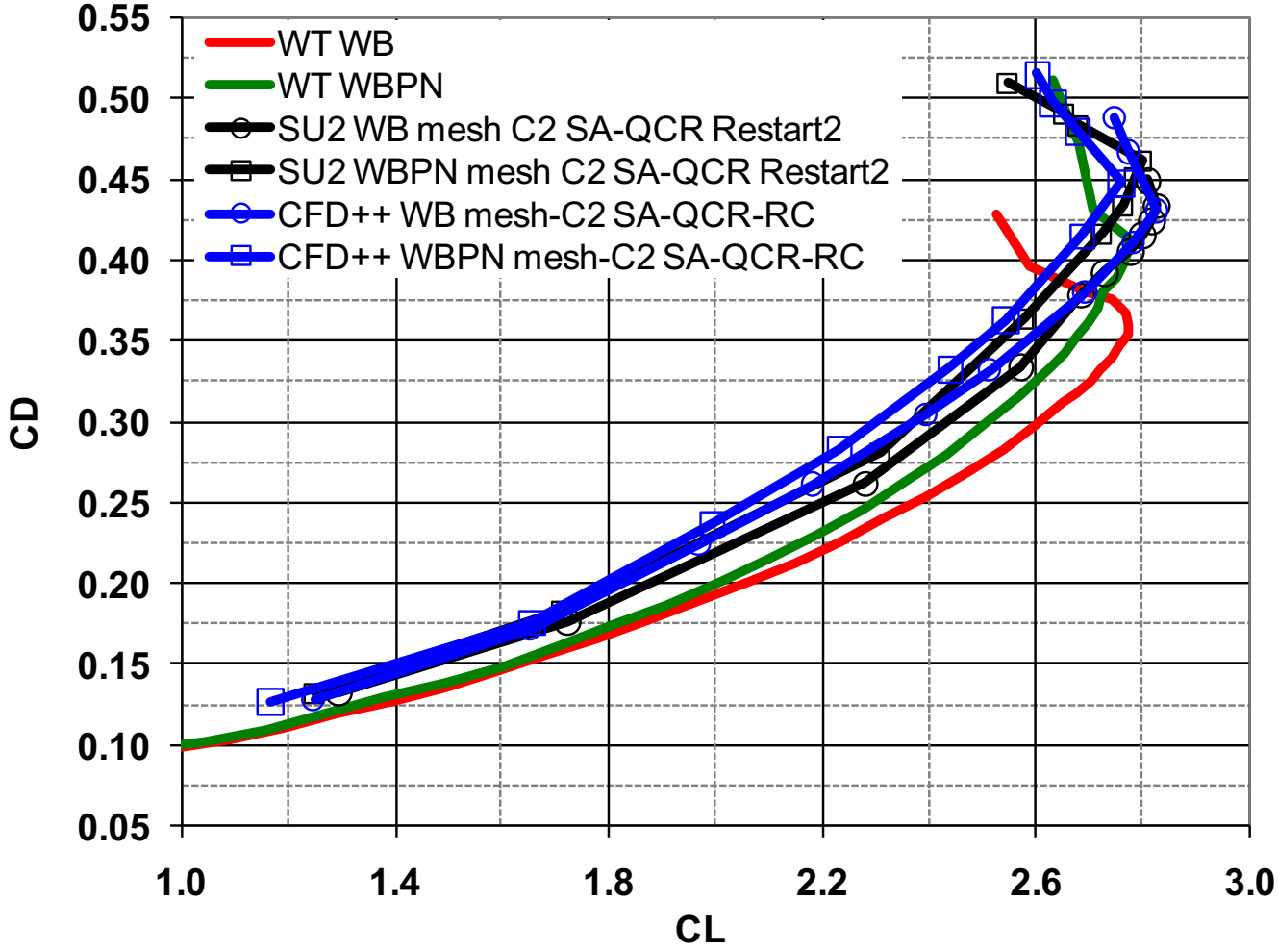
JSM results – CFD++ x SU2

SU2: SA
CFD++: SA
mesh family C2

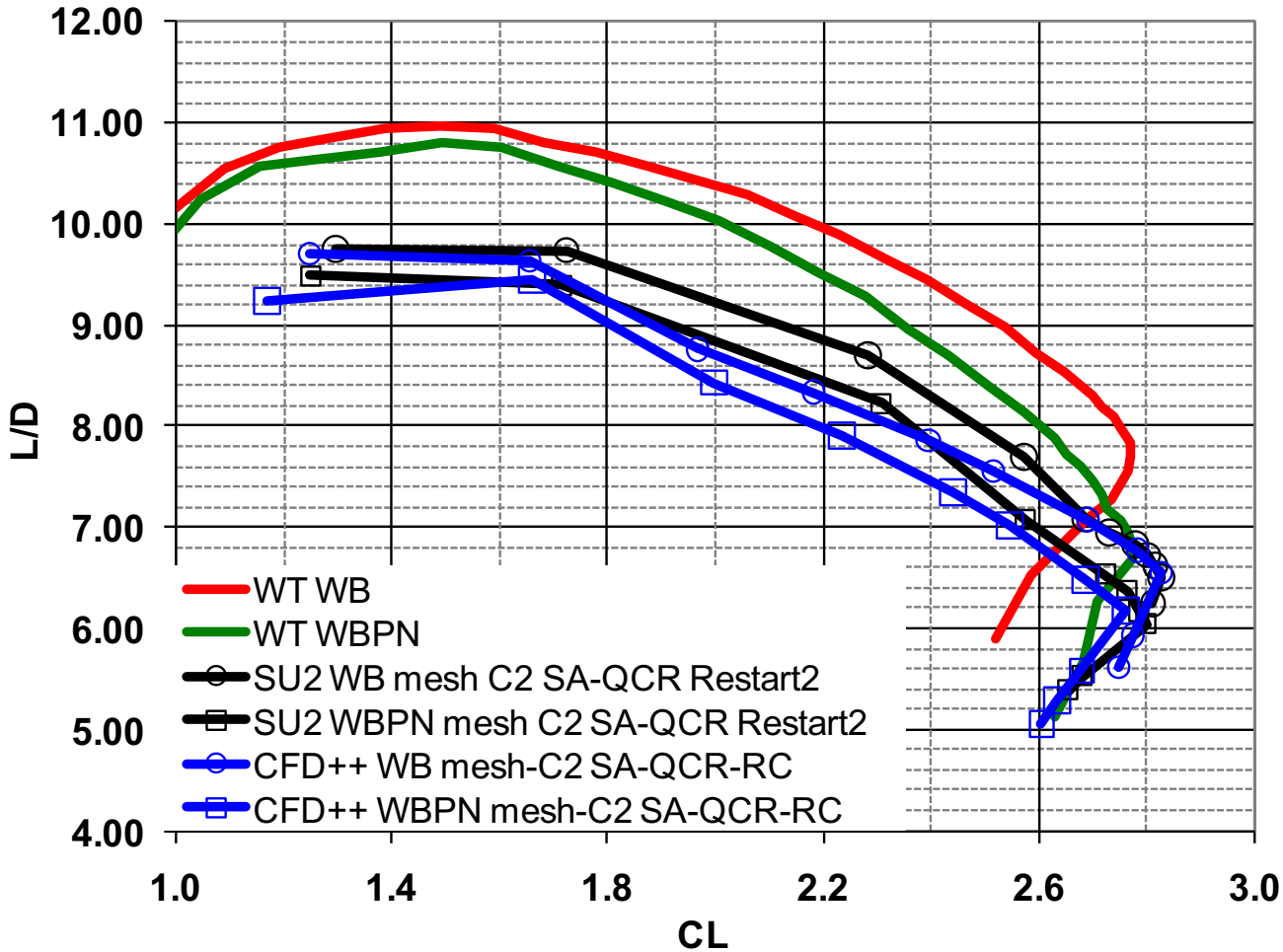


JSM results – CFD++ x SU2

SU2: SA
CFD++: SA
mesh family C2



JSM results – PyNaOn x PyNaOff

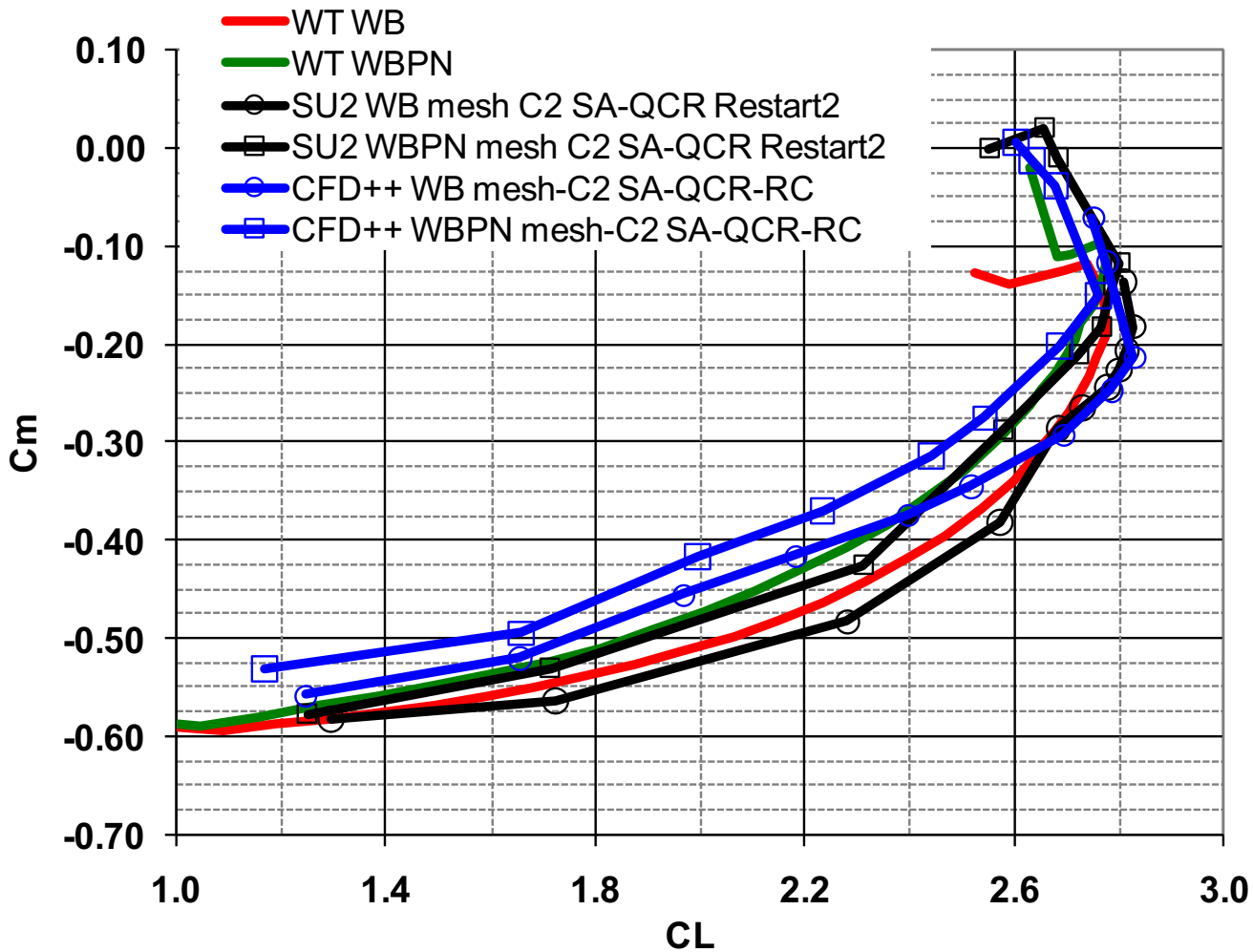


Captured the change in L/D ratio

Overall poor comparison

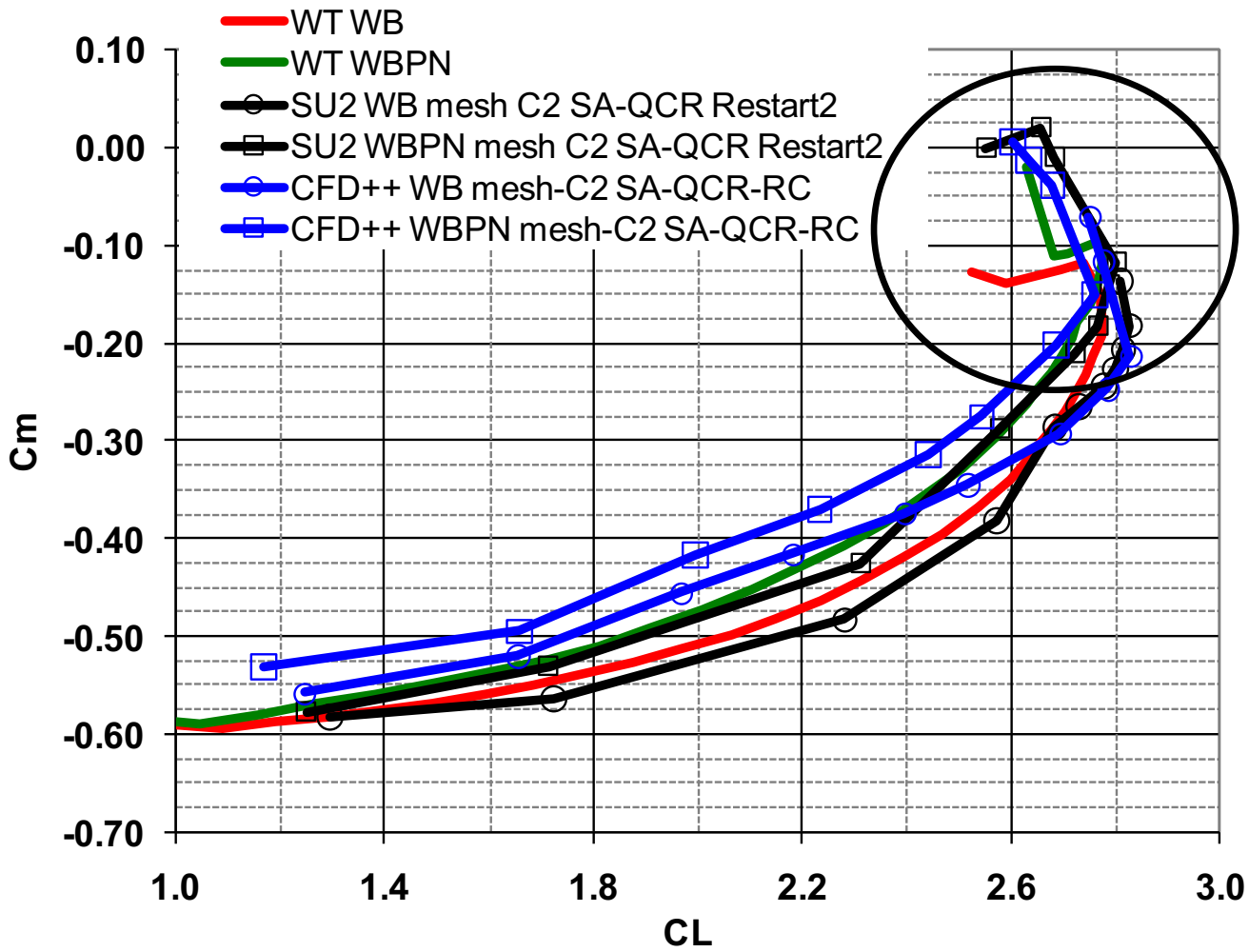
JSM results – PyNaOn x PyNaOff

SU2: SA
CFD++: SA
mesh family C2



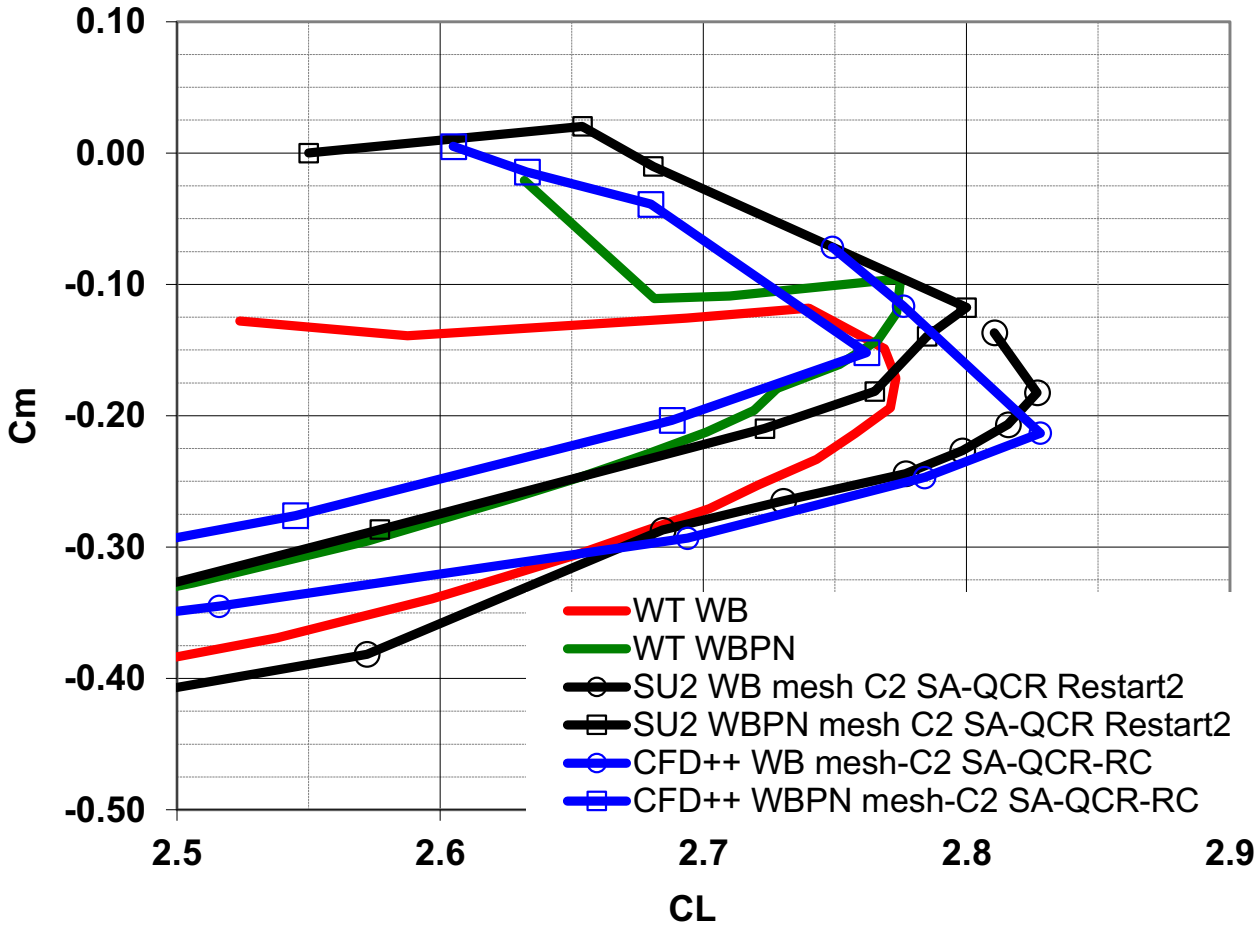
JSM results – PyNaOn x PyNaOff

SU2: SA
CFD++: SA
mesh family C2

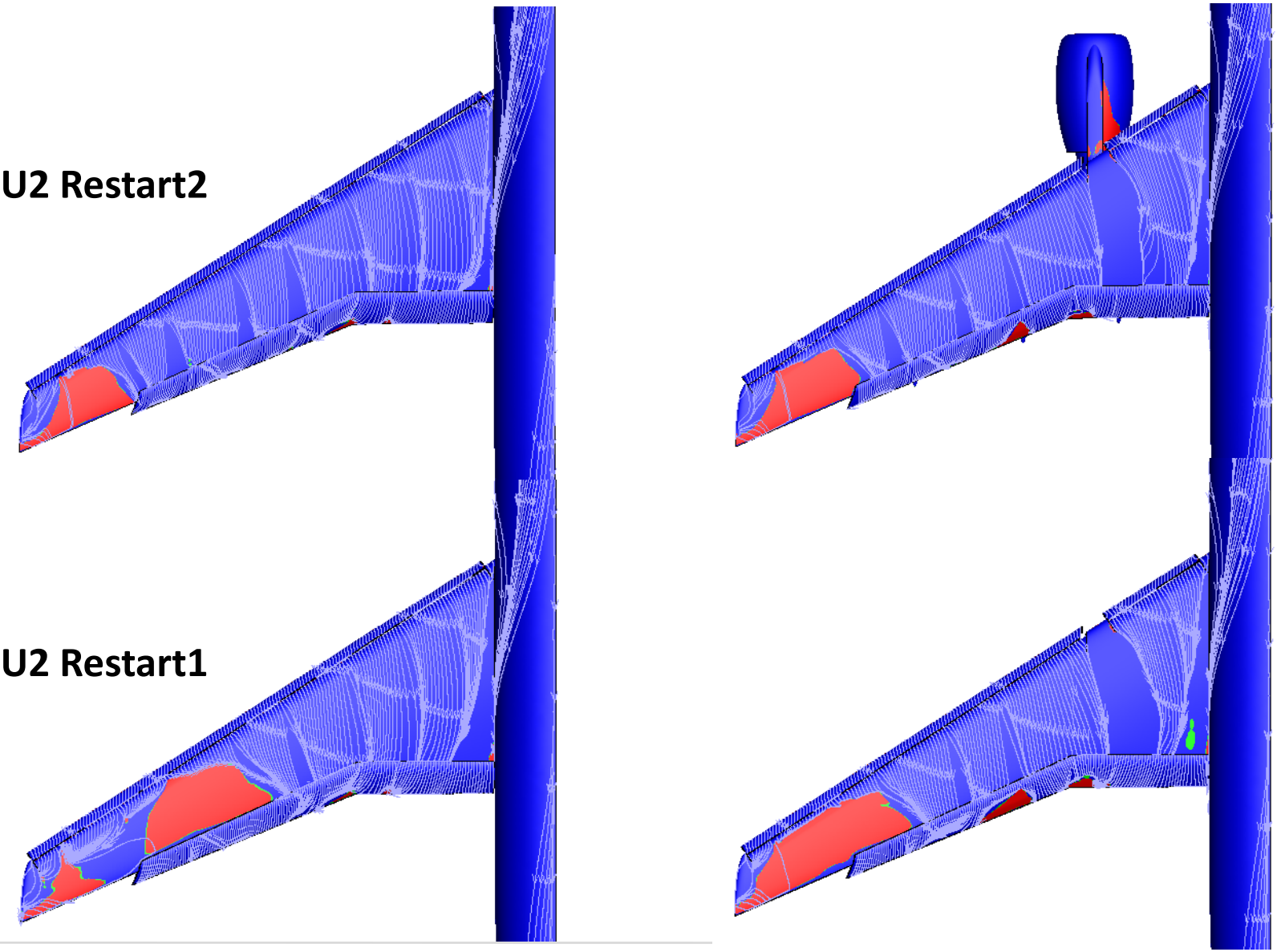


JSM results – PyNaOn x PyNaOff

SU2: SA
CFD++: SA
mesh family C2



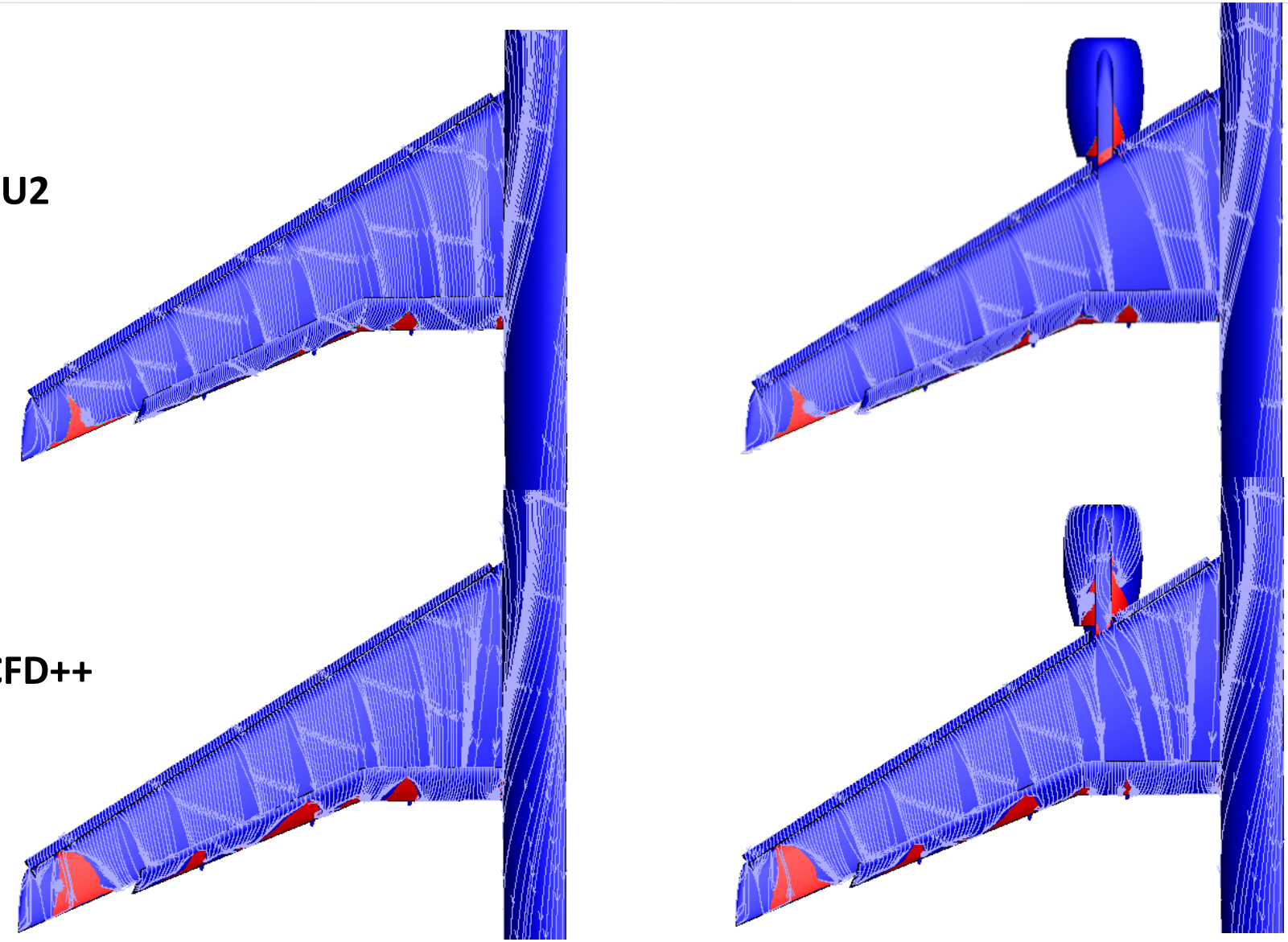
JSM results – C2 – Restart 1 vs Restart 2 – 18.58°



JSM results – C2 – PyNaOn x PyNaOff – 10.47°

SU2

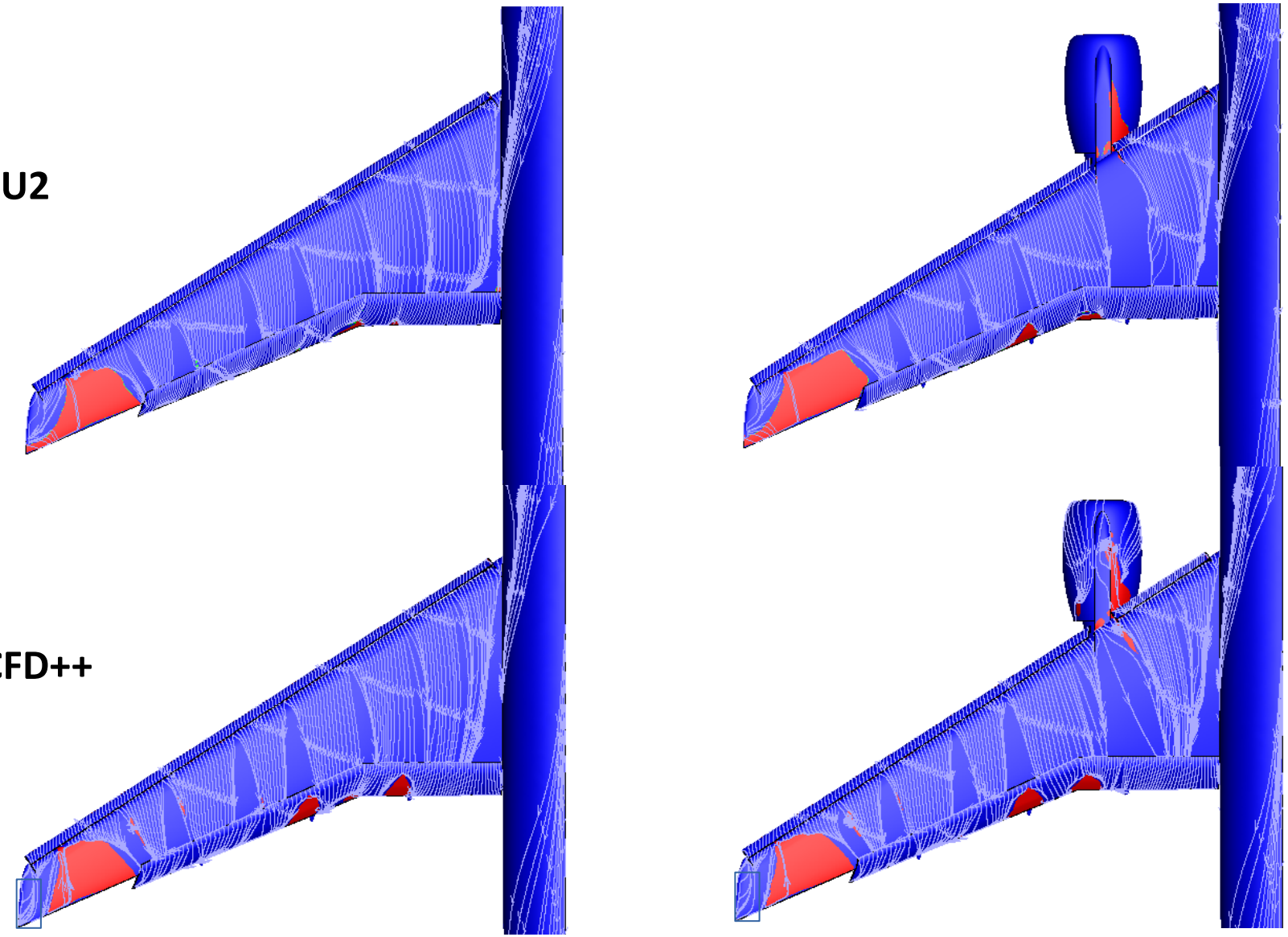
CFD++



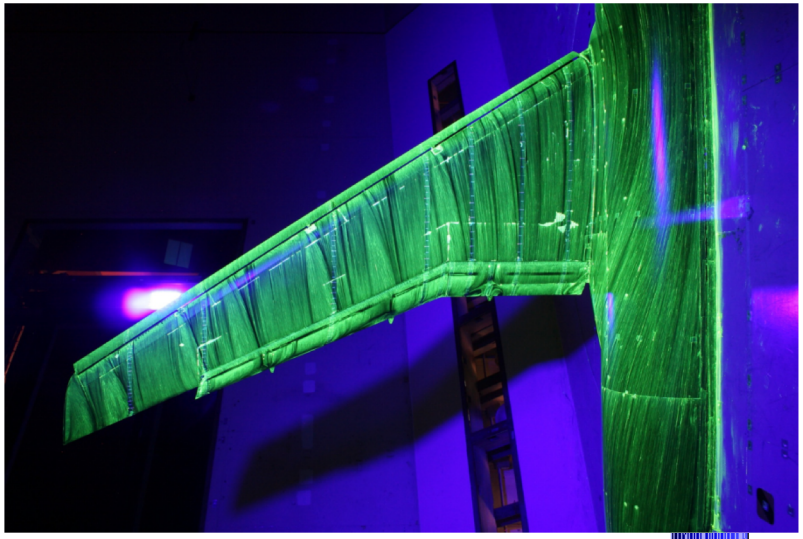
JSM results – C2 – PyNaOn x PyNaOff – 18.58°

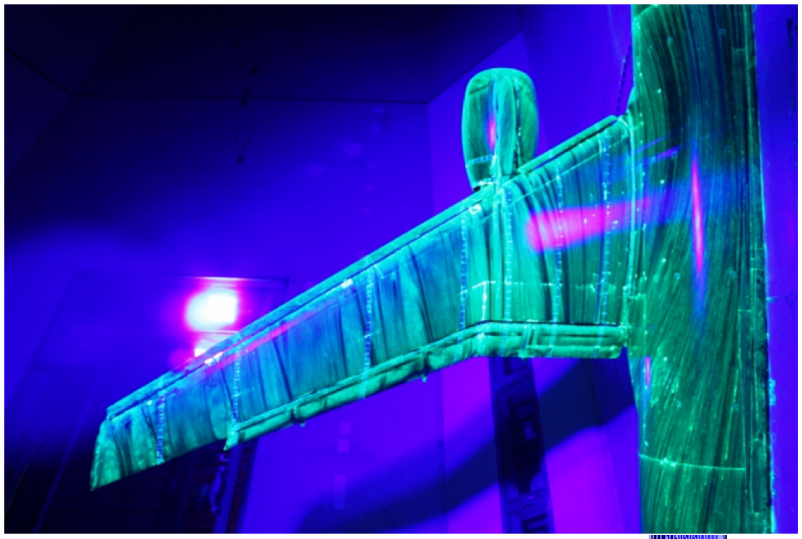
SU2

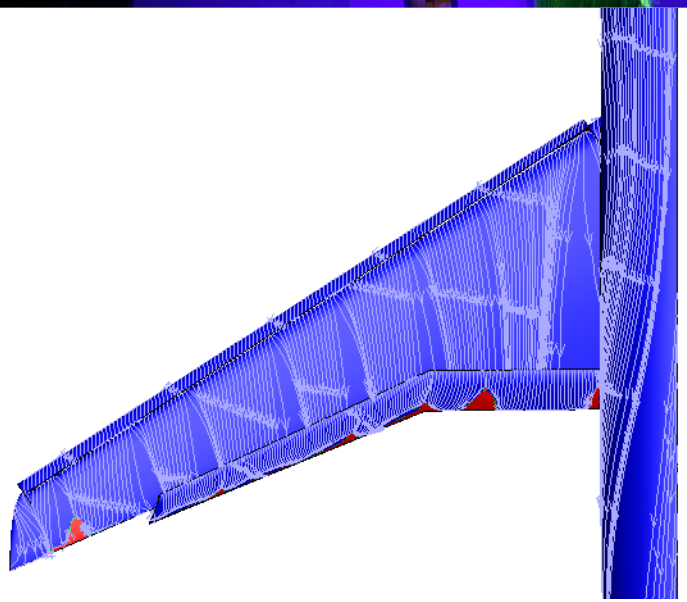
CFD++

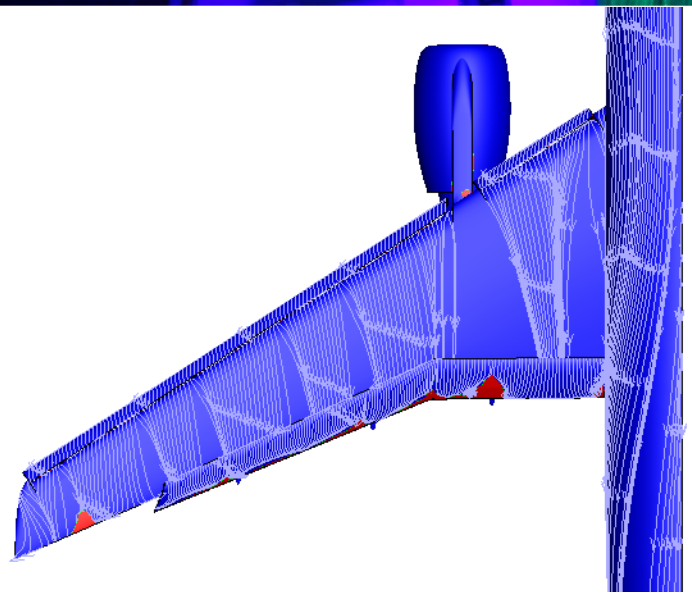


JSM results – C2 – PyNaOn x PyNaOff – 4.36°

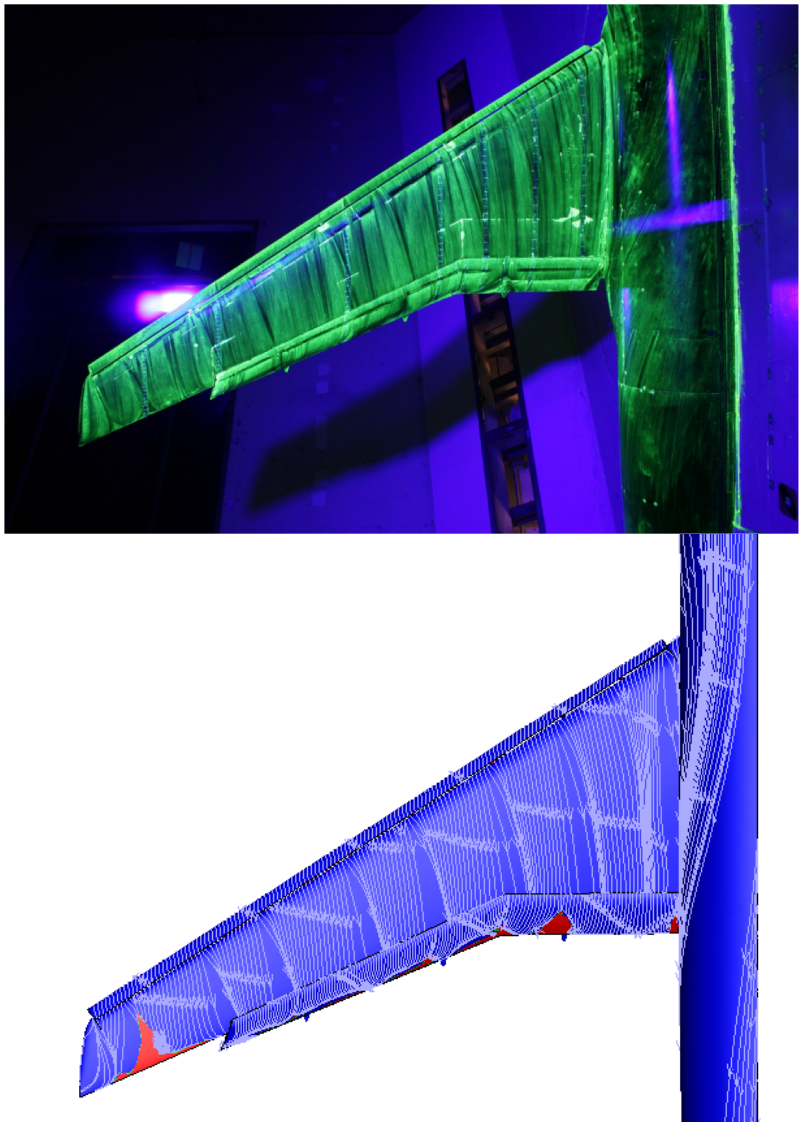


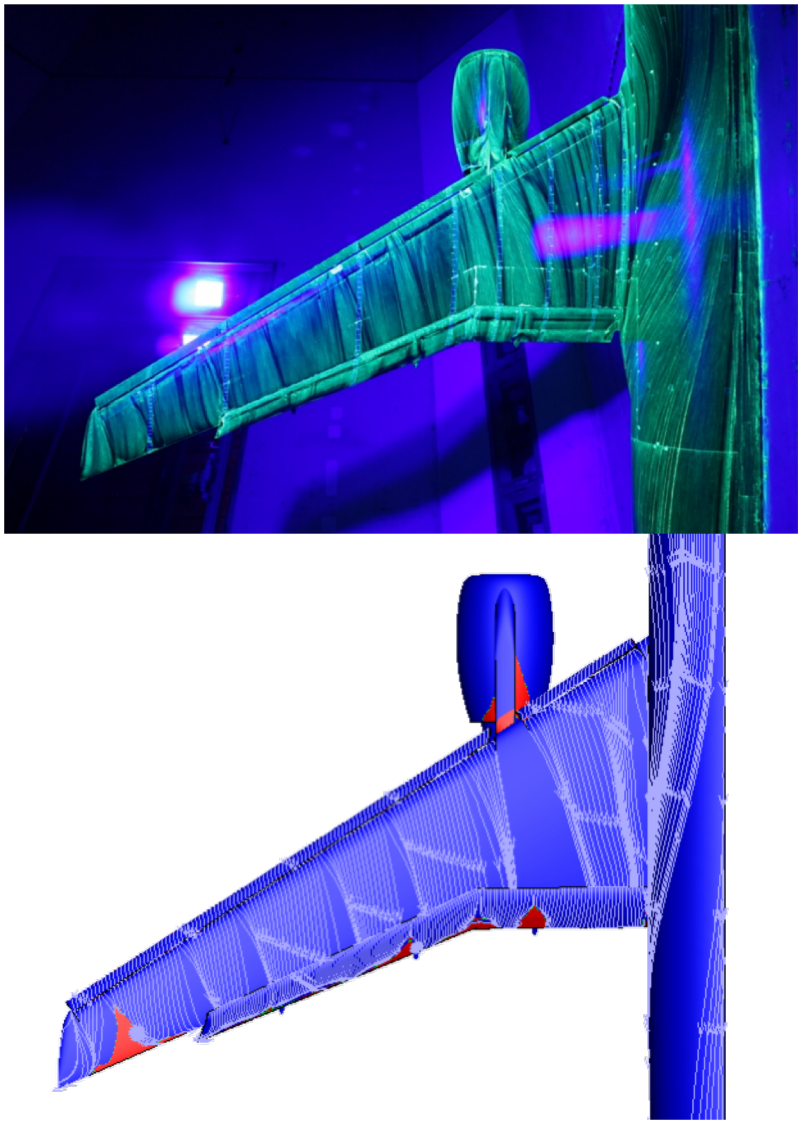




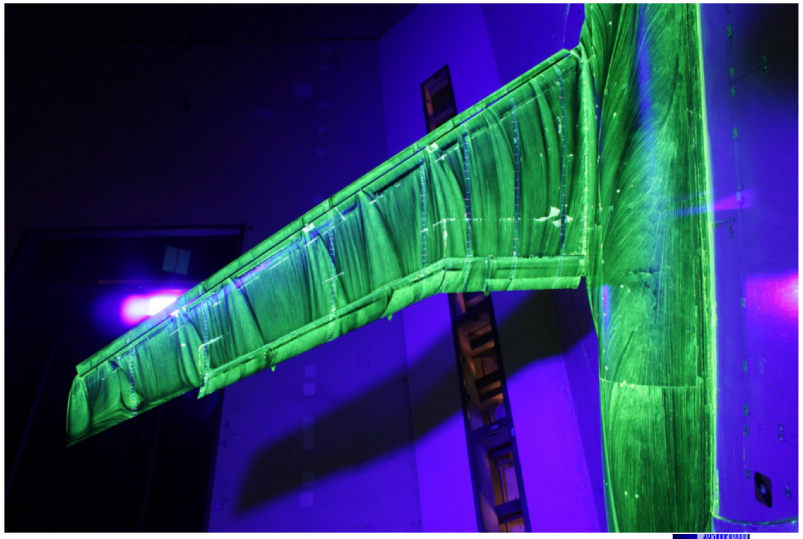


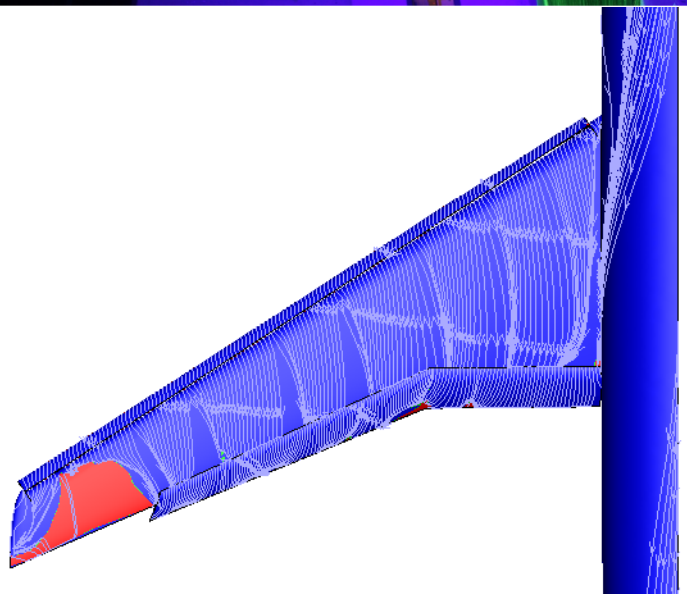
JSM results – C2 – PyNaOn x PyNaOff – 10.47°

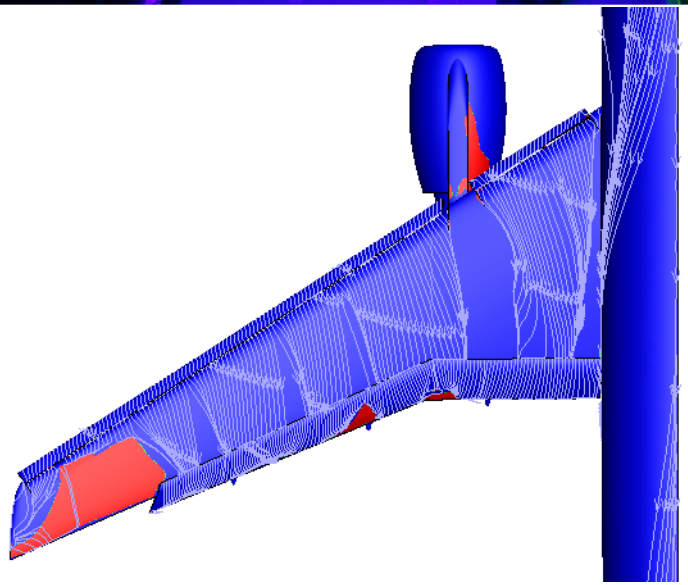




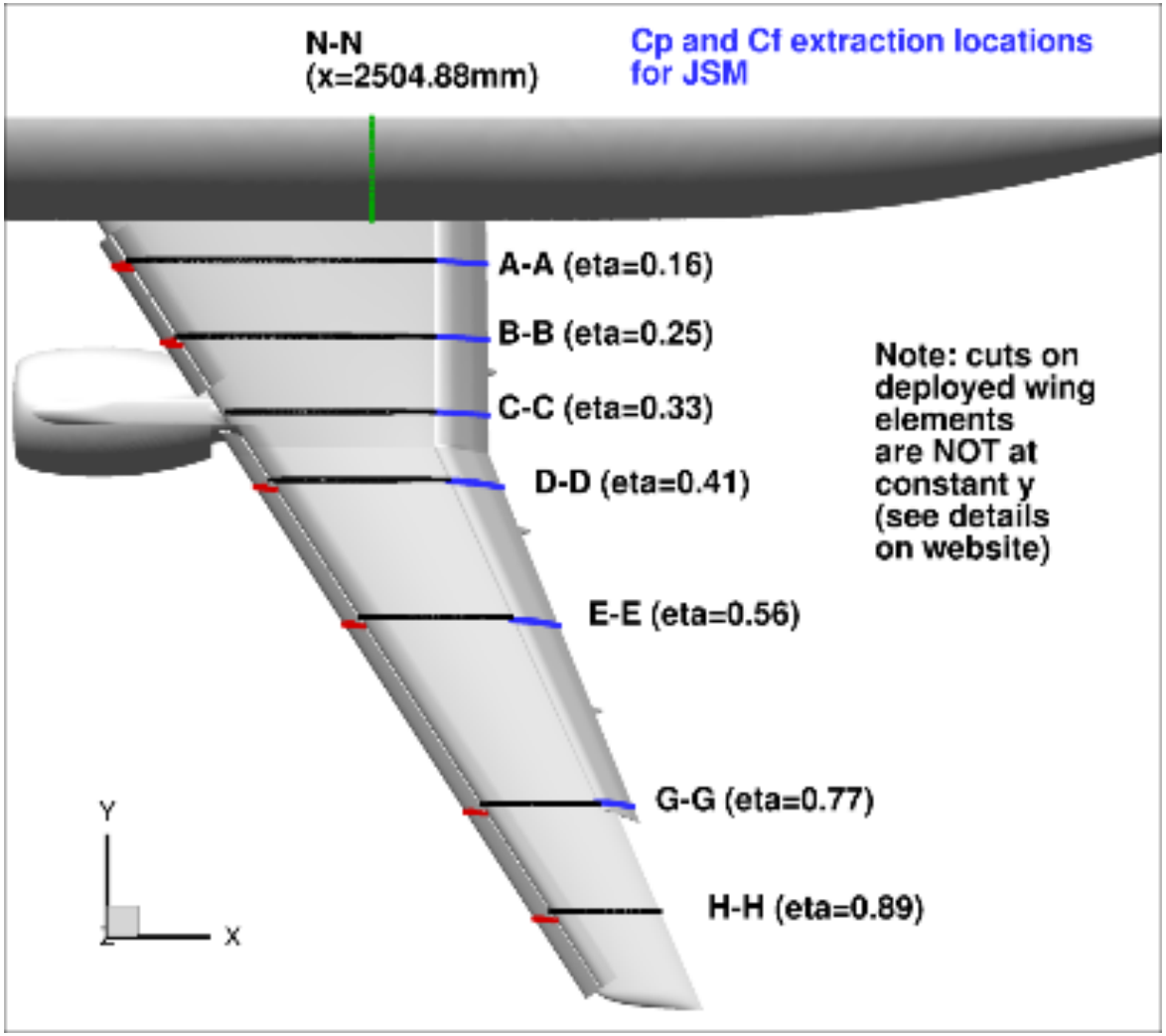
JSM results – C2 – PyNaOn x PyNaOff – 18.58°



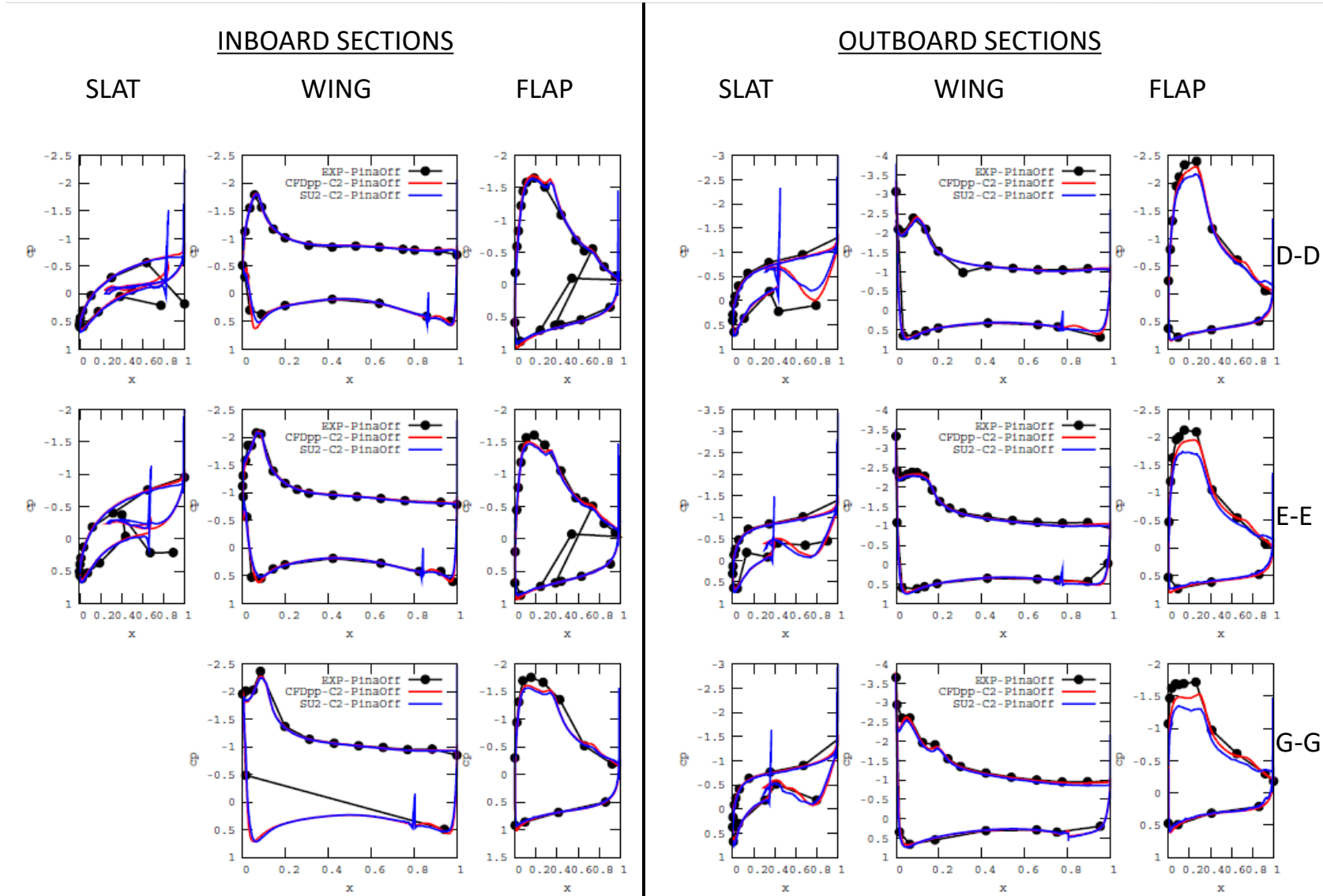




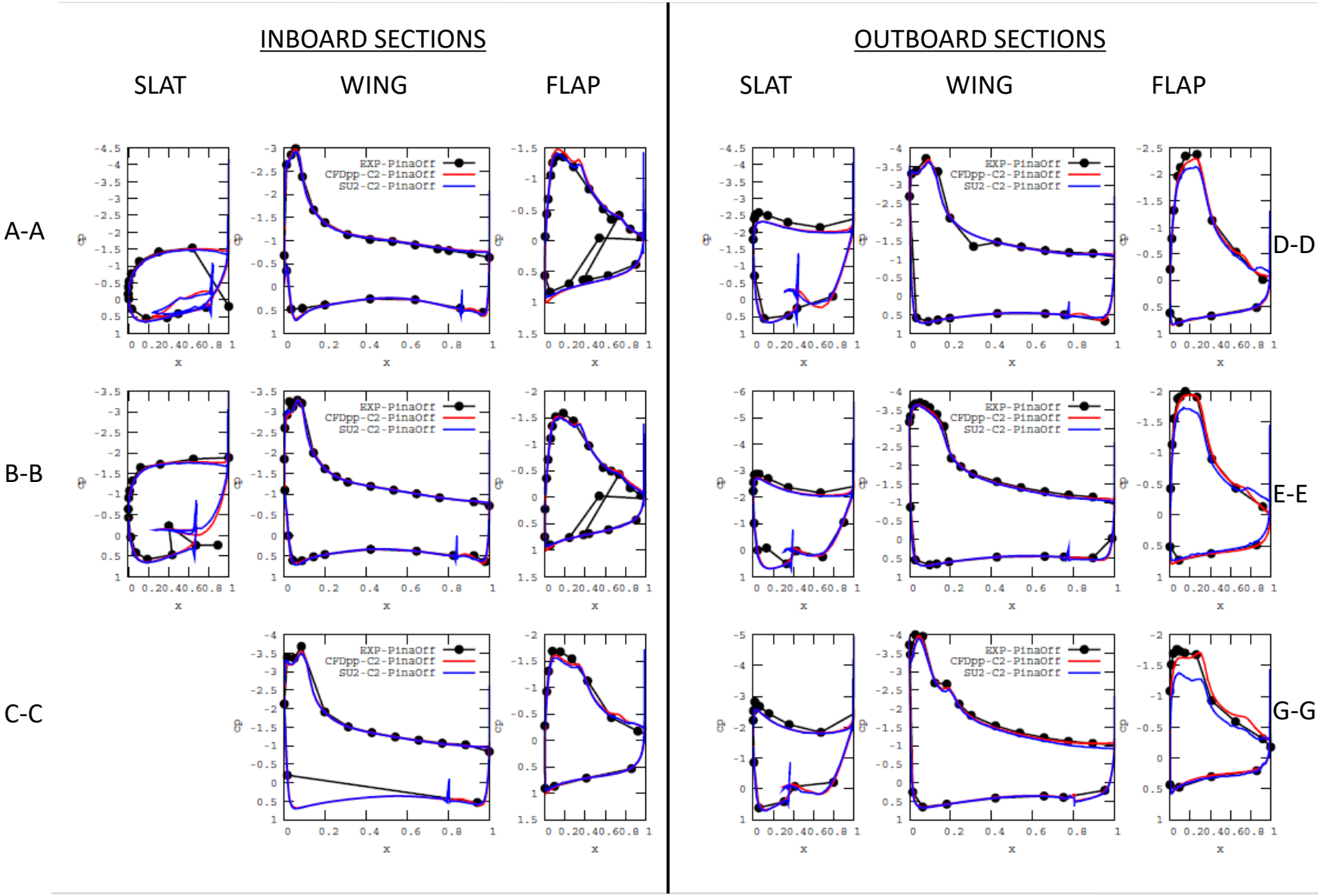
JSM results – Cp's



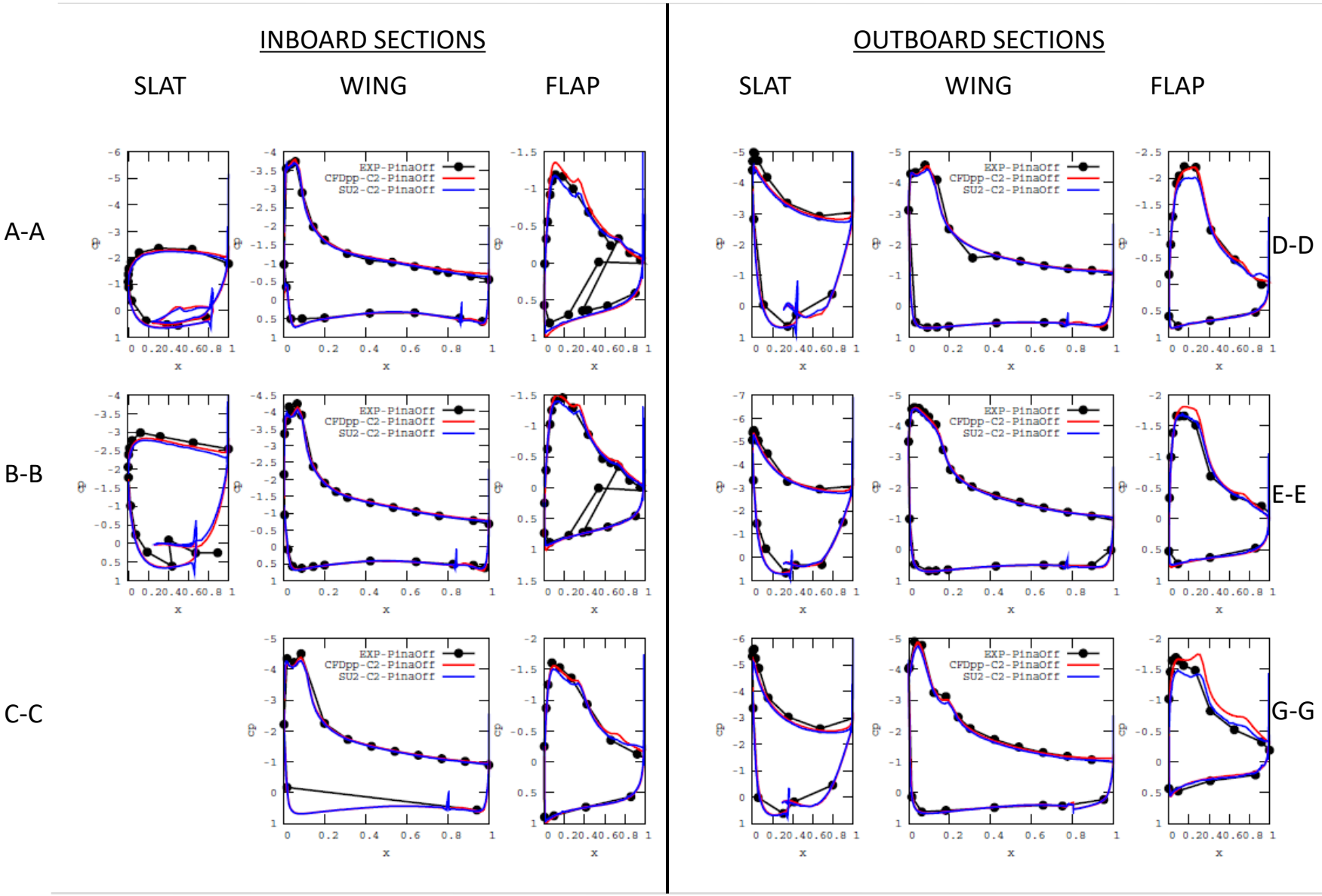
JSM results – C2 –PyNaOff – 4.36°



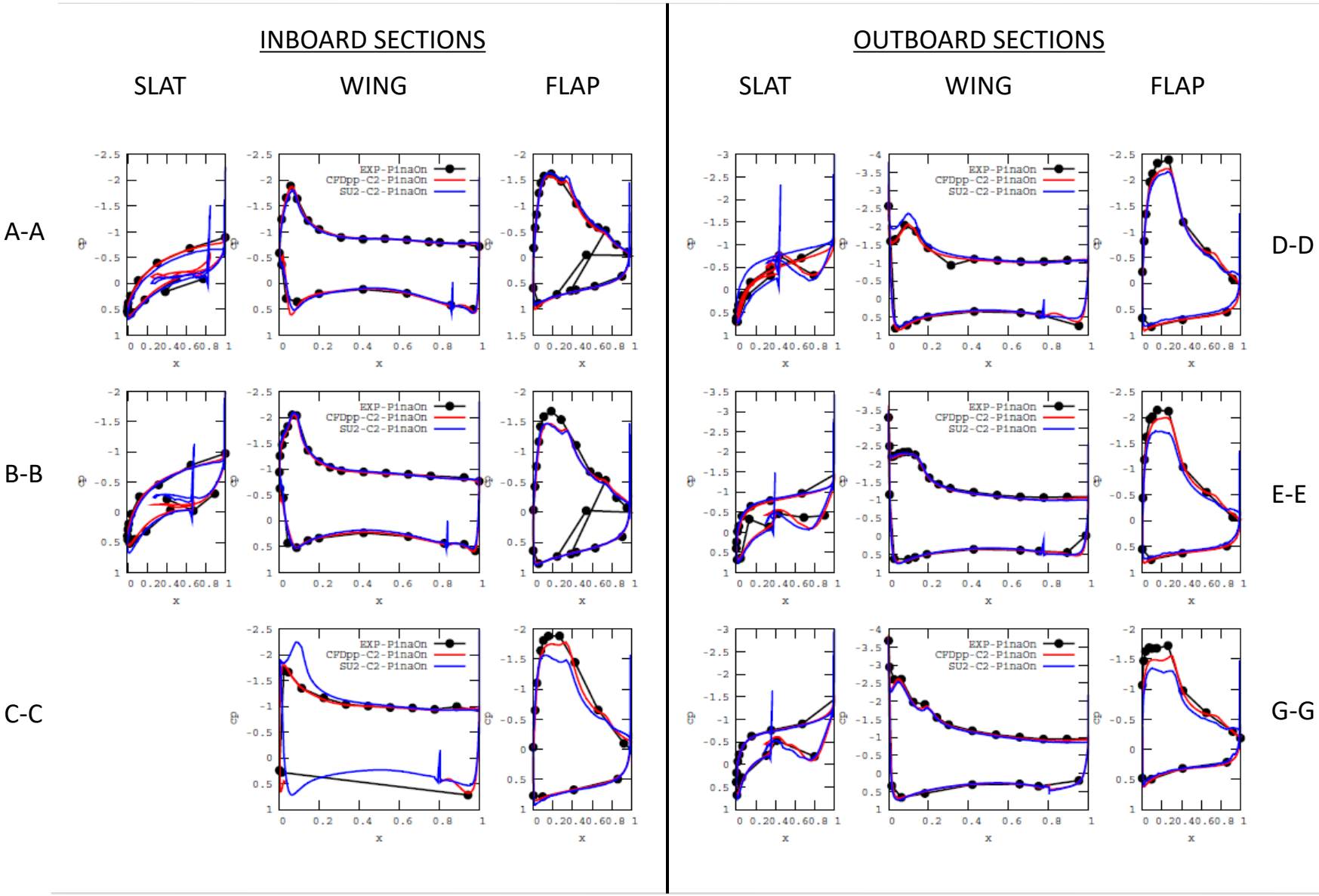
JSM results – C2 –PyNaOff – 10.48°



JSM results – C2 –PyNaOff – 14.54°



JSM results – C2 –PyNaOn – 4.36°



JSM results – C2 –PyNaOn – 10.48°

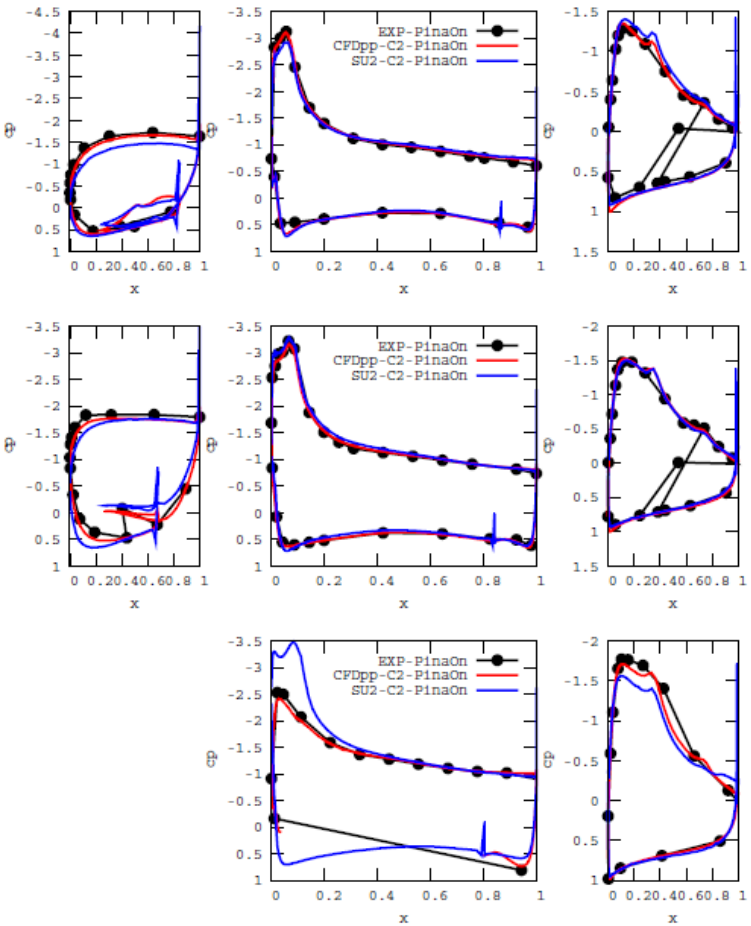
INBOARD SECTIONS

SLAT WING FLAP

A-A

B-B

C-C



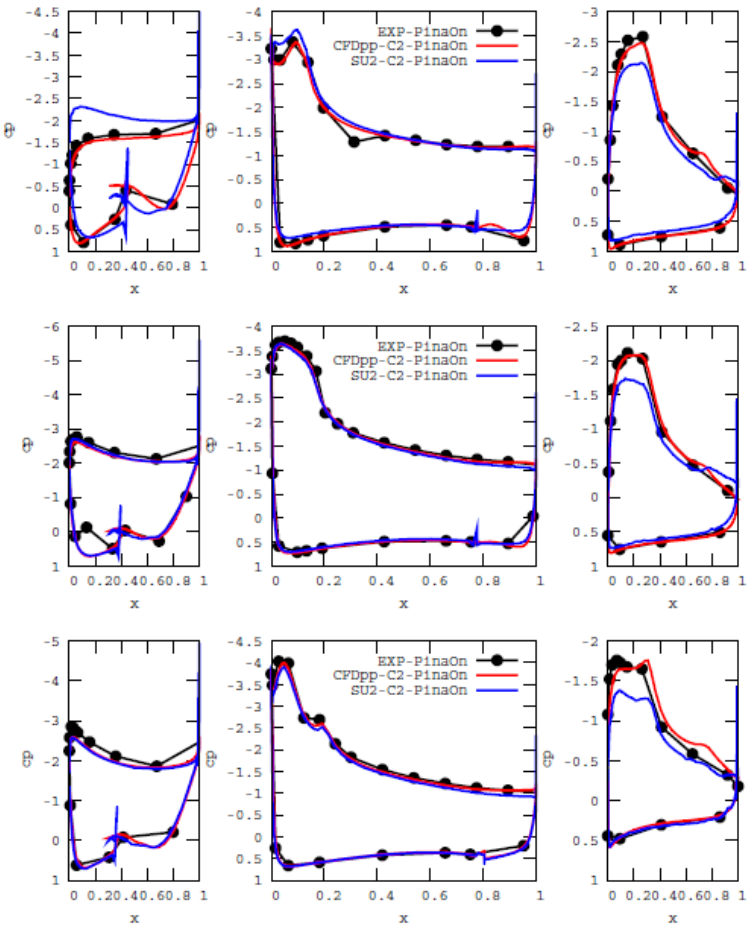
OUTBOARD SECTIONS

SLAT WING FLAP

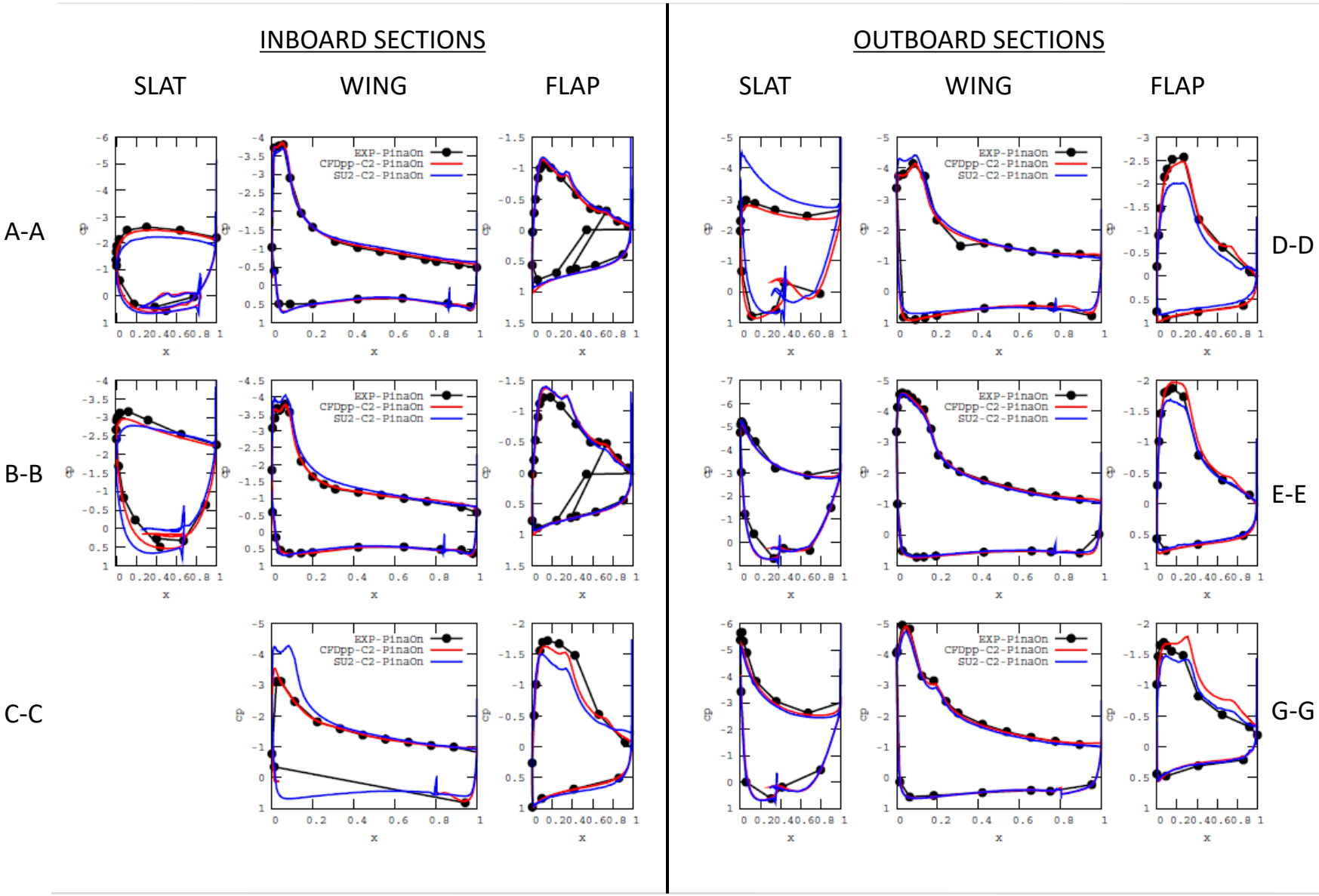
D-D

E-E

G-G



JSM results – C2 –PyNaOn – 14.54°



Brief overview of JSM results

- Setup improvement
  - With Restart 2, delta alpha 0.5, and QCR the SU2 have almost the same CFD++ results (CL vs Alpha)
- Coefficients & surface streamlines
  - CL/CD ratio did not compare well to experiment
    - Peniche effect on aspect ratio?
  - Both codes have similar stall behavior

Objective

- Aerodynamic shape optimization
  - Accuracy
    - Transonic
    - High-lift configuration
  - Robustness
    - Mesh
    - Conditions/Restart
  - Speed
    - CPU hours
  - Baseline setup

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Next Steps

- Aerodynamic shape optimization
  - Wing-Body cruise configuration:
    - Profile
    - Wing Shape Optimization
  - 2D and 3D High-Lift
  - Wing-Body-Pylon-Nacelle
    - Nacelle position
    - Pylon profile

THANK YOU!

QUESTIONS?