# AIAA 4th Drag Prediction Workshop

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- Grid information
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SOLVER INFORMATION

- METHOD NAME: CFD++ Software Suite.
- BASIC ALGORITHM: finite volume unstructured mixed-element cell-based.
- TURBULENCE MODELS: (1) wall-distance-free realizable k-$\varepsilon$ (incl. time-scale realizability), (2) S-A.
- Tu=2.0%, $\mu_t/\mu$=3.0.
- RESIDUALS: Based on absolute value sum over all cells, divided by the number of cells. Residuals are available for all equations separately.

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TEST CASES (NASA CRM configuration, free air, fully turbulent)

(1.1) Grid convergence study at M=0.85, $C_L$=0.500±0.001

- Tail incidence angle=0
- Coarse, medium, fine, extra-fine grids
- $Re_c$=5×10$^6$ based on $c_{REF}$=275.80”
- $T_{REF}$=100° F

(1.2) Downwash study at M=0.85

- Use Medium grid
- Drag polars at $\alpha$=0.0, 1.0, 1.5, 2.0, 2.5, 3.0 and 4.0°
- Tail incidence angles: -2.0, 0.0 and +2.0°
- No tail
- Trimmed drag polar derived from polars at -2.0, 0.0 and +2.0°
- $\Delta$ drag polar of tail on vs. tail off
- $Re_c$=5×10$^6$ based on $c_{REF}$=275.80”
- $T_{REF}$=100° F
- Moment ref. center: $X_{REF}$=1325.90”, $Z_{REF}$=177.95”

(2.0) Mach sweep: M=0.70, 0.75, 0.80, 0.83, 0.85, 0.86, 0.87

- Medium grid
- WBH iH=0
- $C_l$ =0.400, 0.450, 0.500

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## Grid sizes (1/2 model)

| Config. | Coarsest | Coarse | Medium | Fine | Extra Fine |
|---|---|---|---|---|---|
| WB | | | 17.0 M | | |
| WBH | 11.5 M | 16.6 M | 22.7 M | 28.6 M | 33.9 M |

## Grid information

- GRID-GENERATOR NAME: MIME (Multi-purpose Intelligent Meshing Environment).
- GRID TYPE: Mixed elements. Prism layers are grown from all surfaces of the aircraft, transitioning to tetrahedral elements within the volume. In the transition zone both hexahedral and pyramid elements can appear.
- BL 1st cell size: $5.08X10^{-5}$ m ($y^+ < 1$)
- BL max. growth rate: 1.235

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SOLUTION INFORMATION

Two computing platforms were used: (1) for preliminary calculations and $C_L$-driver-based grid sensitivity assessment (Task 1.1) and (2) for preparation of polars and Mach sweep data (Tasks 1.2 & 2.0).

## Platform 1

- COMPUTER PLATFORM: cluster of Linux-based machines. Each machine has 2 dual-core AMD Opteron processors.
- INTERCONNECTION: infiniband-based.
- NO. OF PROCESSORS: 8 machines (32 CPUs).
- OPERATING SYSTEM: Kernel 2.6.9 (SMP) of Linux from Red Hat.
- COMPILER: GNU C-compiler.
- RUN TIME WALL-CLOCK: about 8 hours for 400 iterations (22.7M cells).
- MEMORY REQUIREMENTS: 79 GB (22.7M cells)

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Platform 2

- COMPUTER PLATFORM: Cluster of 1800 compute nodes, each containing dual Intel Xeon quad Core E5365, 3.0 GHz processors,. 16 GB memory and 72 GB Hard disk.
- INTERCONNECTION: 4X DDR Infiniband, Bandwidth of 20 Gbps bidirectional.
- NO. OF PROCESSORS: 14400 Cores (7200 CPUs).
- OPERATING SYSTEM: XC-3.2.1 with latest updates
- COMPILER: GNU C-compiler.
- EKA Details: The system has a peak compute capacity of 180 teraflops and has achieved sustained compute capacity of 132.8 teraflops for the LINPACK benchmark.

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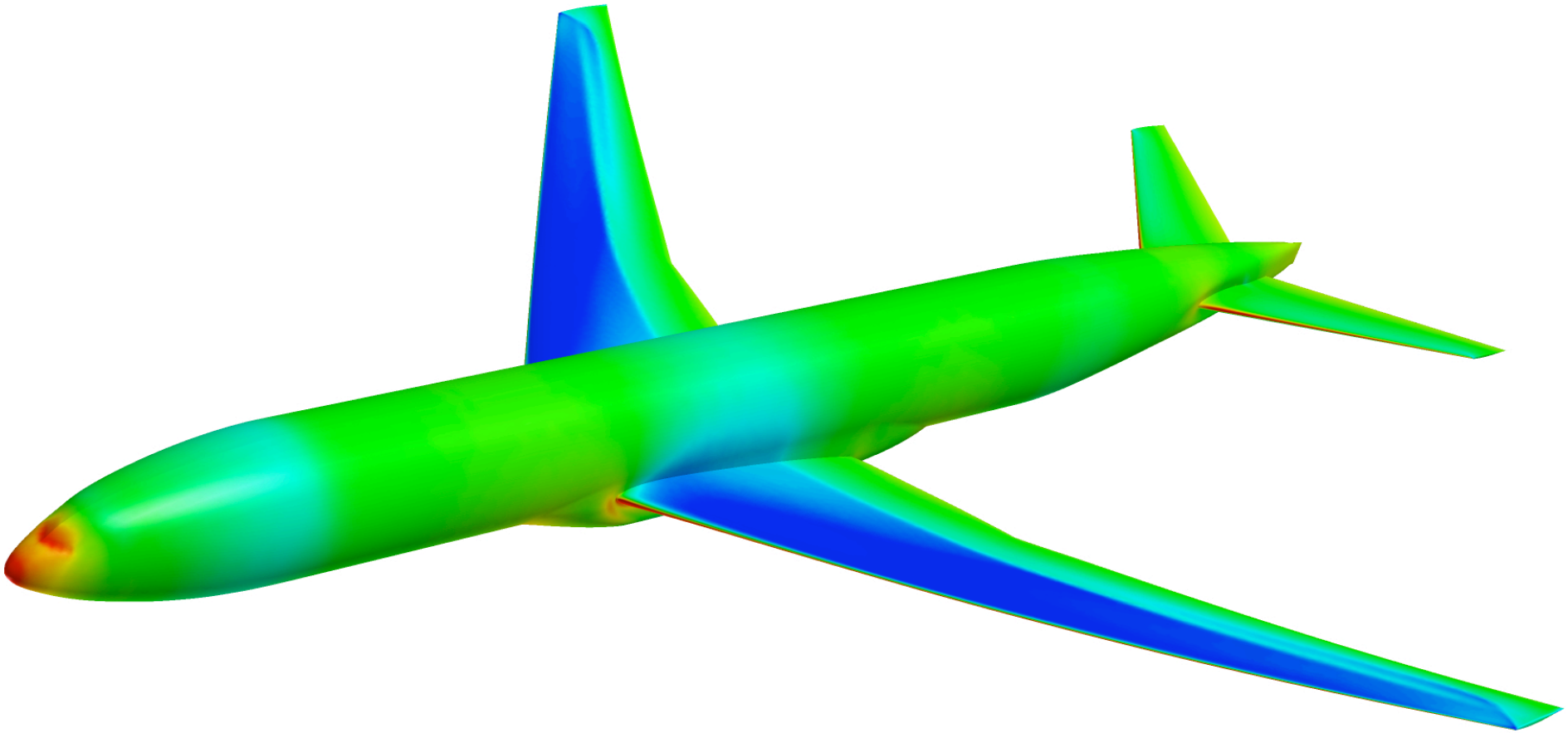
- Sample results (1)



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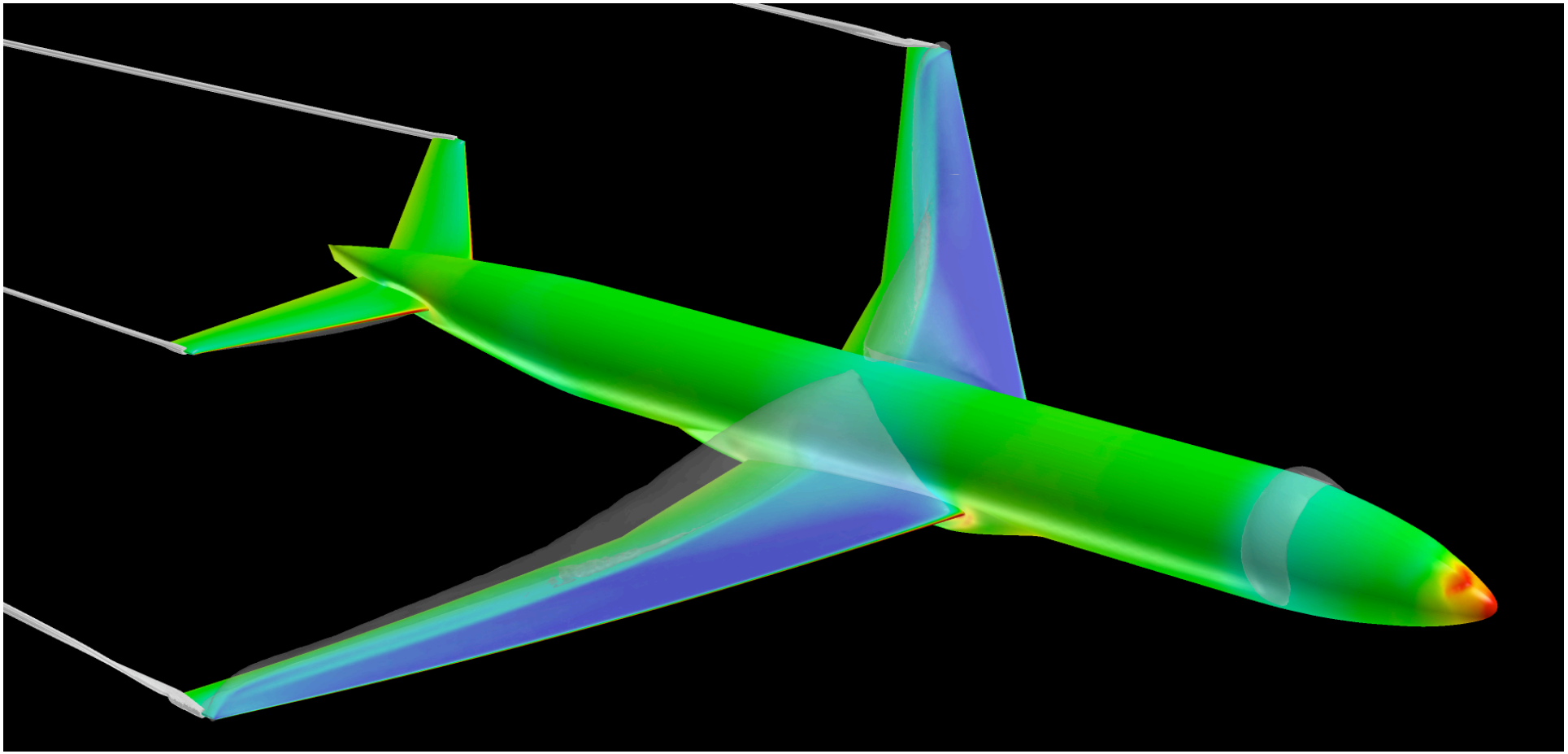
- Sample results (2)



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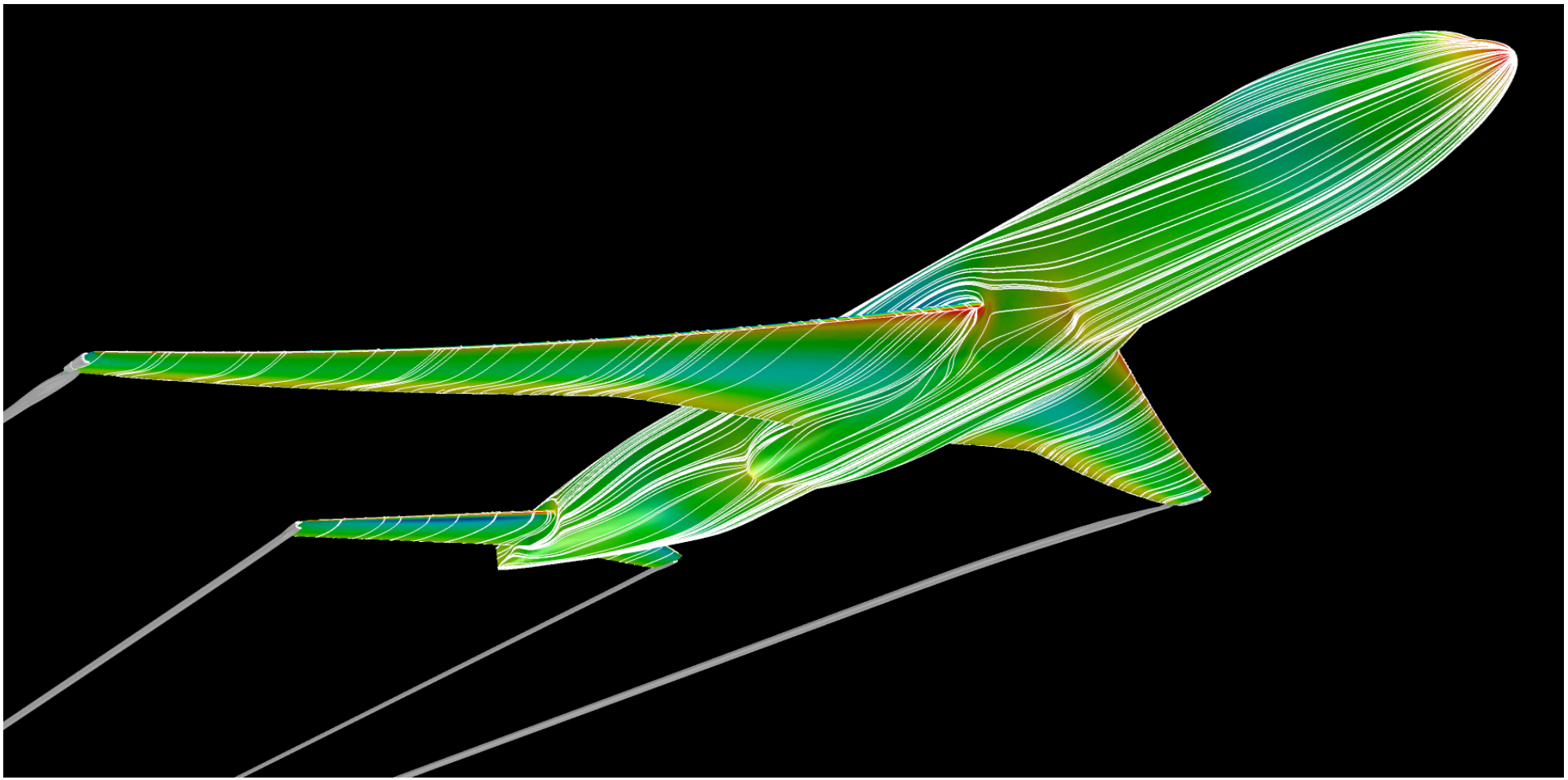
- Sample results (3)



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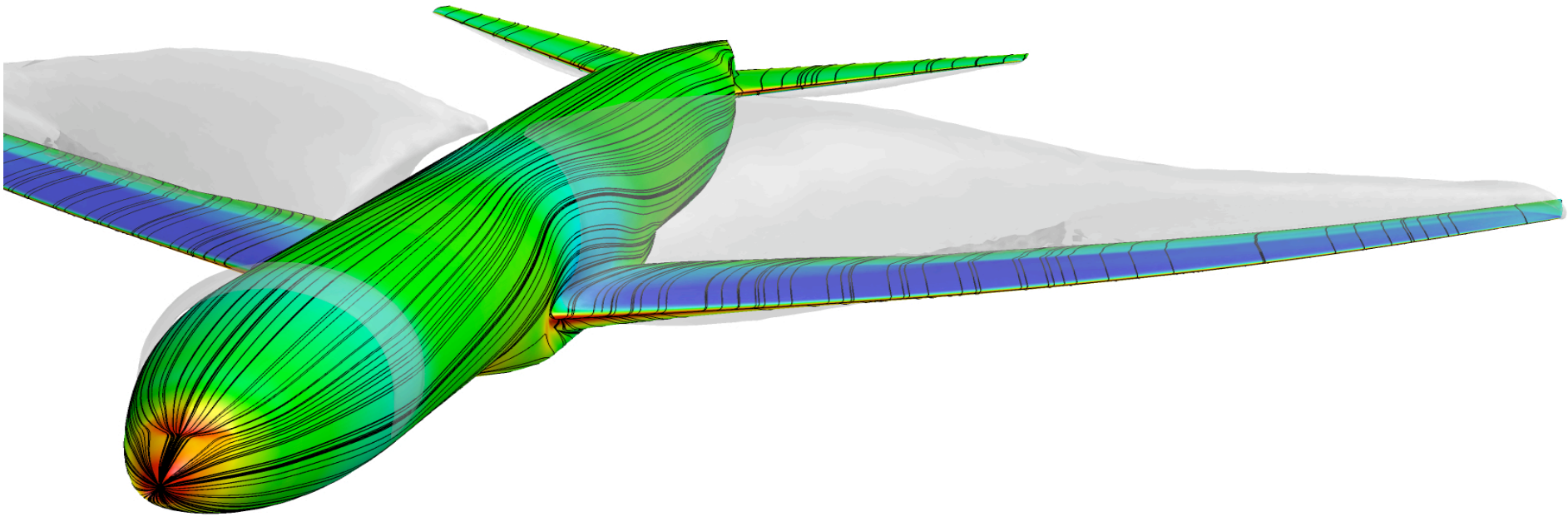
- Sample results (4)



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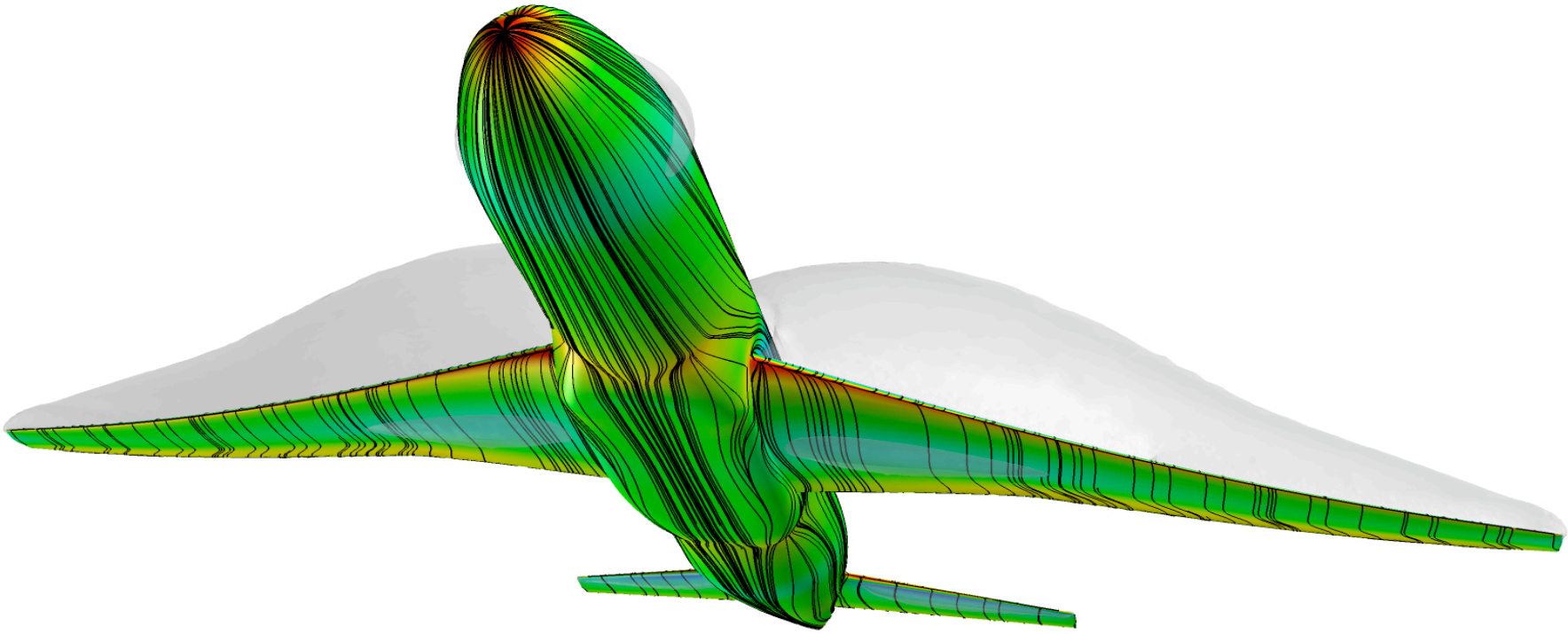
- Sample results (5)



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- Sample results (6)

Wing: suction side, fine mesh

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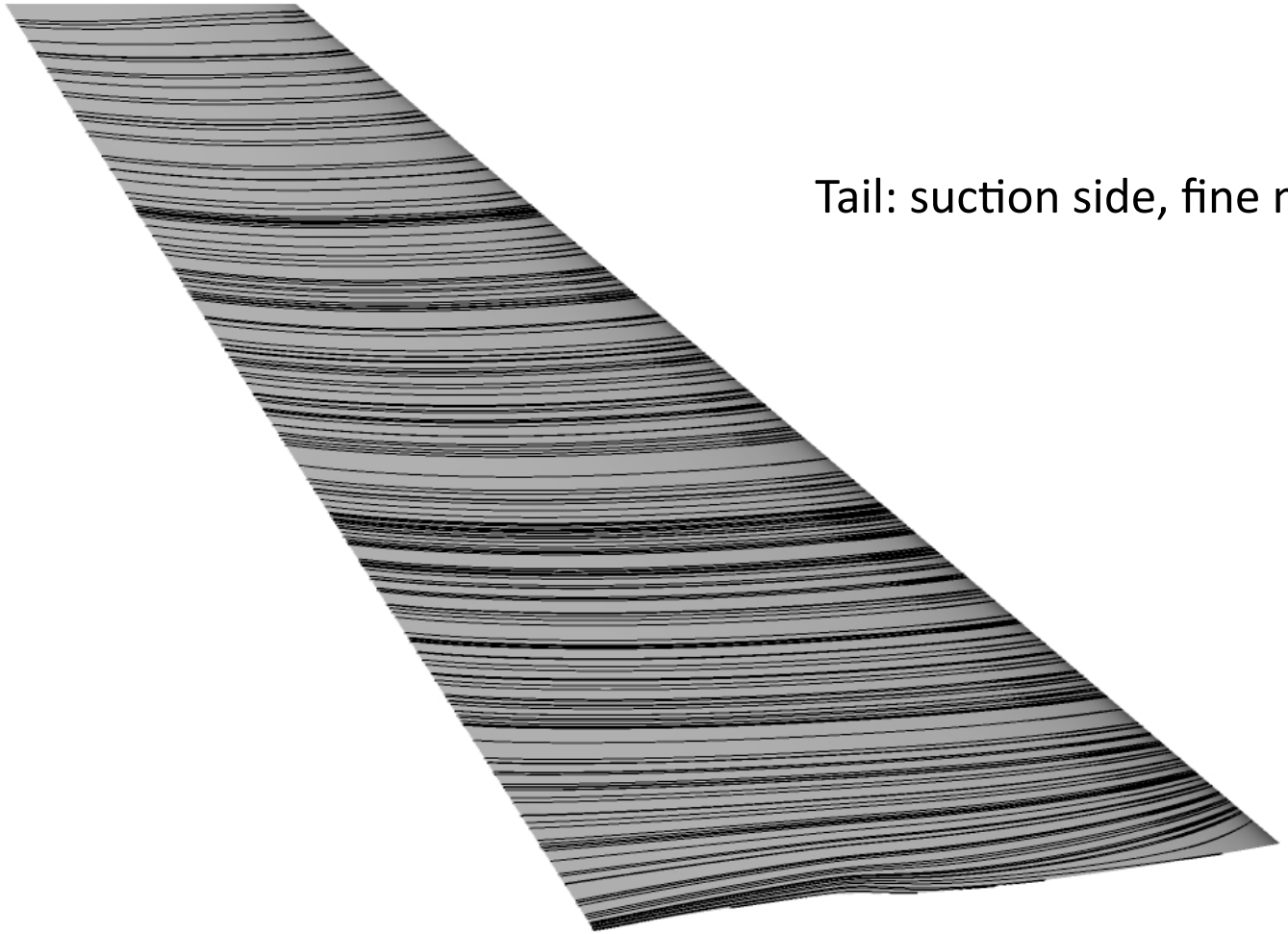
- Sample results (7)



Tail: suction side, fine mesh

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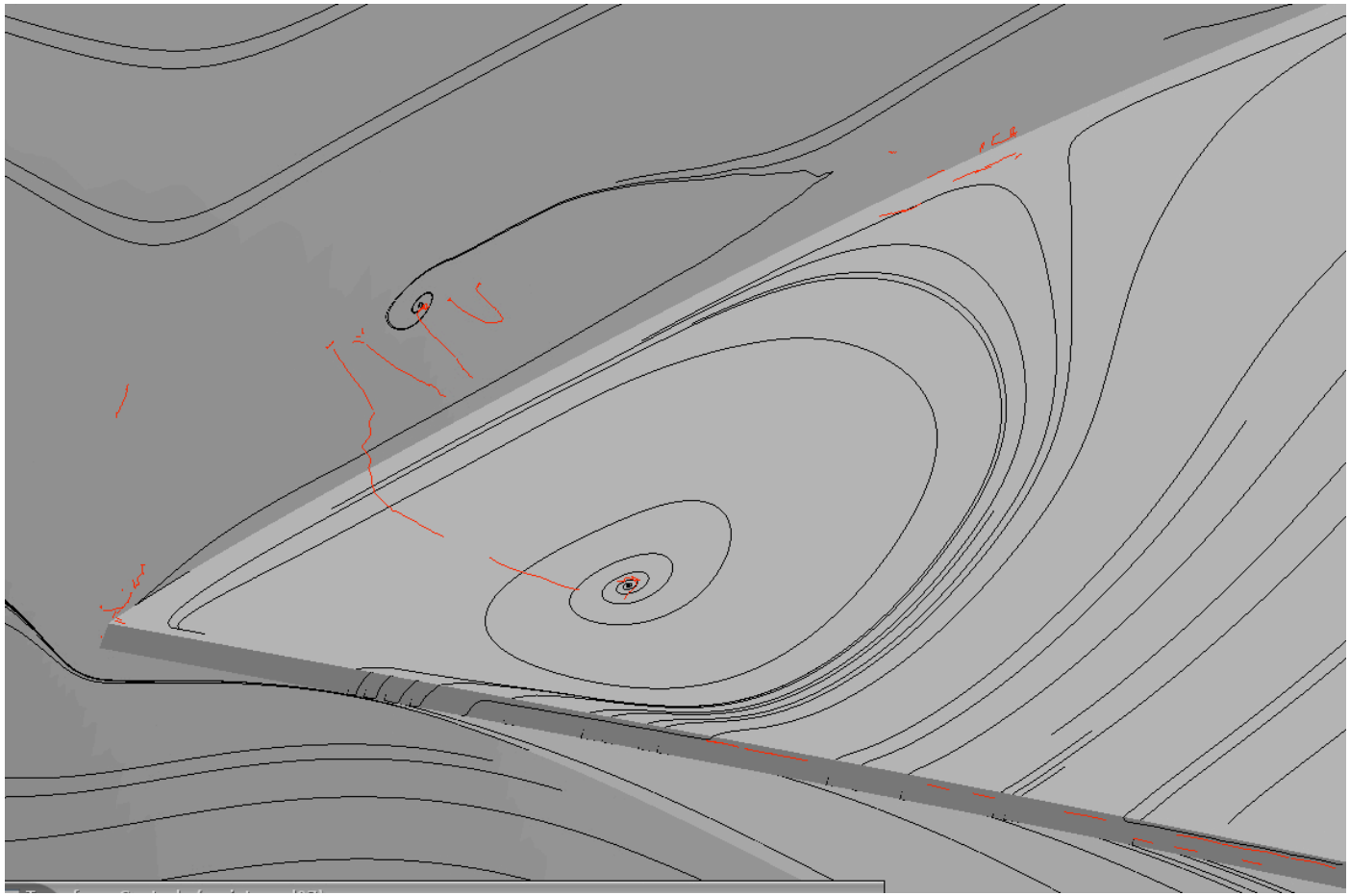
- Sample results (8)

Wing/fuselage separation bubble



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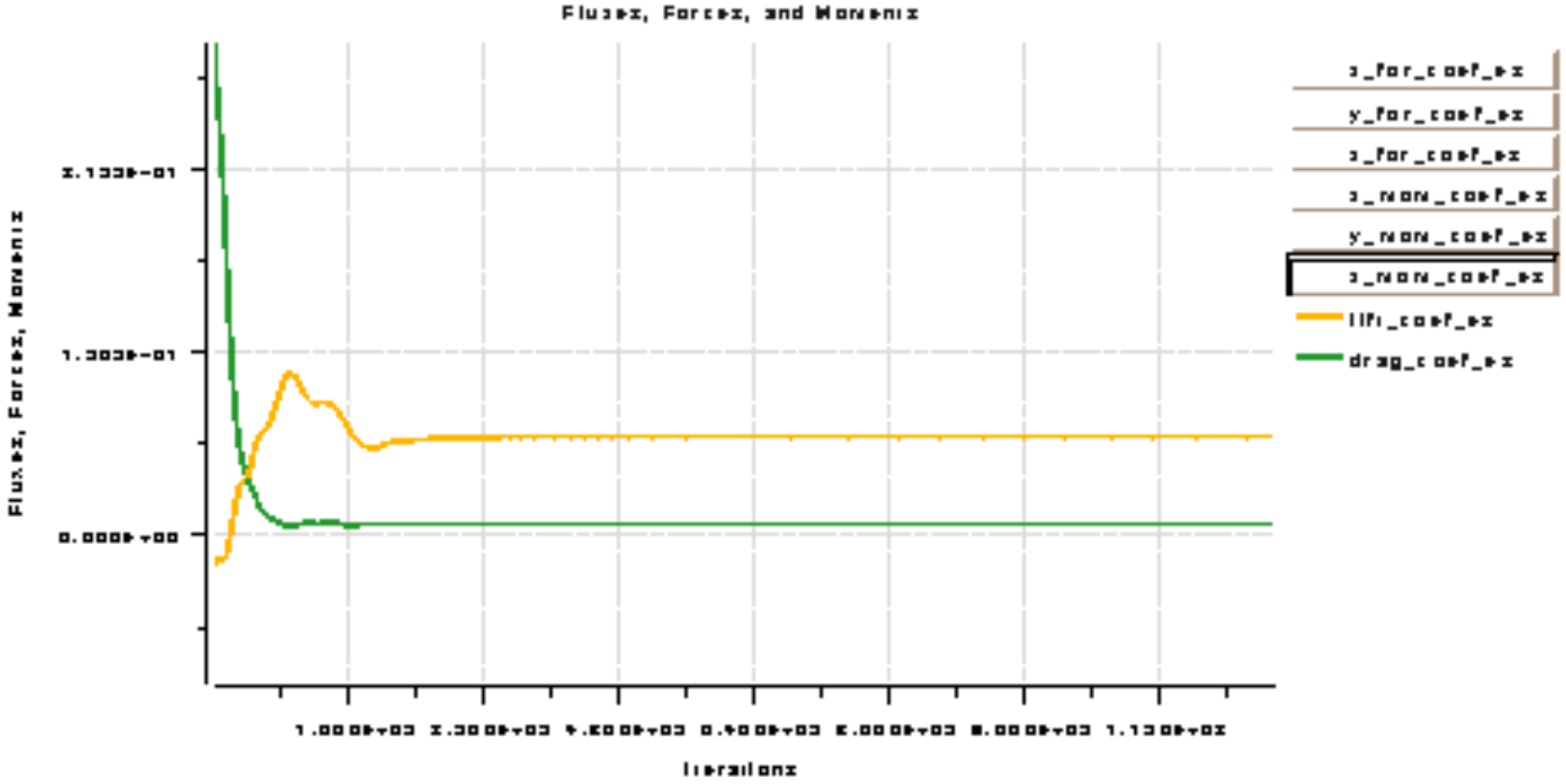
- Sample results (9): Typical WBH forces convergence



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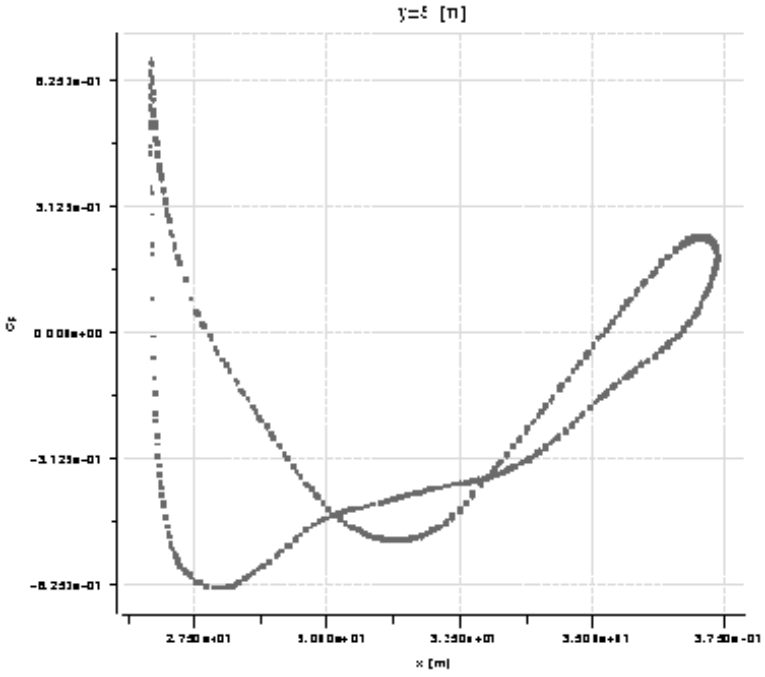
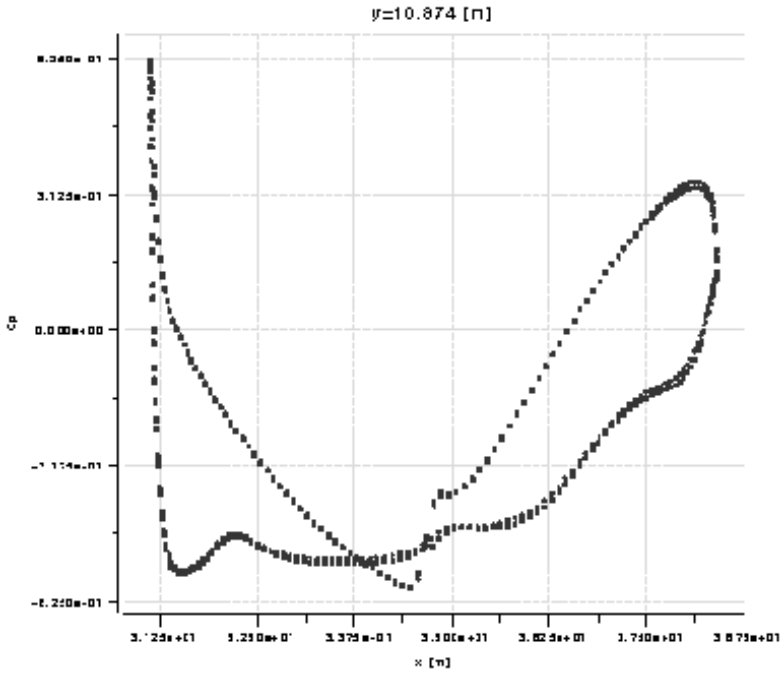
- Sample results (10): $C_p$ profiles (S-A & k-ε)




Y=5 m




y=10.874 m

η=0.397

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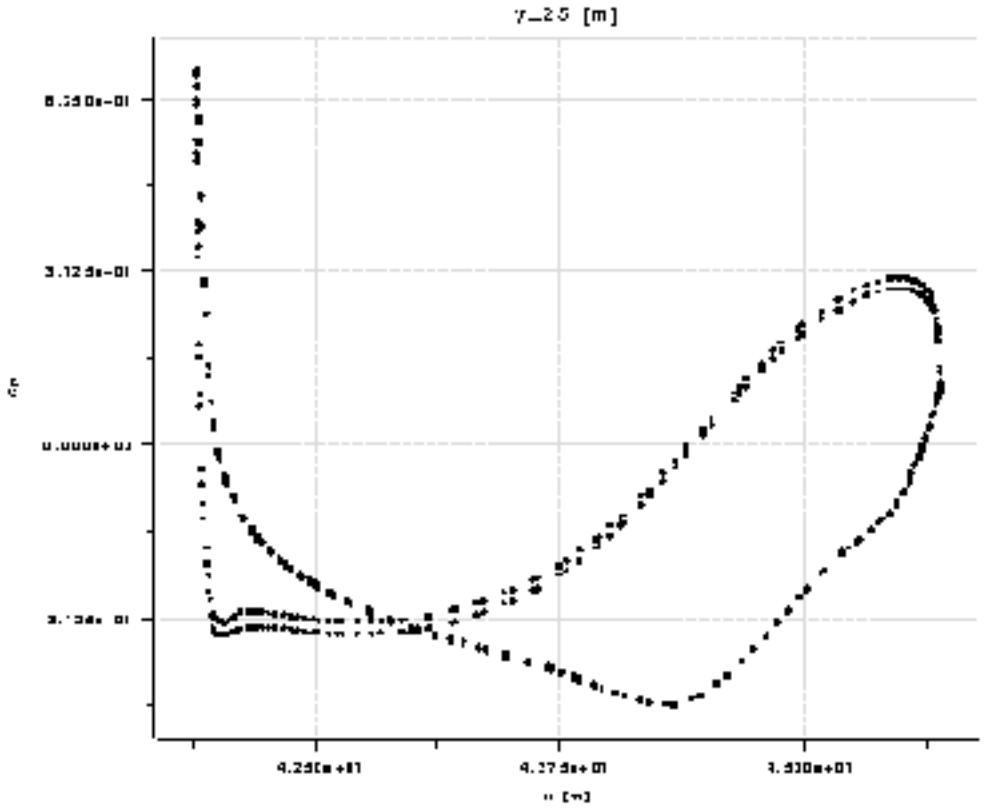
- Sample results (11): $C_p$ profiles (S-A & k-ε)




Y=25 m

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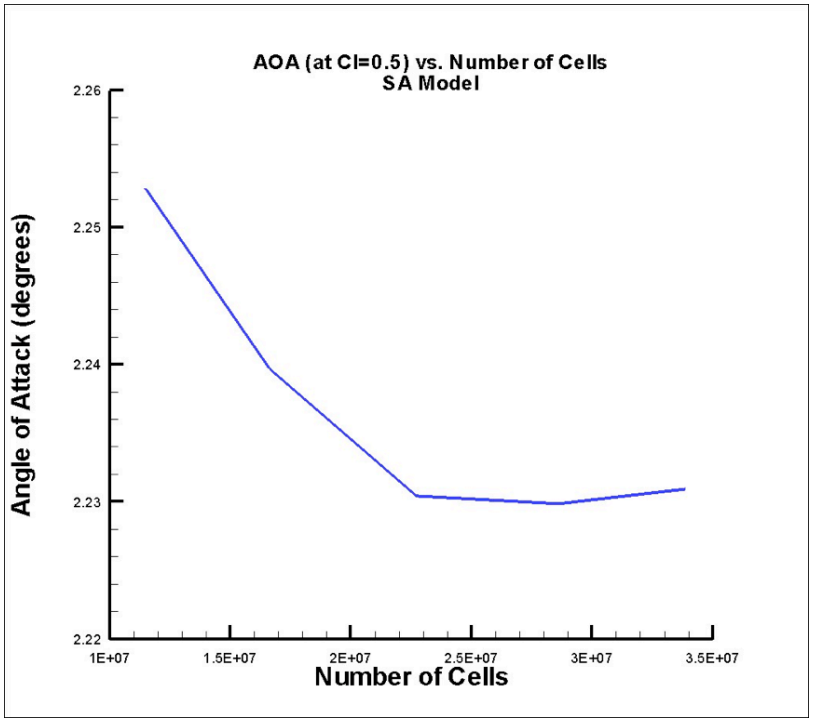
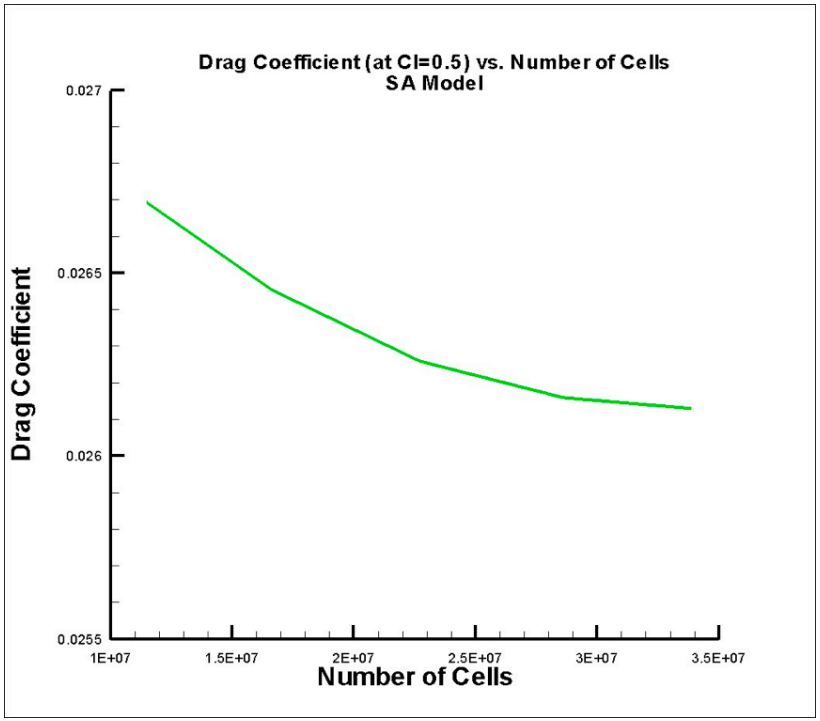
- Sample results (12): Grid convergence study (1.1)



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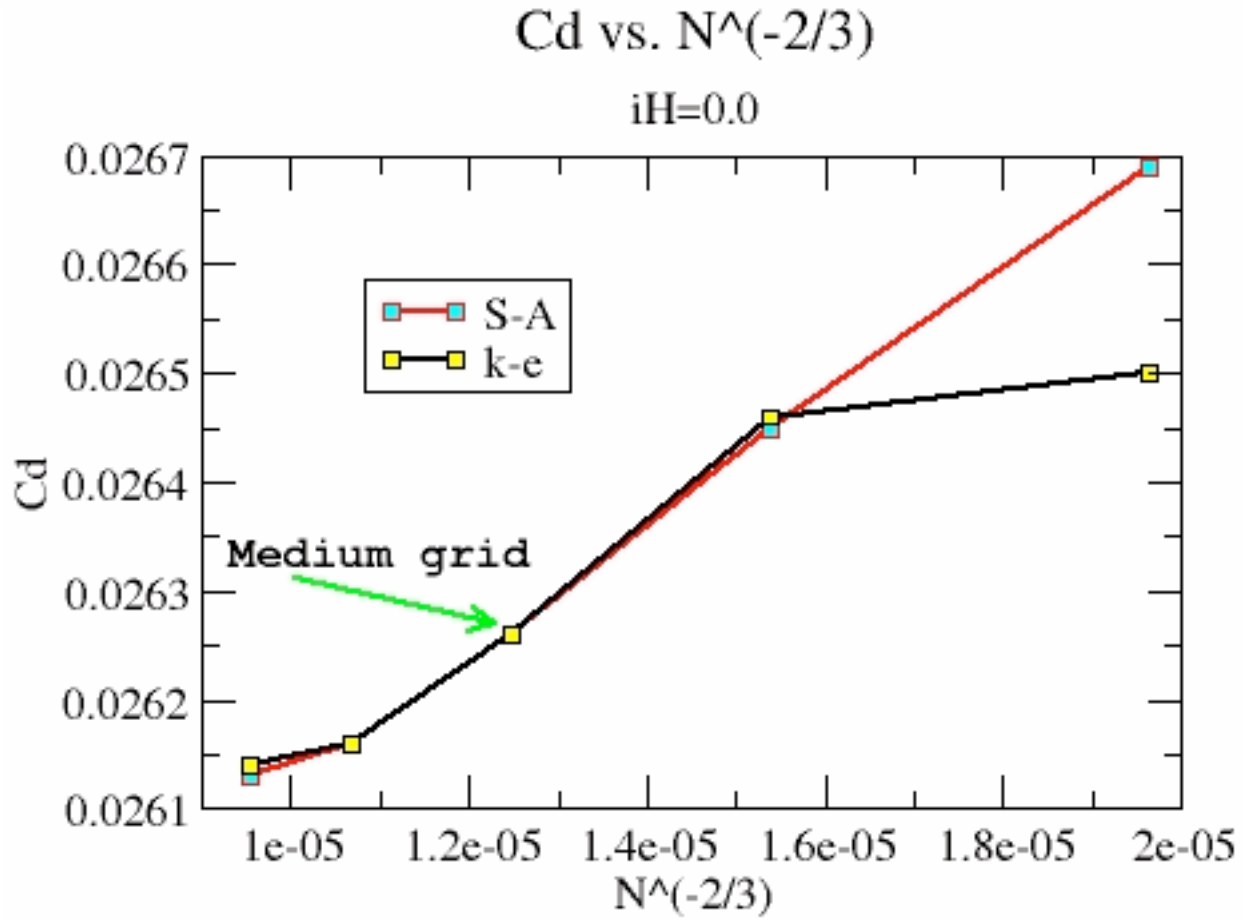
- Sample results (13): Grid convergence study (1.1)



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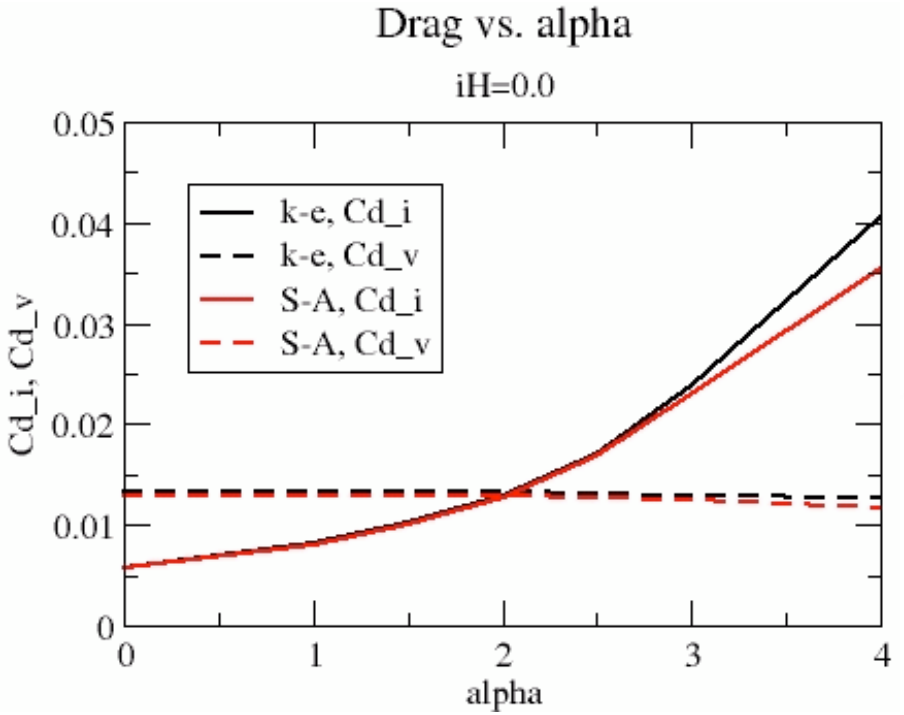
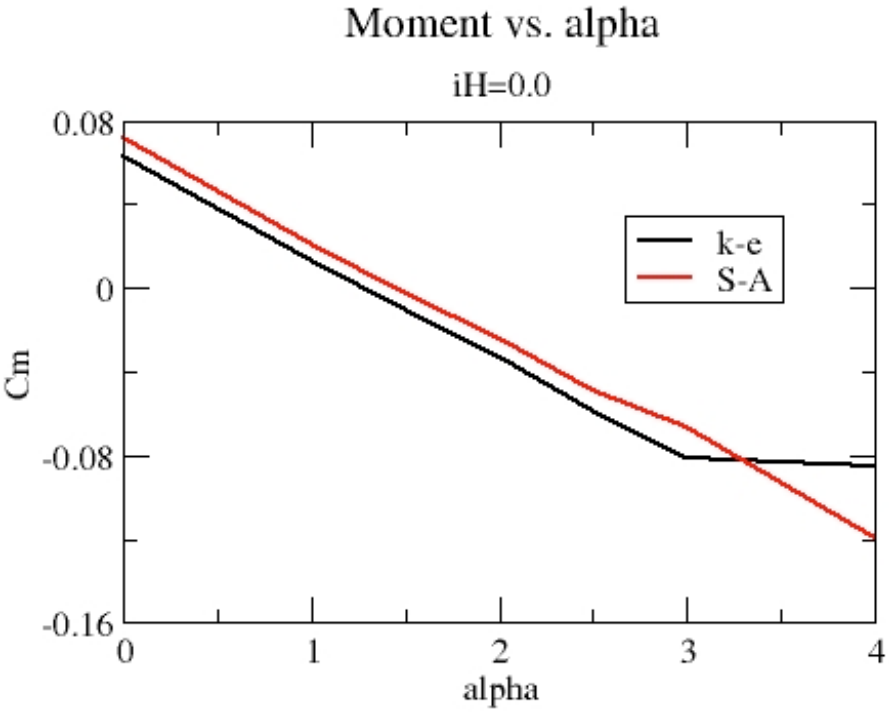
- Sample results (14): Polar plots (1.2)



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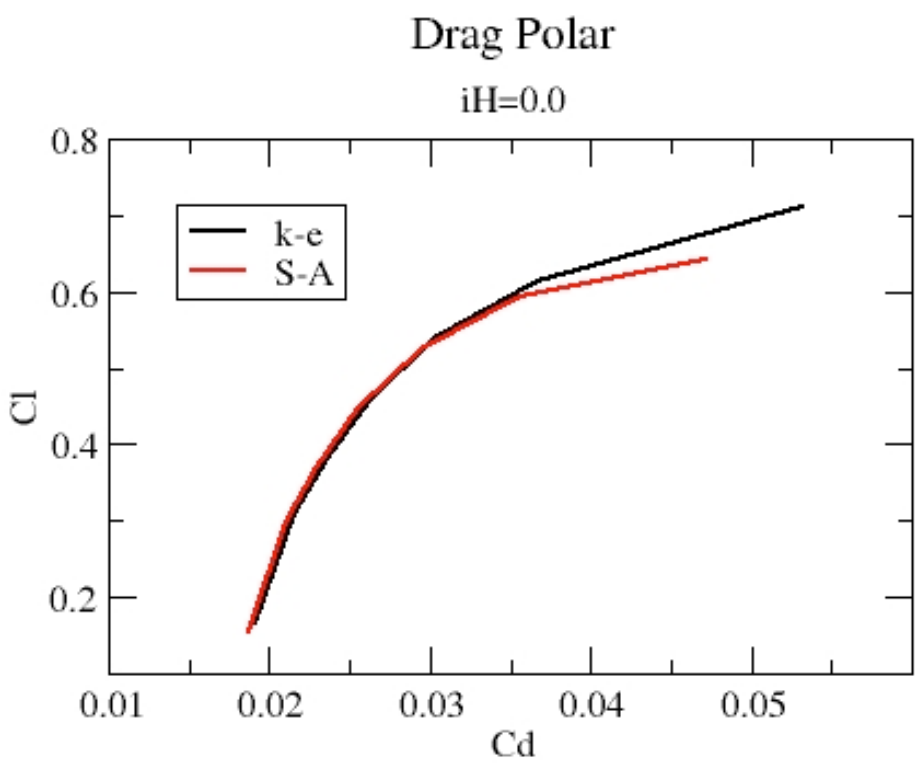
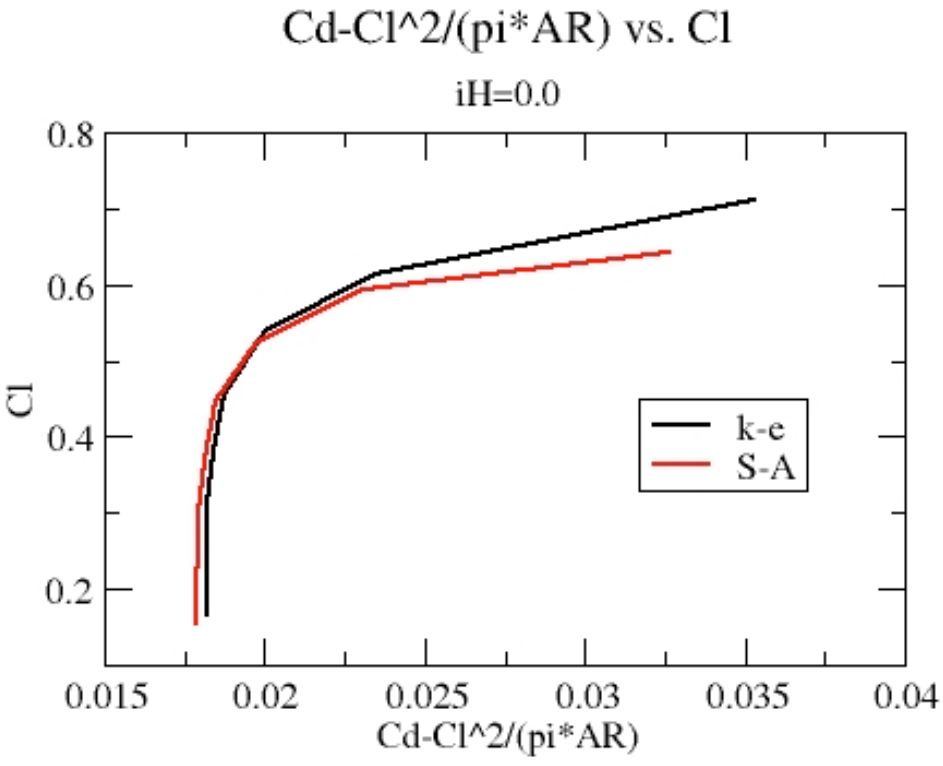
- Sample results (15): Polar plots (1.2)



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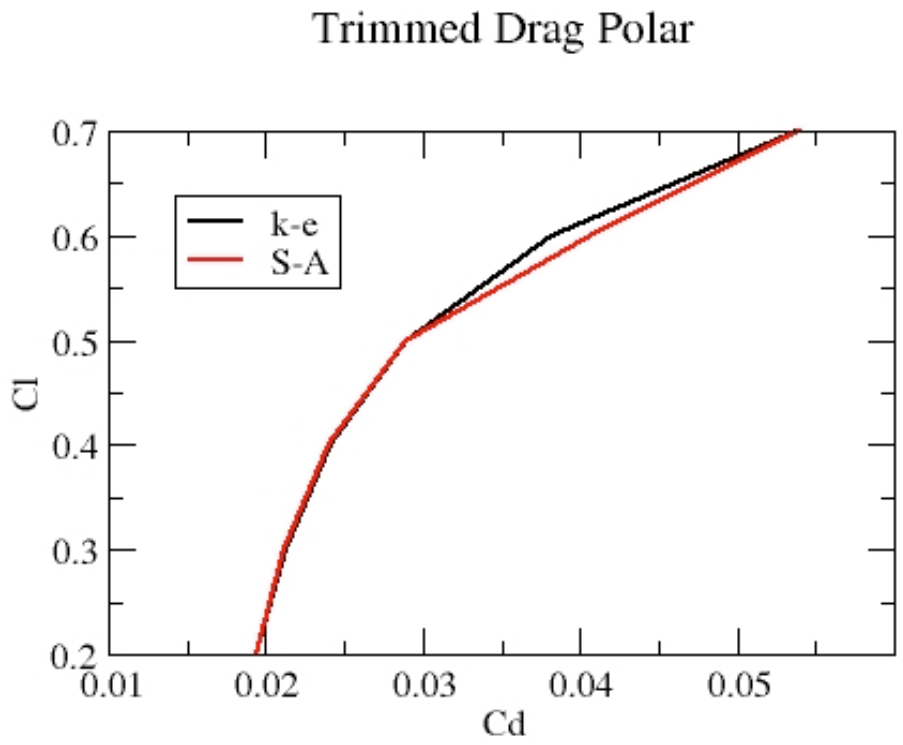
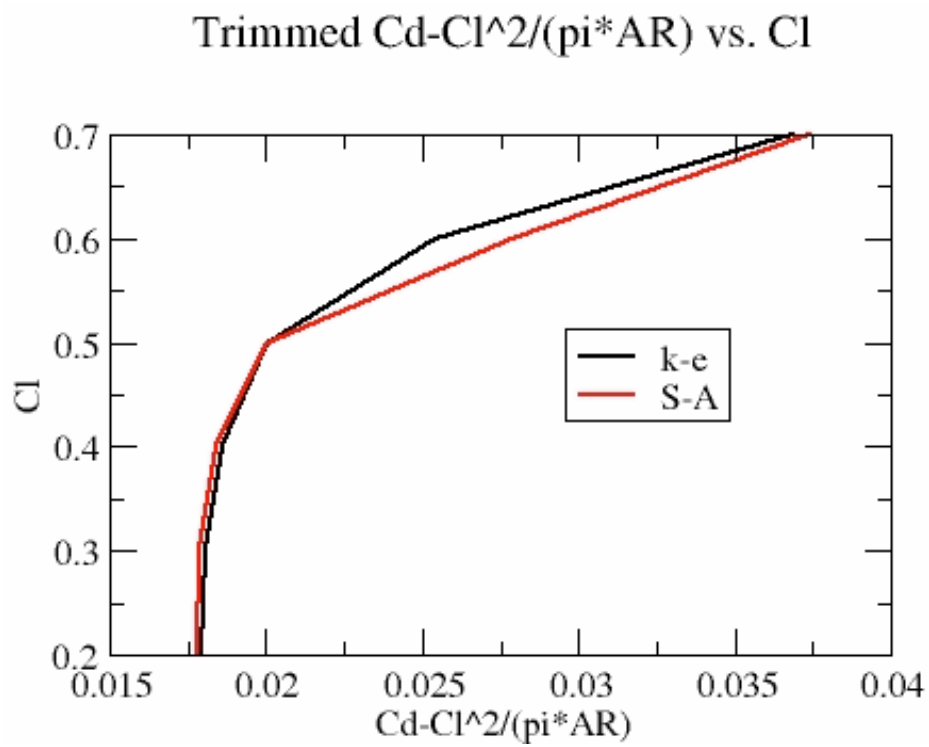
- Sample results (16): Polar plots (1.2)



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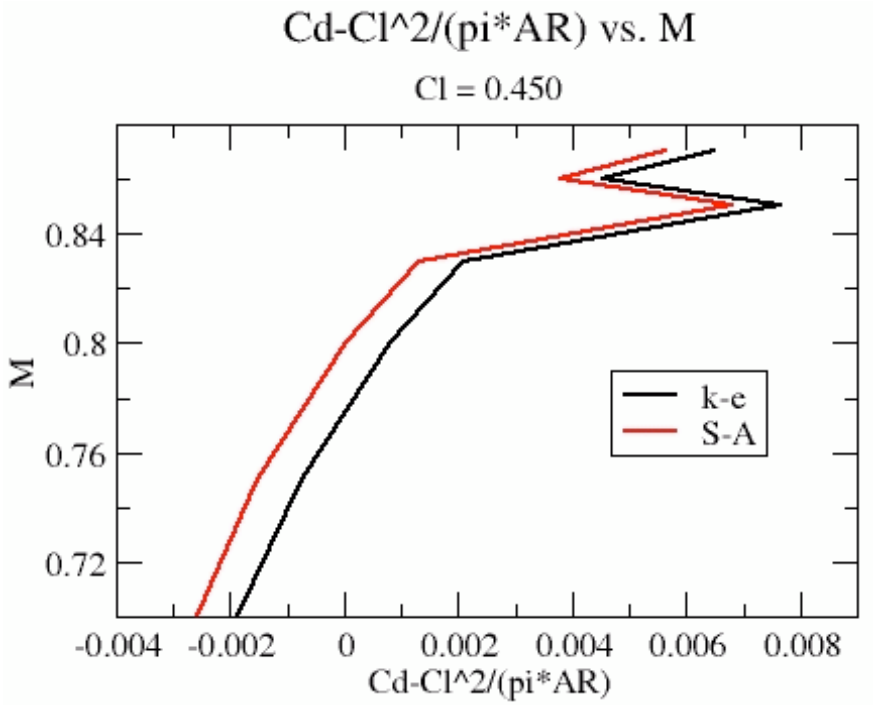
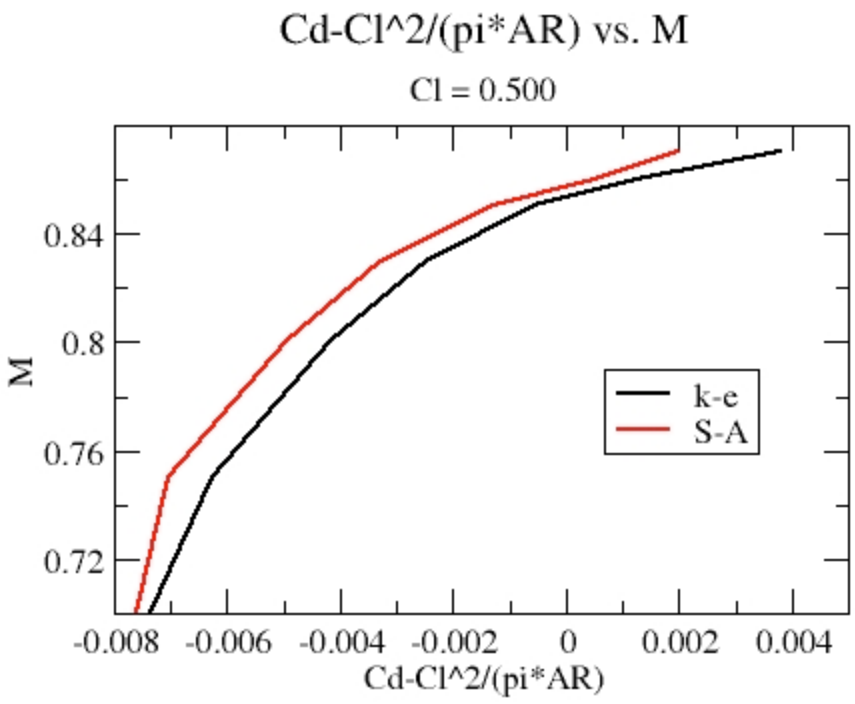
- Sample results (17): Mach sweep (2.0)



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## Summary

- MIME used to generate 5 hierarchical grids
- CFD++ used to compute Cases 1.1, 1.2, 2.0
- Most solutions generated by CRL India
- Results presented with S-A and k-ε models:
  - Grid convergence same except for coarsest mesh
  - Wing/fuselage & wing TE separations predicted by both models on all grids
  - Trimmed polars by the 2 models are very close
  - At $\alpha > 3^o$ $(C_{Di})_{k-\varepsilon} > (C_{Di})_{S-A}$