WB and WBF Results using NSU3D

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NSU3D Description

- Unstructured Reynolds Averaged Navier-Stokes solver
  - Vertex-based discertization
  - Mixed elements (prisms in boundary layer)
  - Edge data structure
  - Matrix artificial dissipation
    - Option for upwind scheme with gradient reconstruction
  - No cross derivative viscous terms
    - Thin layer in all 3 directions
    - Option for full Navier-Stokes terms

Solver Description (cont'd)

- Spalart-Allmaras turbulence model
  - (original published form)
  - Optional k-omega model

Solution Strategy

- Jacobi/Line Preconditioning
  - Line solves in boundary layer regions
    - Relieves aspect ratio stiffness
- Agglomeration multigrid
  - Fast grid independent convergence rates
- Parallel implementation
  - MPI/OpenMP hybrid model
    - DPW runs: MPI on local cluster and on NASA Columbia Supercomputer

Grid Generation

- Runs based on NASA Langley supplied VGRIDns unstructured grids

- Tetrahedra in Boundary Layer merged into prismatic elements

- Grid sizes up to 41M pts, 240M elements

Sample Run Times

- All runs performed on NASA Columbia Supercomputer
  - SGI Altix 512cpu machines
  - Coarse/Medium (~15Mpts) grids used 96 cpus
    - Using 500 to 800 multigrid cycles
      - 30 minutes for coarse grid
      - 1.5 hrs for medium grid
  - Fine Grids (~40M pts) used 248 cpus
    - Using 500 to 800 multigrid cycles
      - 1.5 to 2 hrs hrs for fine grid
  - CL driver and constant incidence convergence similar
  - WB cases hard to converge (not entirely steady)

WBF Convergence (fixed alpha)
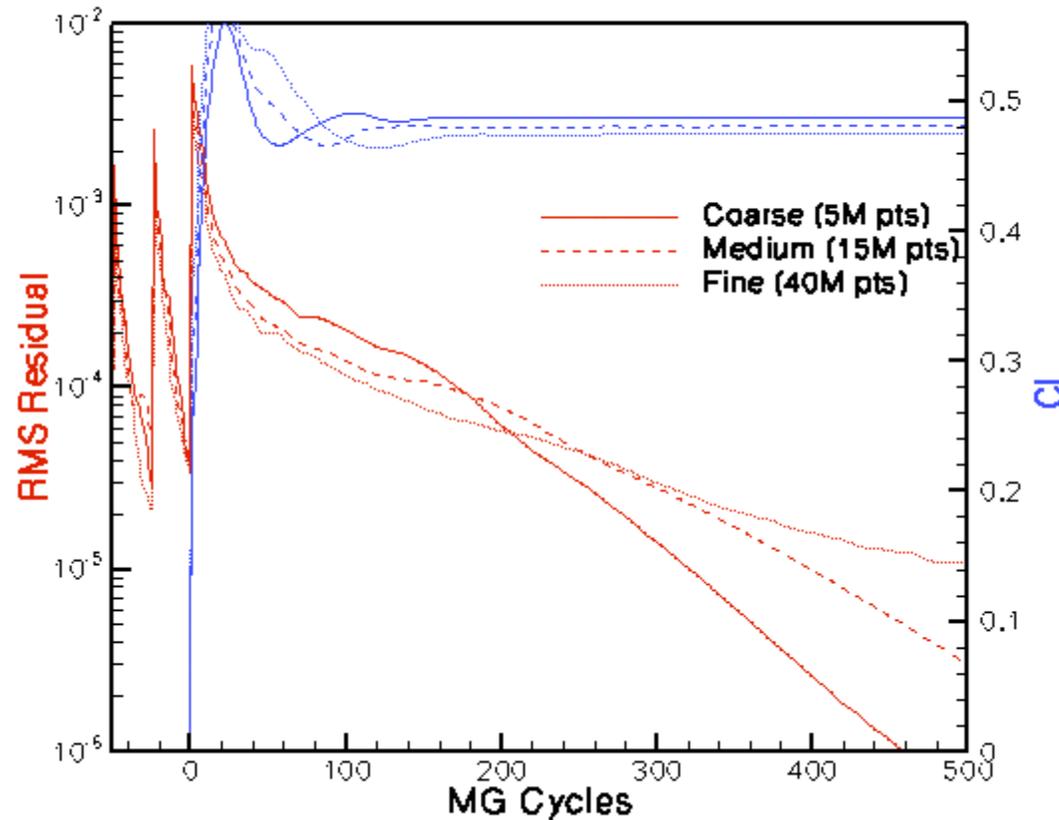
- "Similar" convergence for all grids
- Force coefficients well converged < 500 MG cycles

WBF Convergence
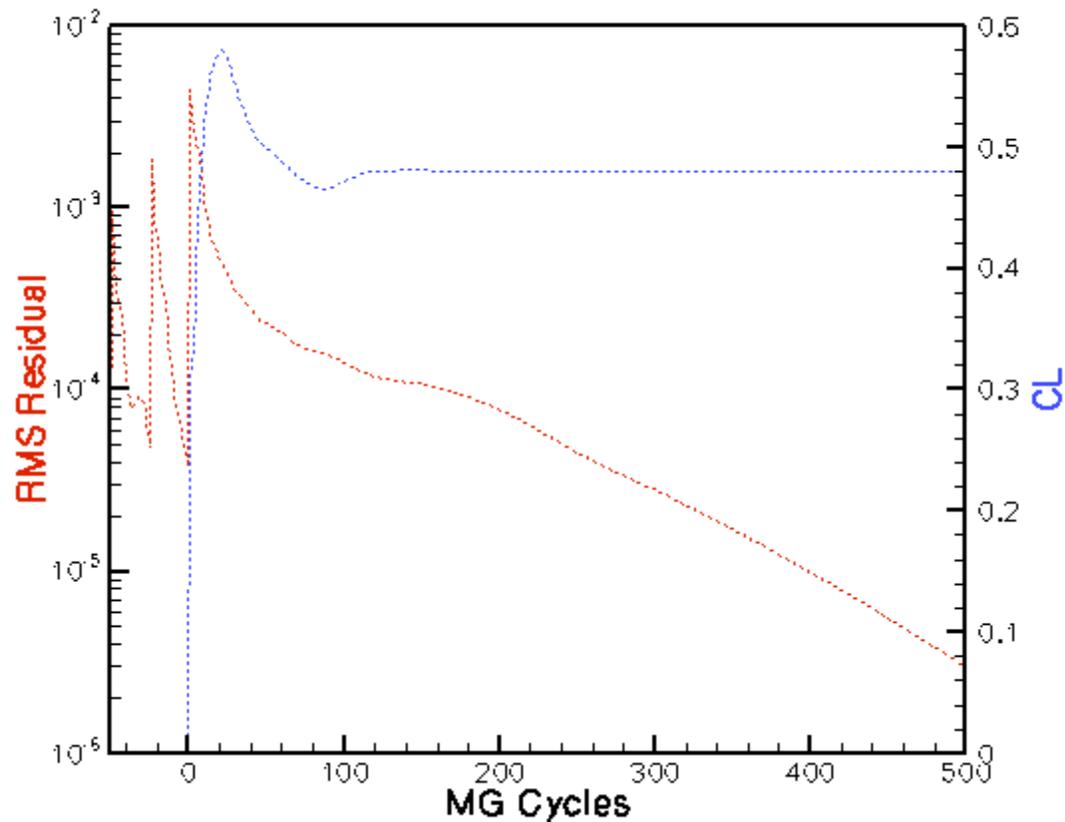
- Medium Grid (15M pts): Fixed alpha

WBF Convergence
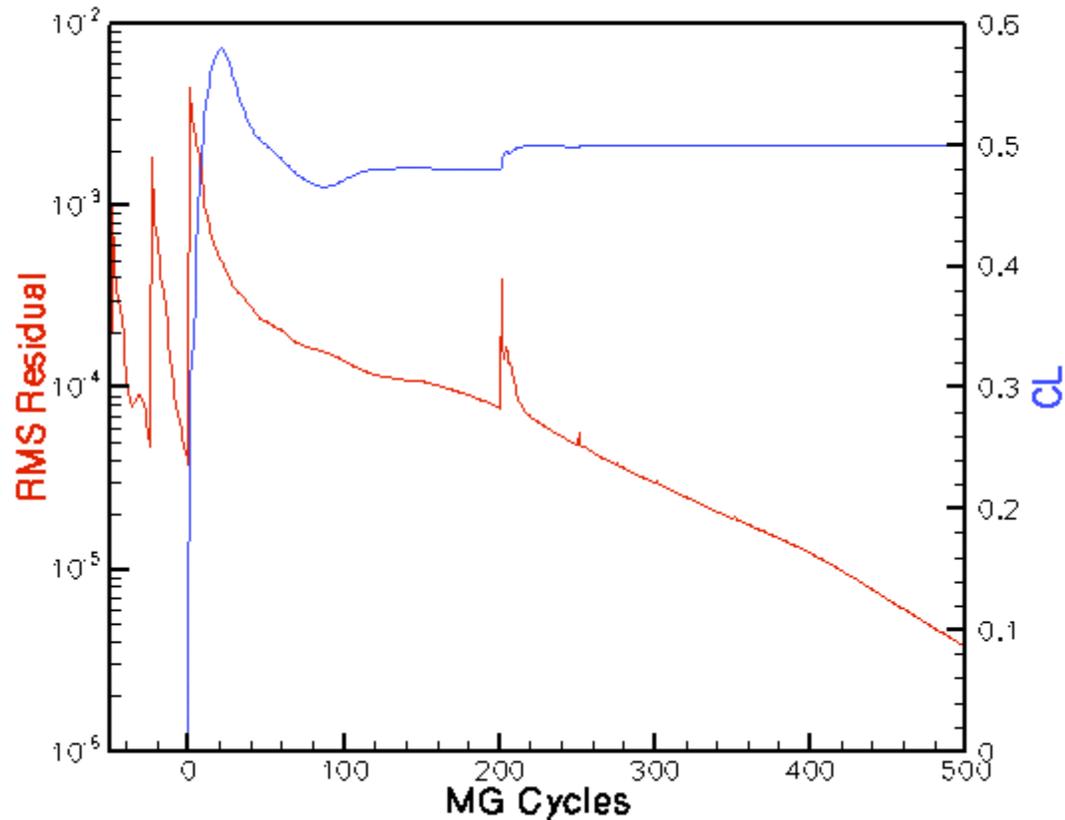
- Medium Grid (15M pts): Fixed CL

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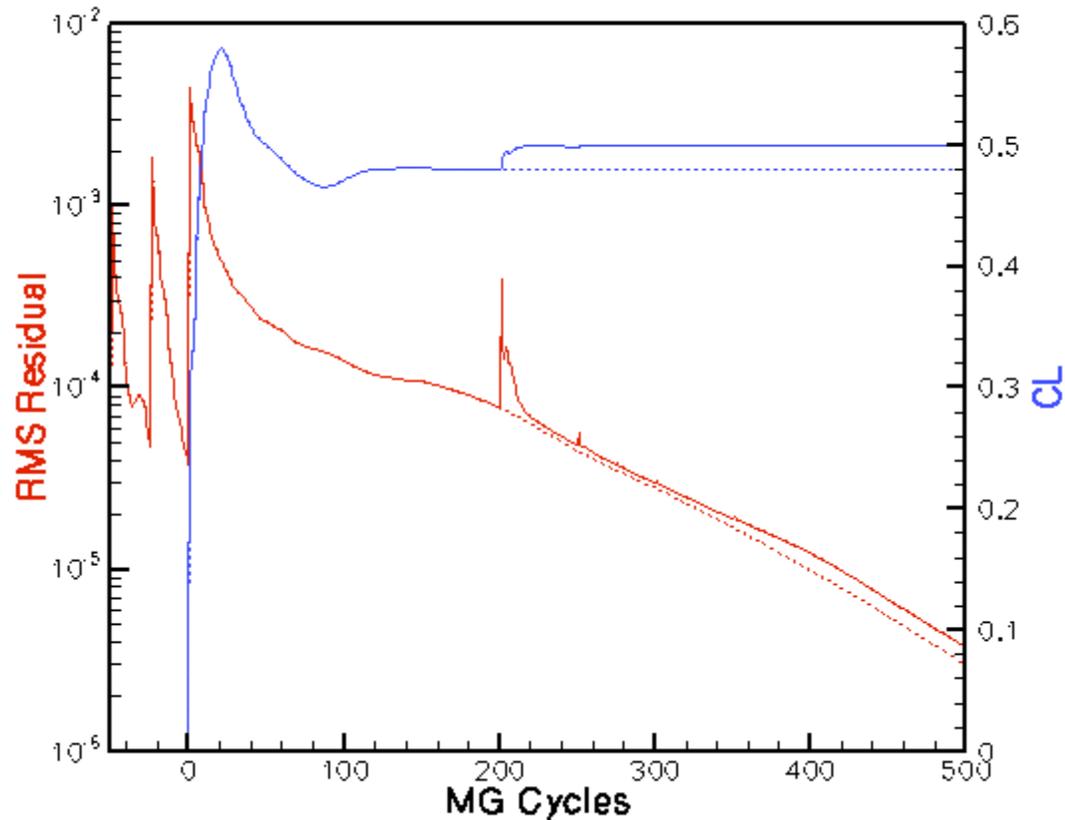
- Similar convergence (Fixed CL or alpha)

WBF: Grid Convergence Study
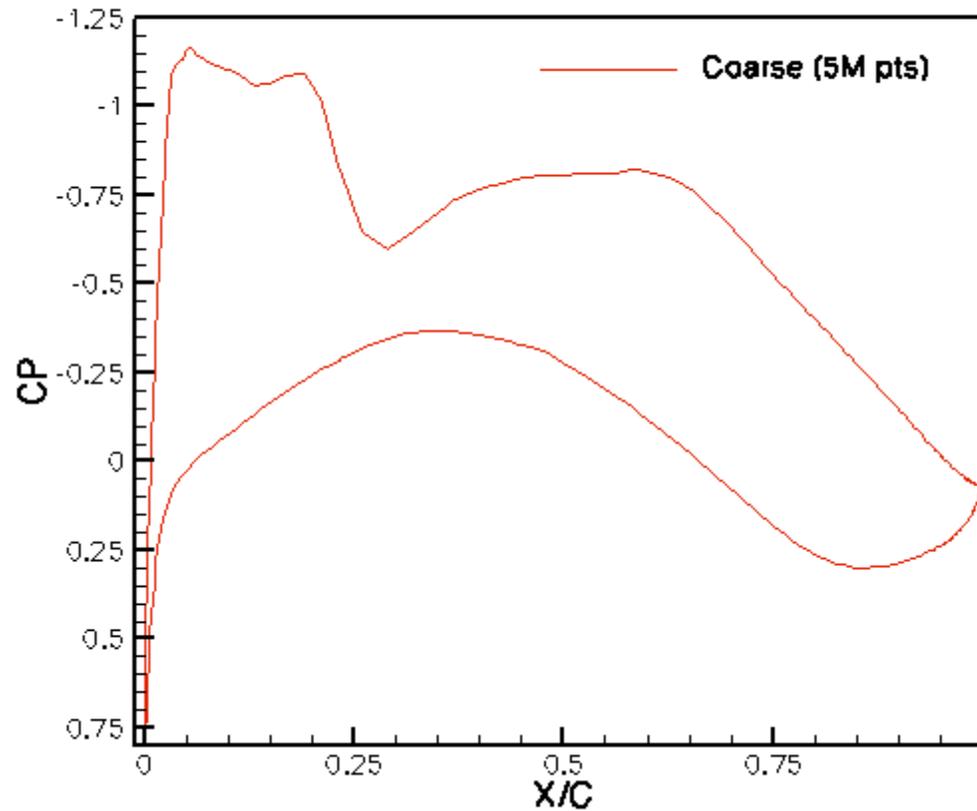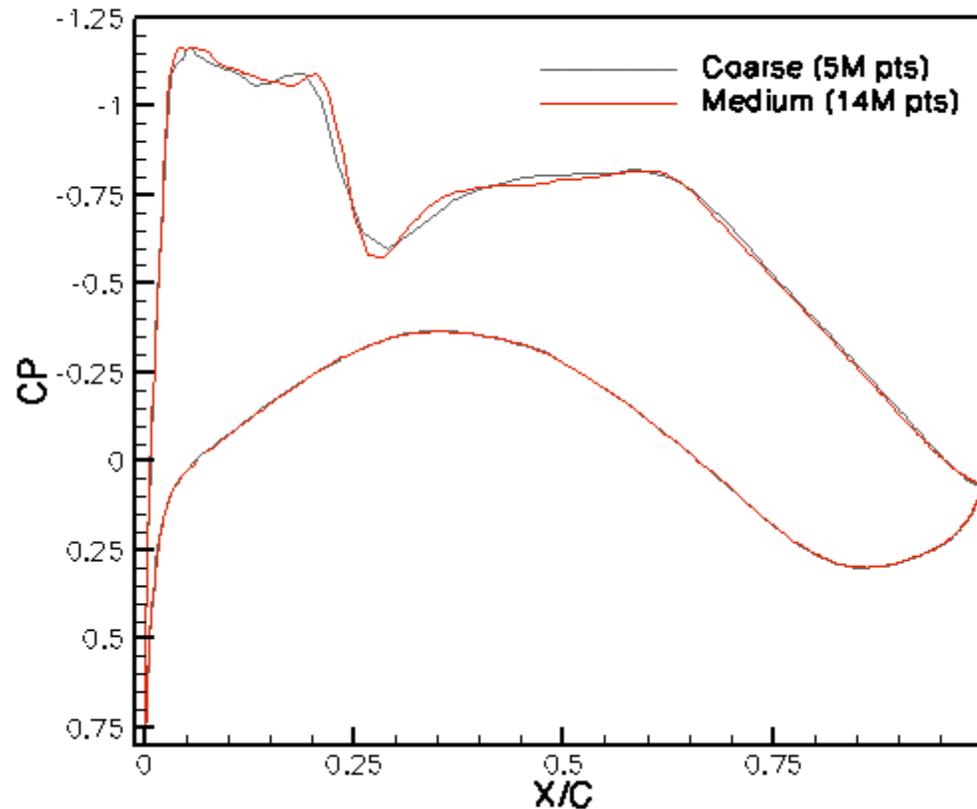
- CP at wing break station (y/b=0.411)

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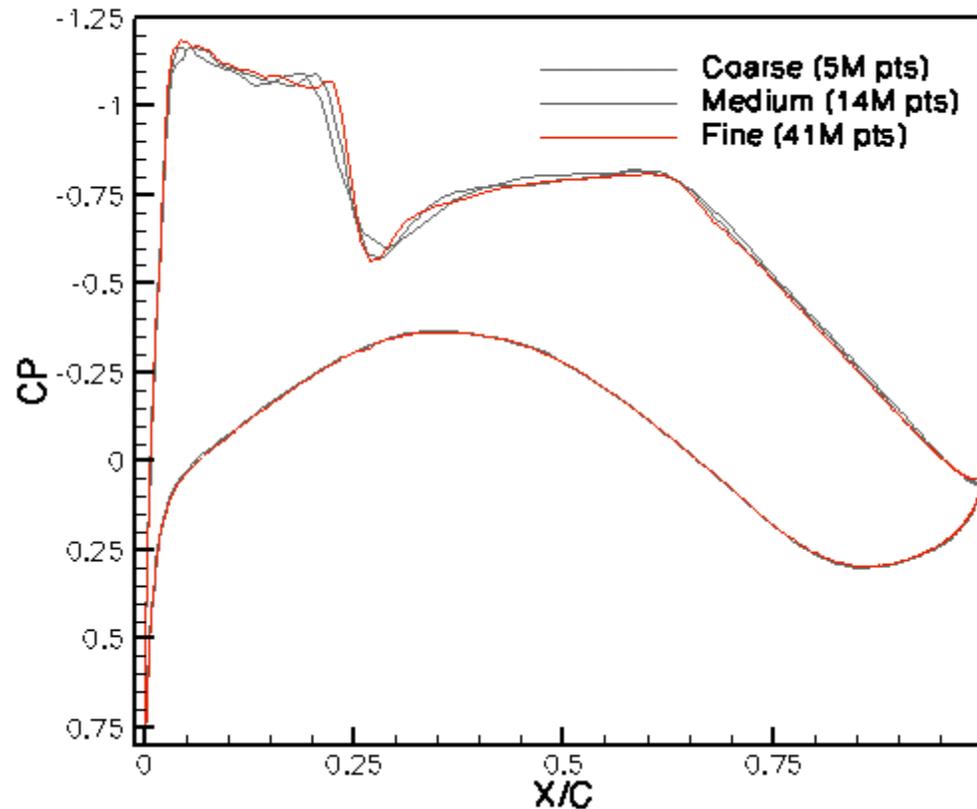
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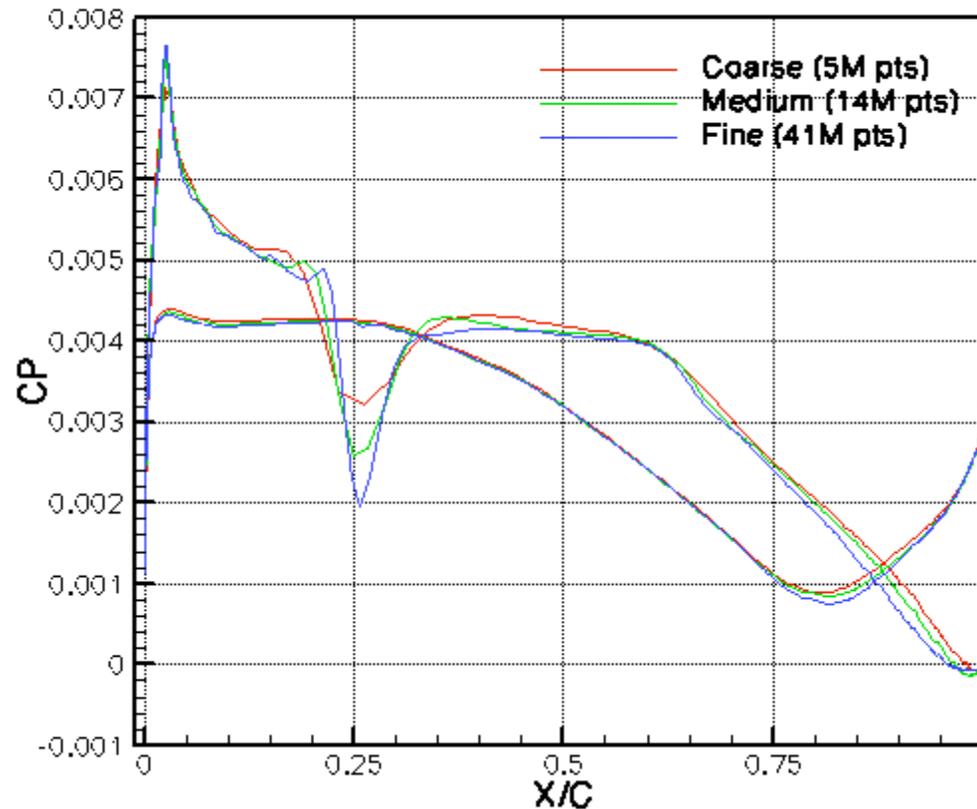
- CF at wing break station (y/b=0.411)

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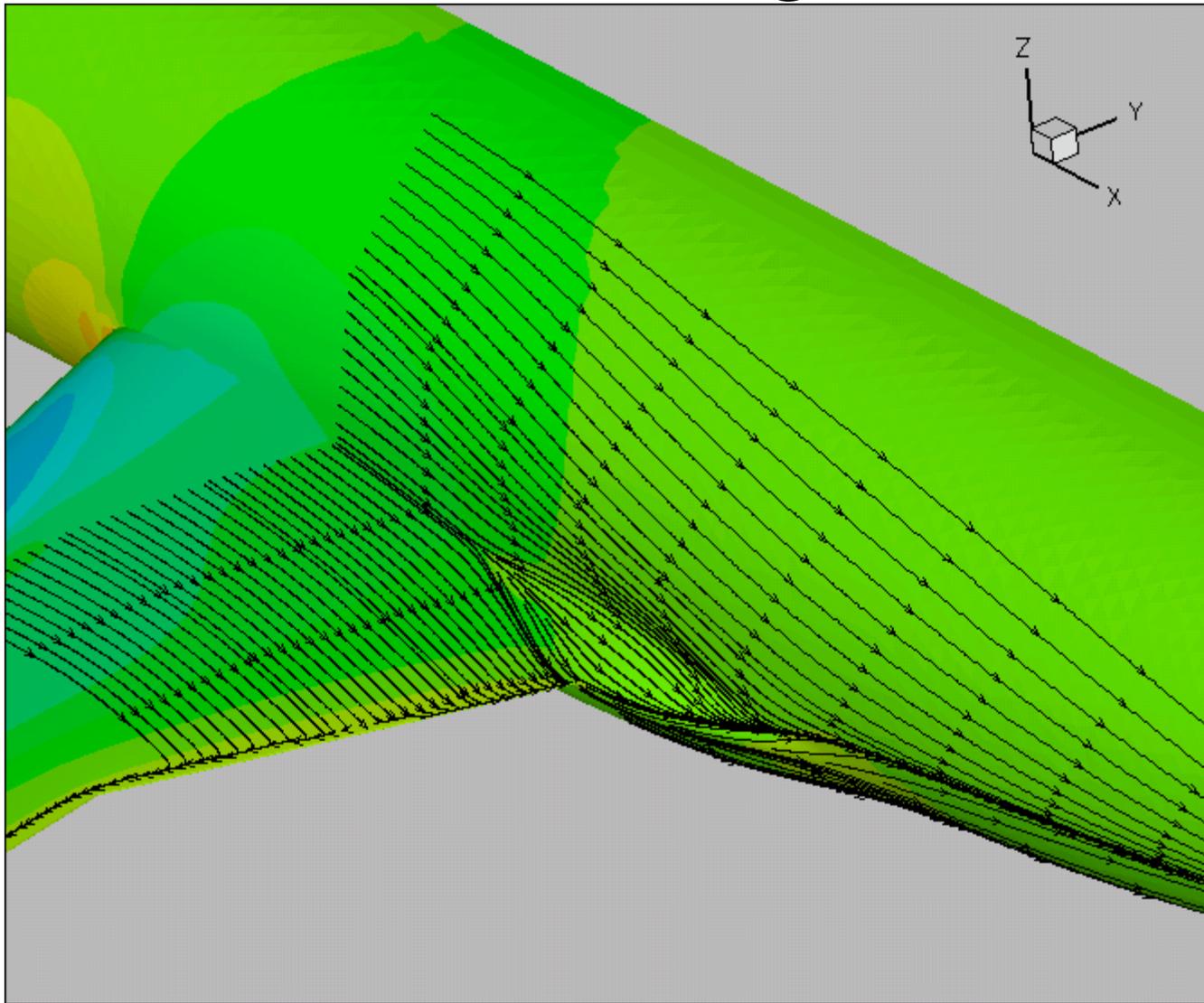
- Good fairing design (coarse grid: 5M pts)

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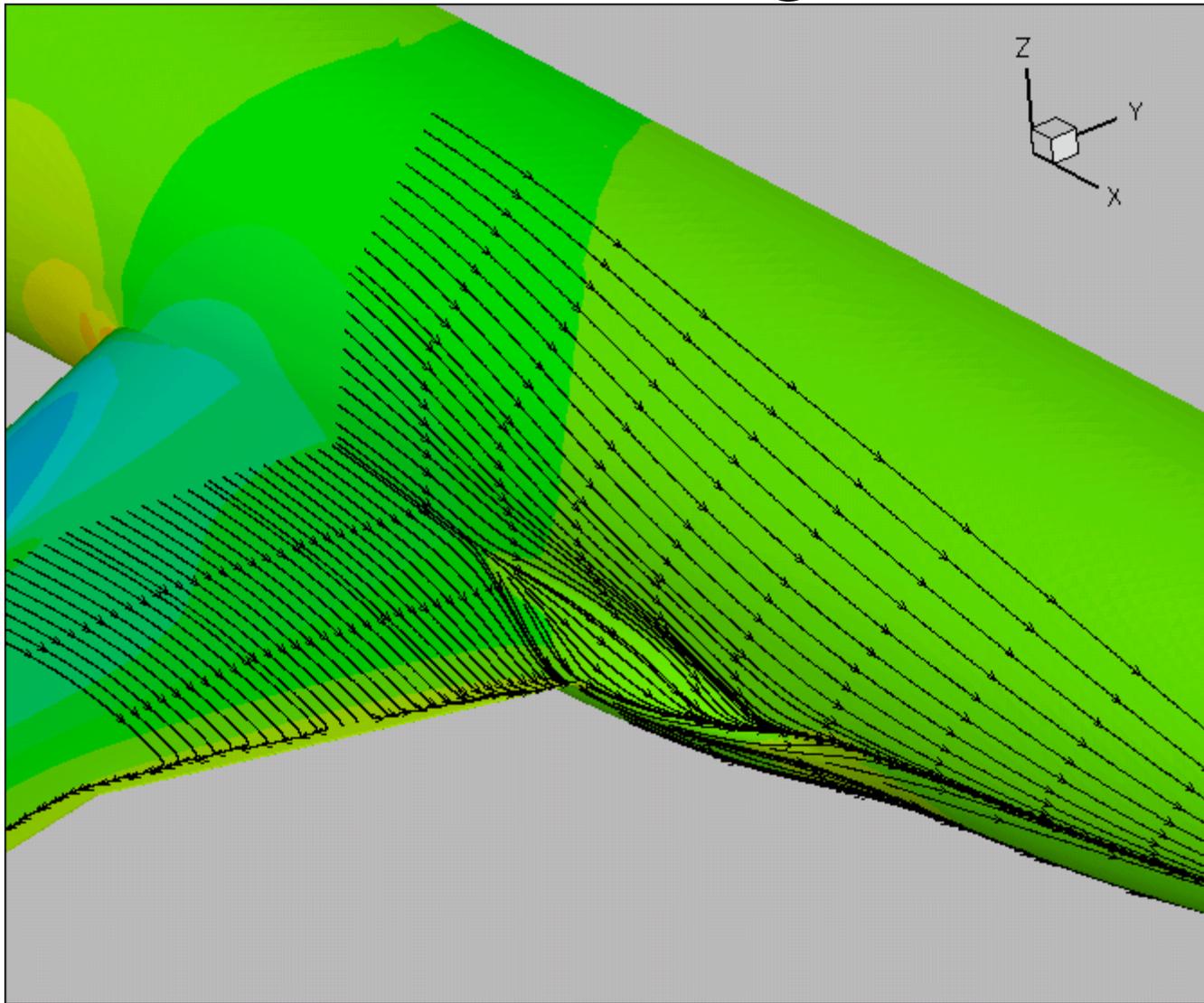
- Good fairing design (medium grid: 15M pts)

WBF: Grid Convergence Study

Frame 001 | 31 May 2006 | GENERIC TECFORM 4.0 INPUT FILE
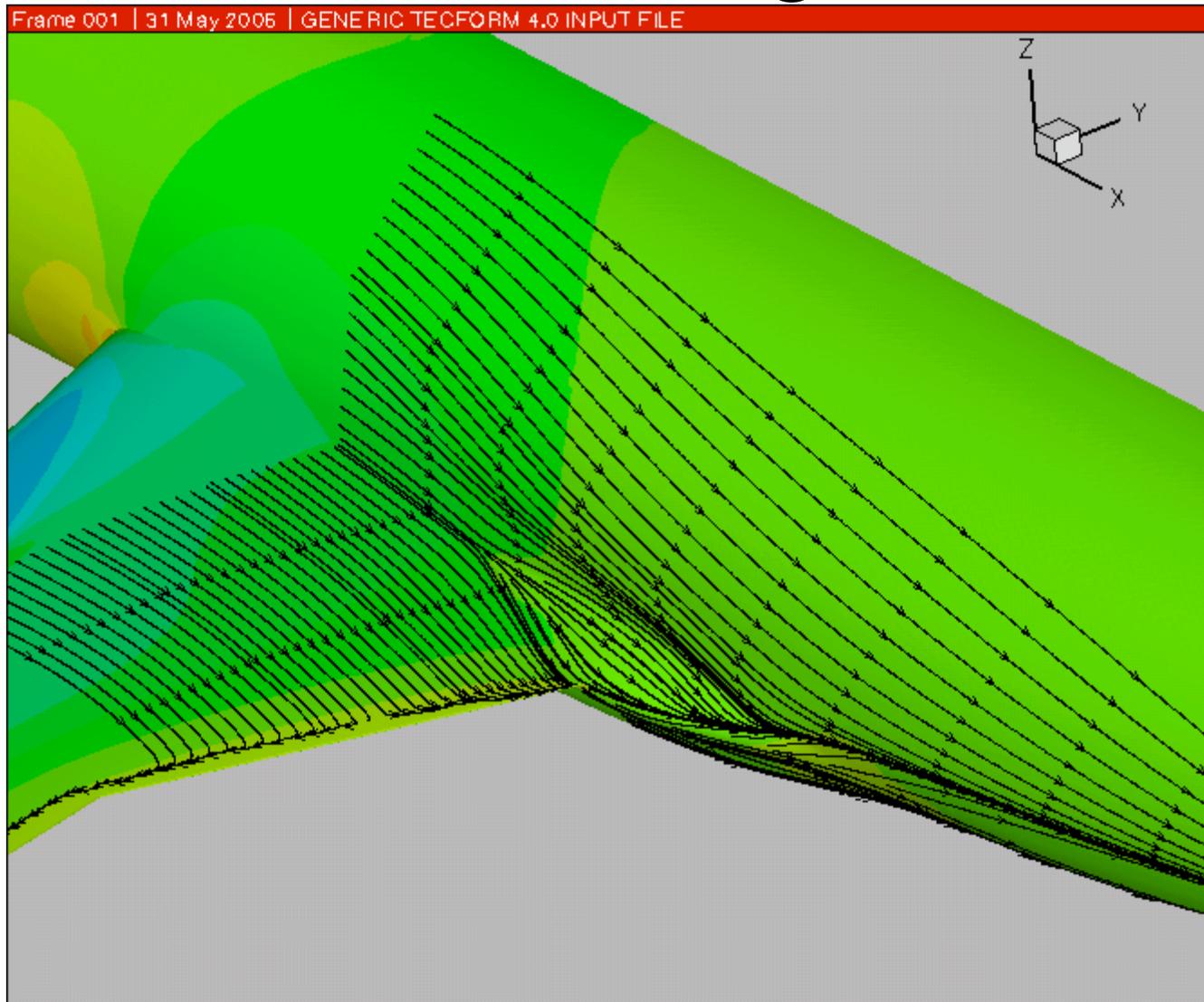
- Good fairing design (fine grid: 40M pts)

WBF: TE Separation
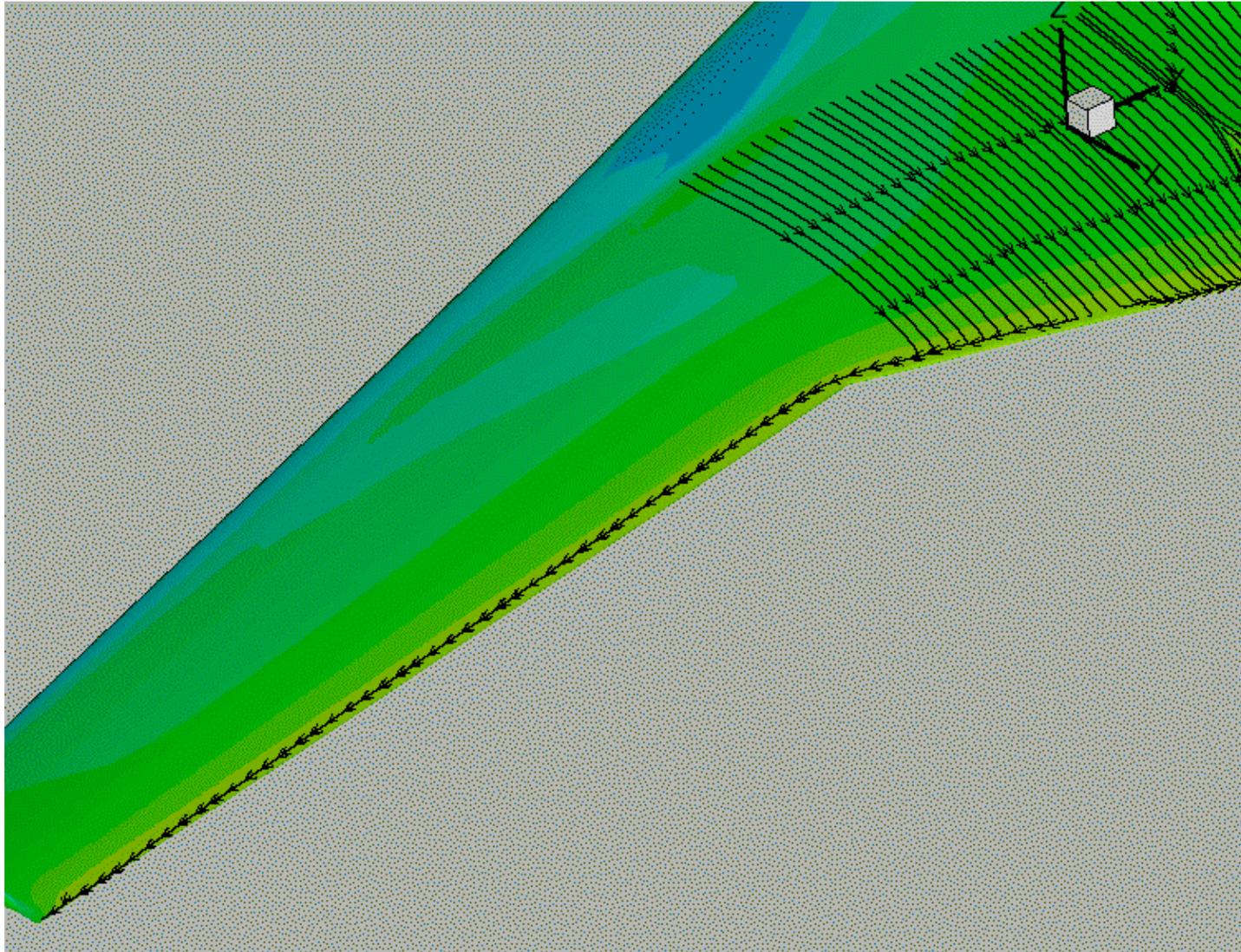
- Coarse grid: 5M pts

WBF: Drag Polar
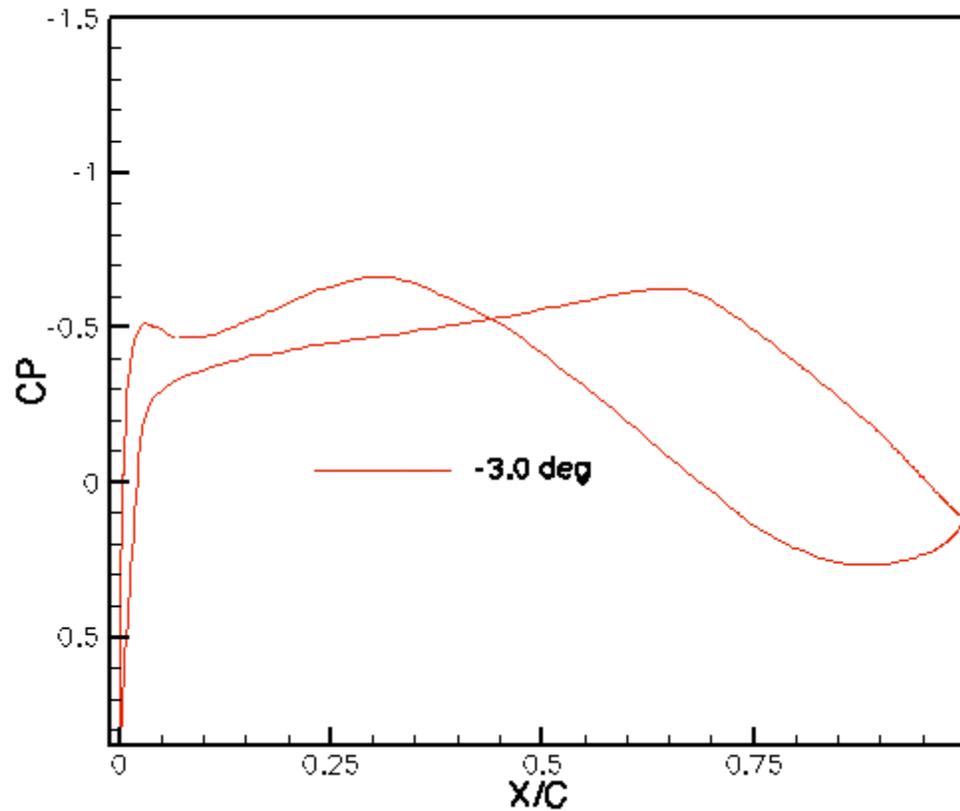
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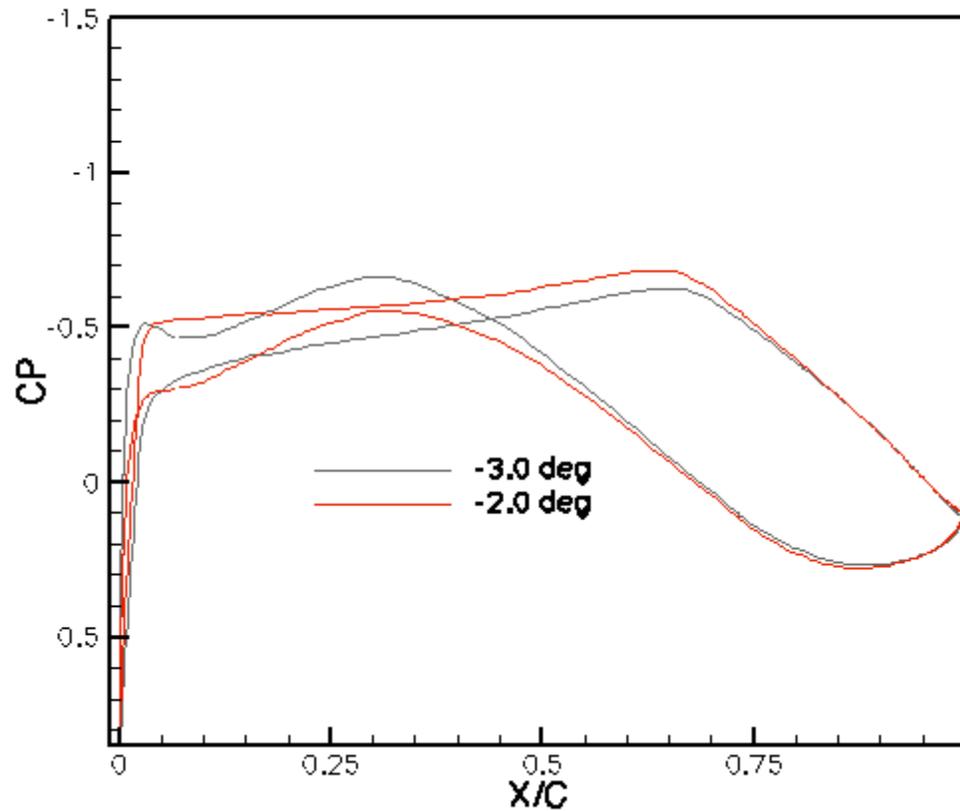
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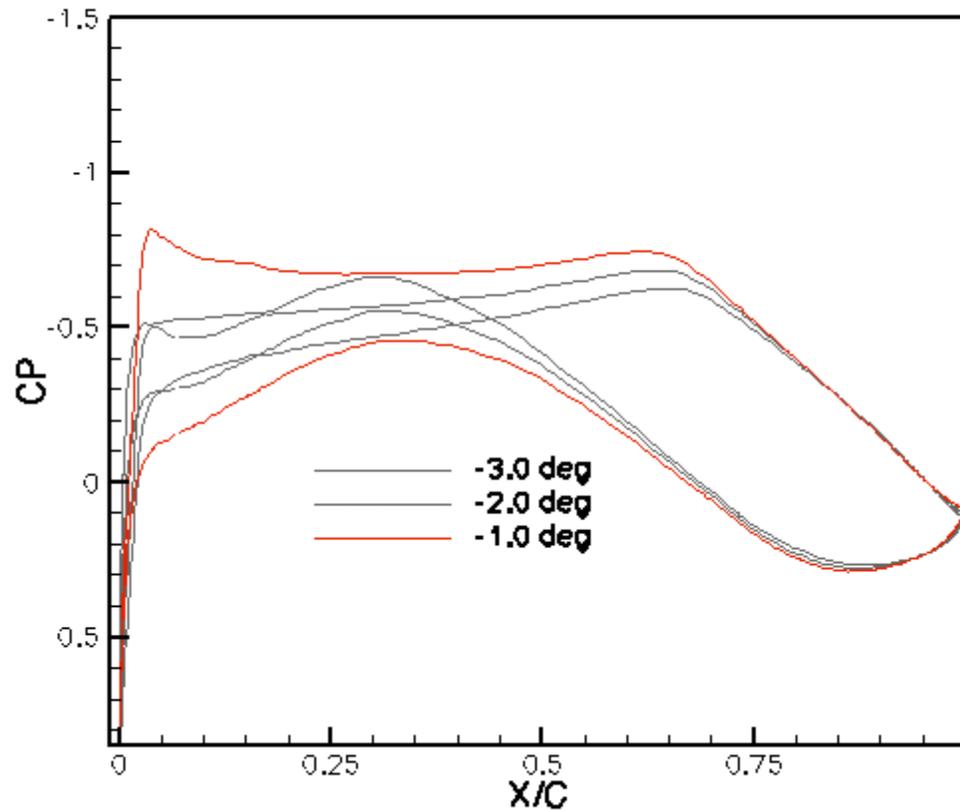
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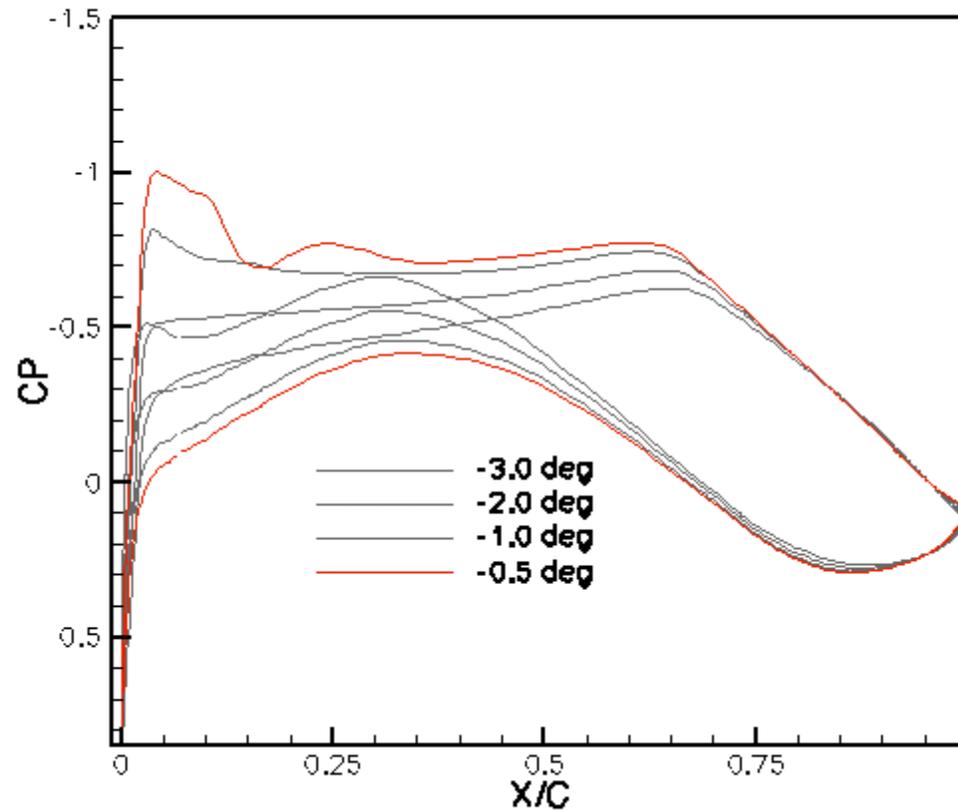
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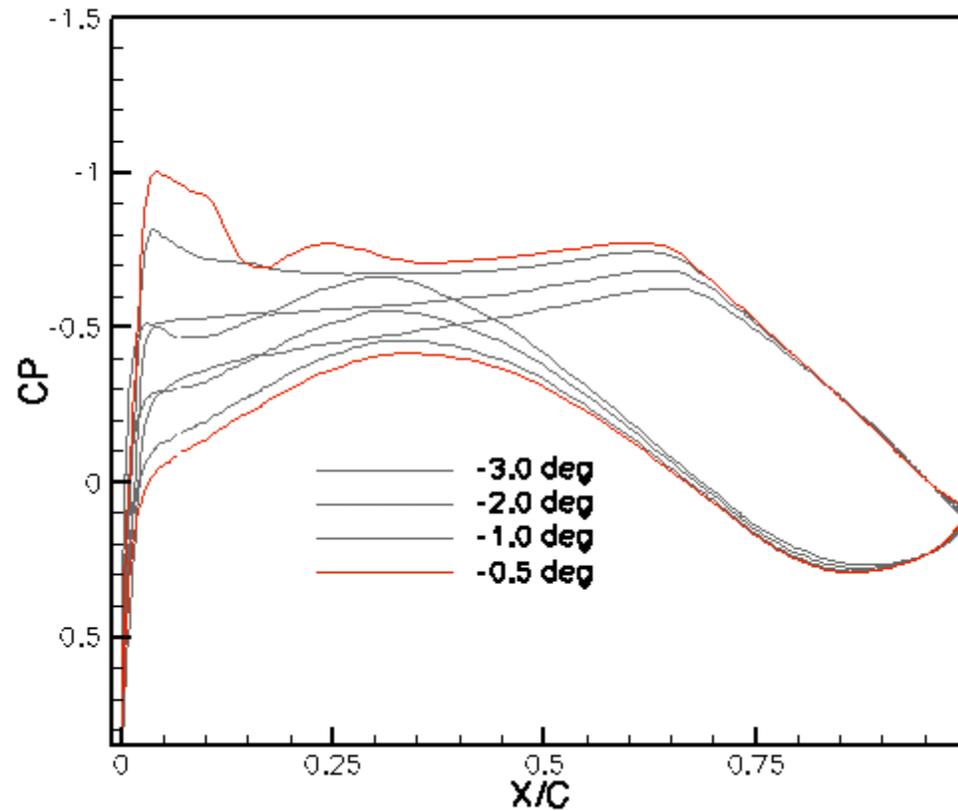
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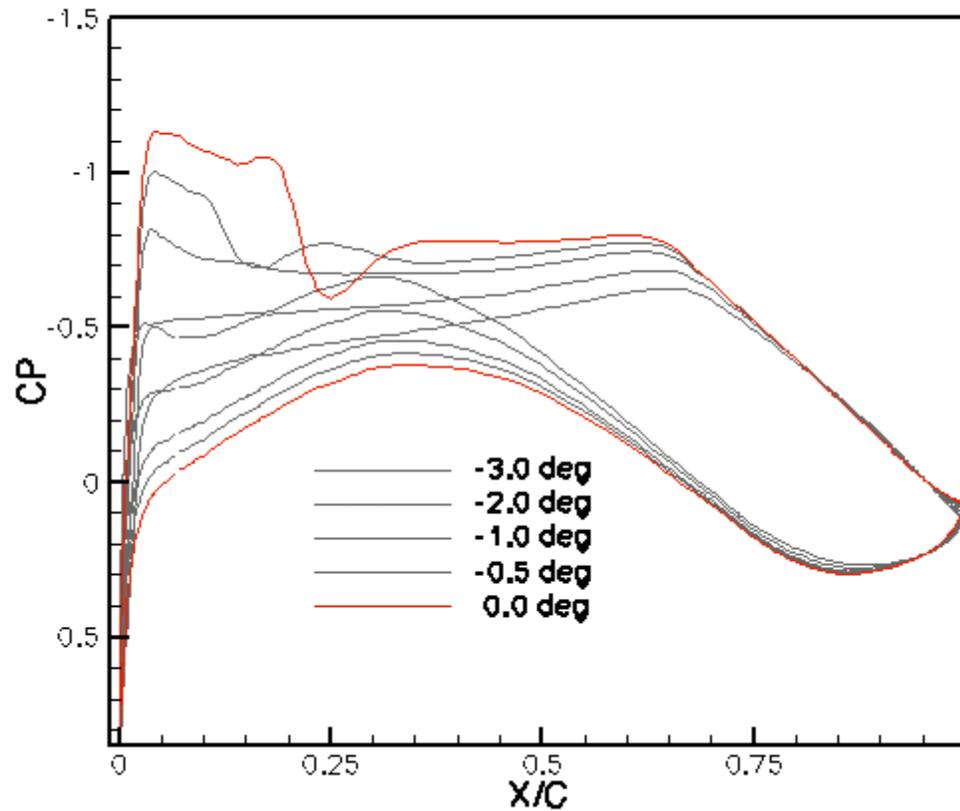
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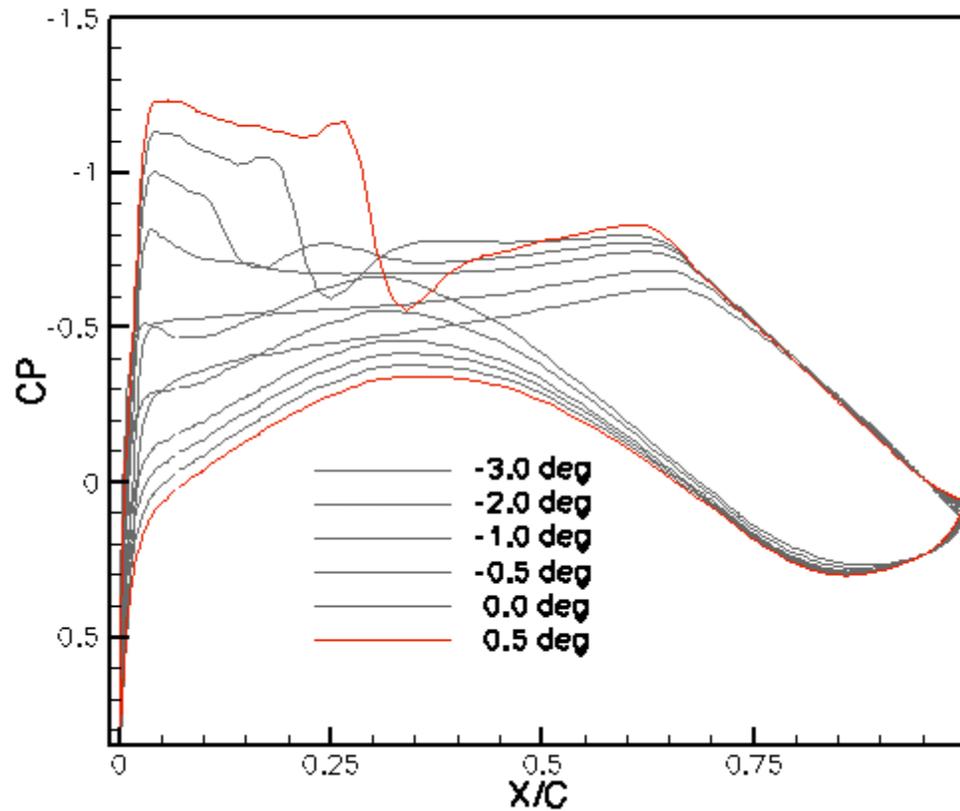
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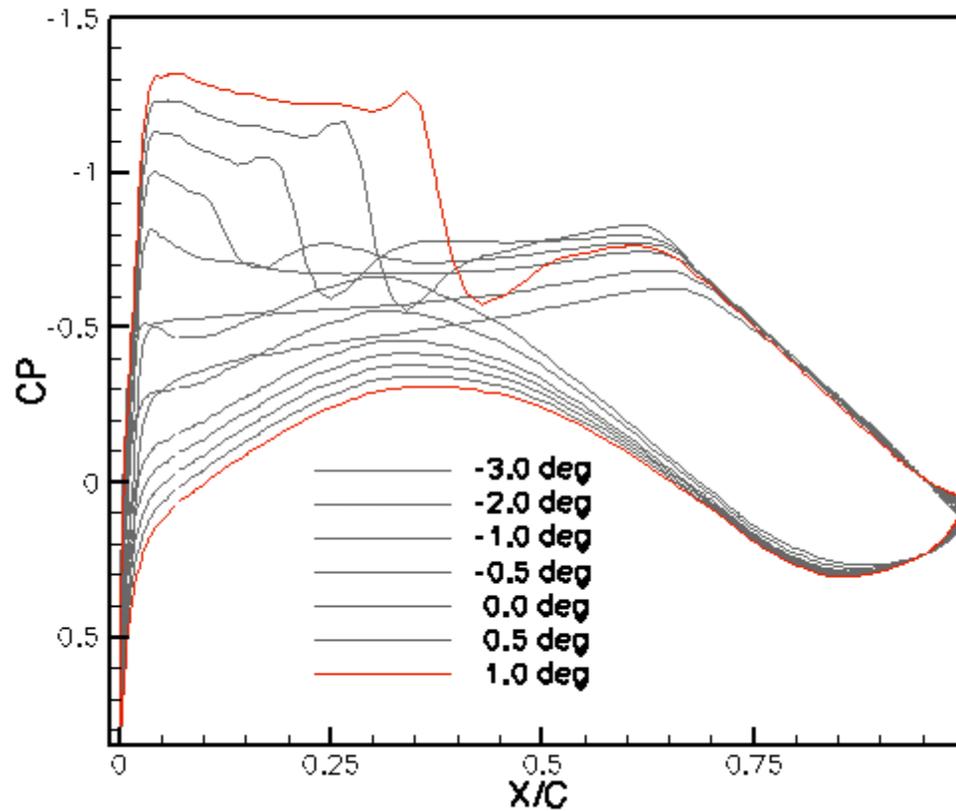
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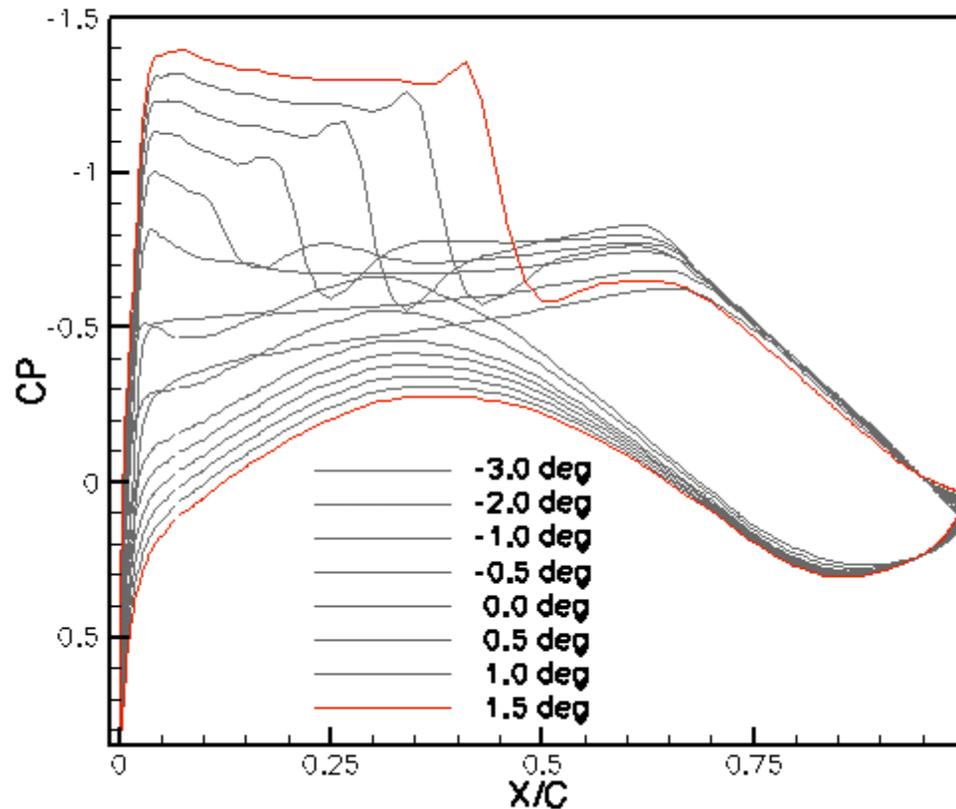
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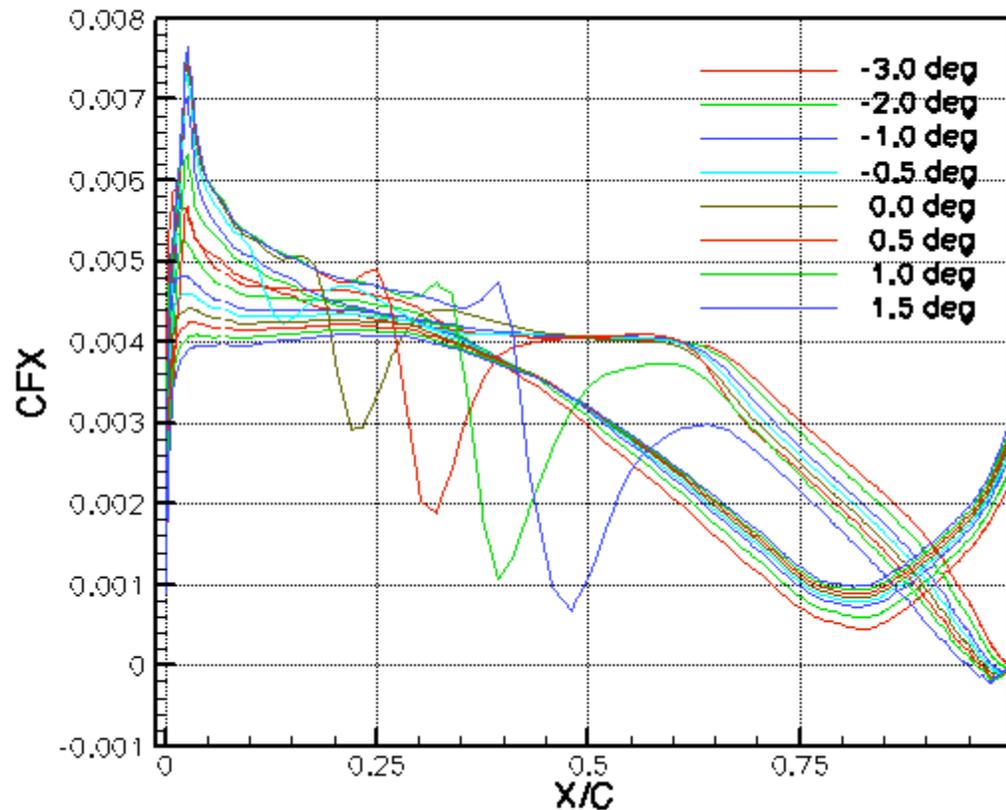
WBF: Drag Polar

- CFX at wing break station (y/b=0.411)
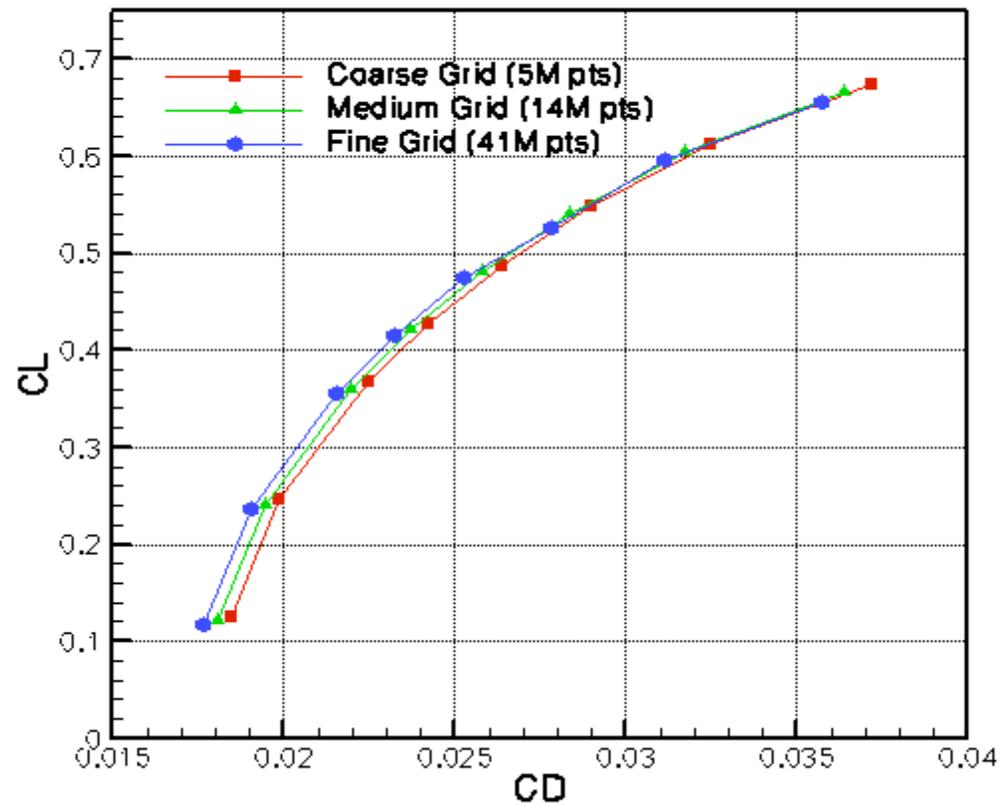
WBF: Drag Polar

- Full Polar run on all 3 grids (5, 15, 40M pts)

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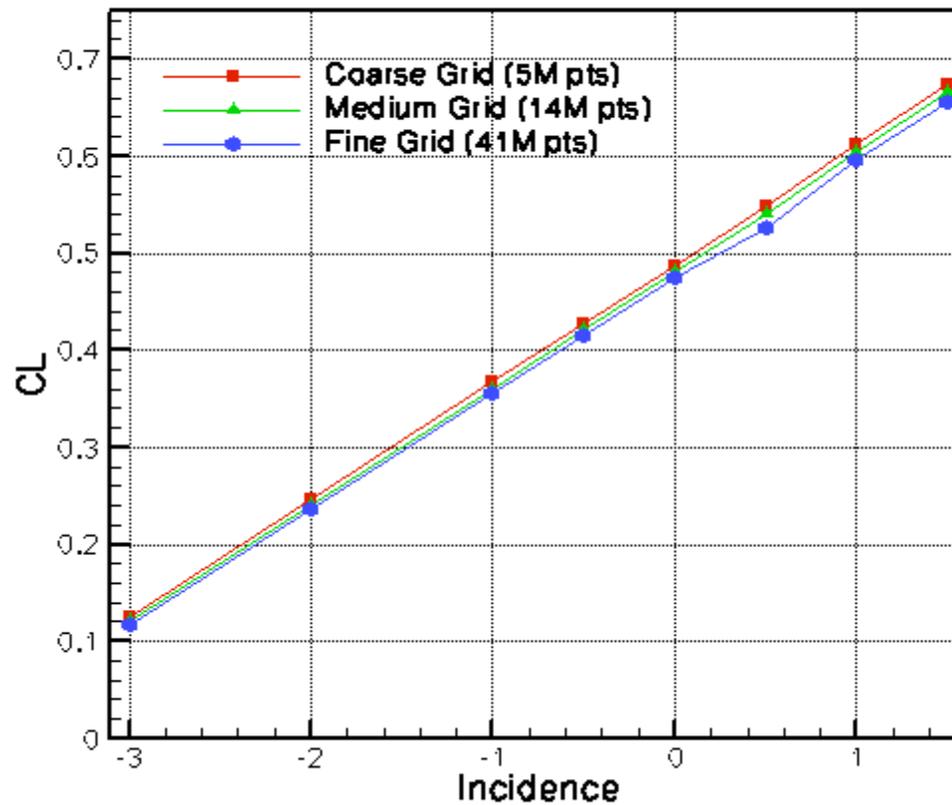
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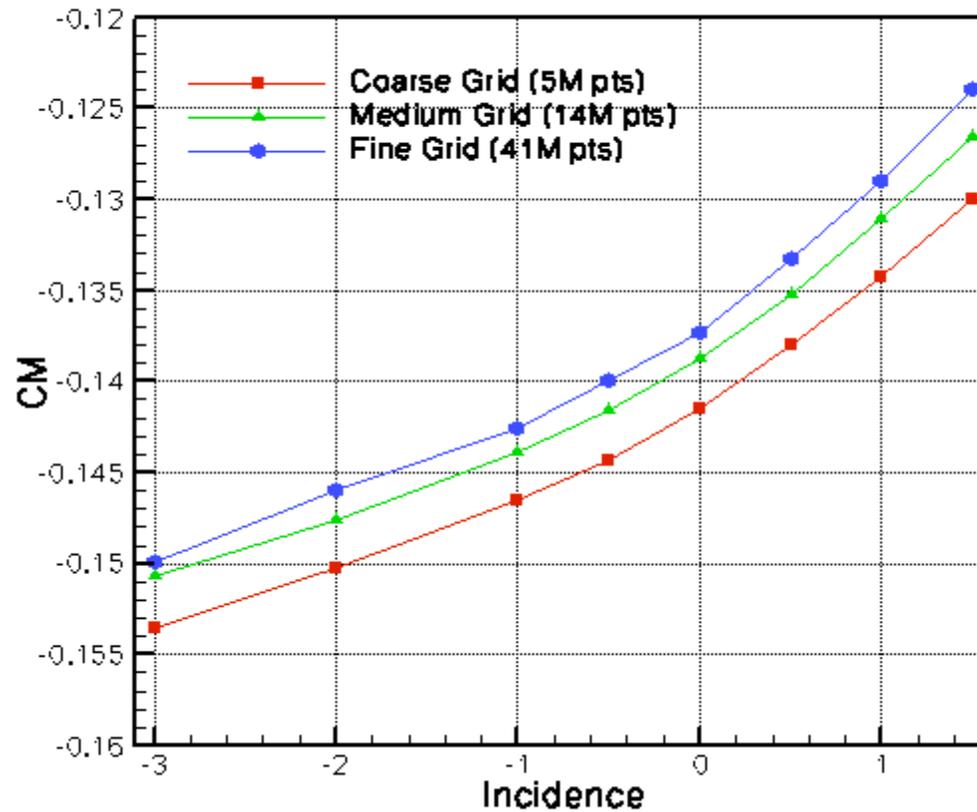
WBF: Moment

- Full Polar run on all 3 grids (5, 15, 40M pts)

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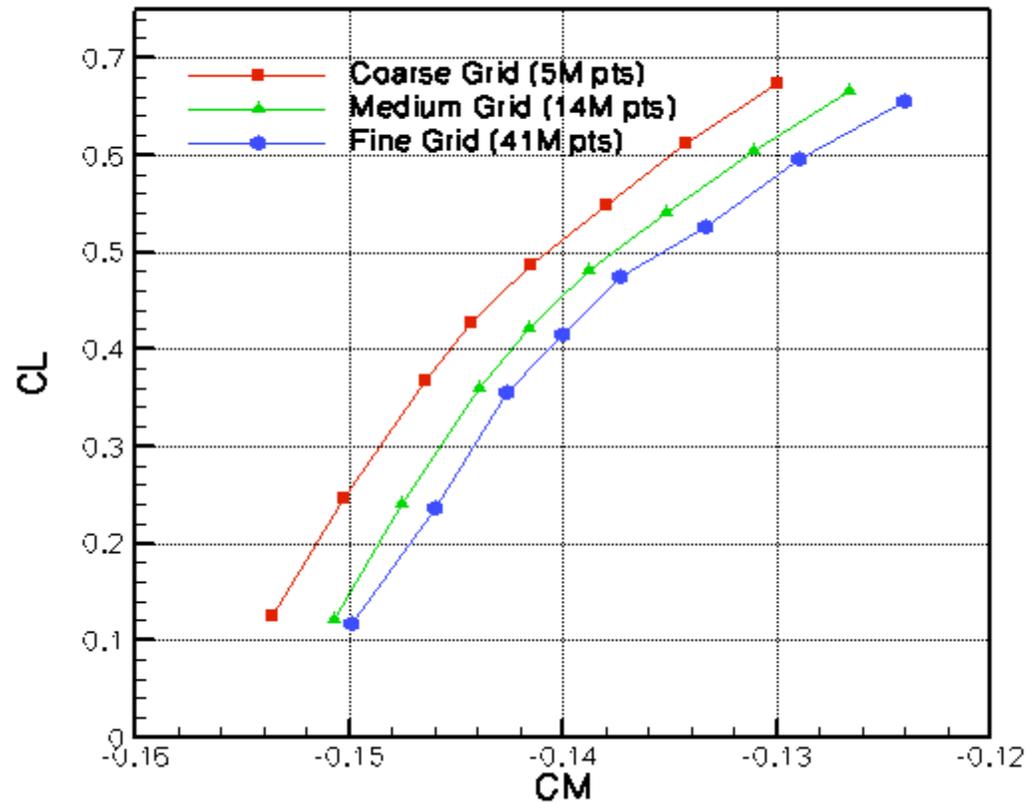
- Full Polar run on all 3 grids (5, 15, 40M pts)

WB Results

- Previous DPW2 Revisited Results (2005)
  - All grids converged well
  - CL CD on Family of grids 2M up to 72M pts appears asymoptotic
  - Grid of 65M pts from different family gives substantially lower CL

- DPW3 Grid Family 5-40M pts
  - Convergence issues

Grid Convergence and Dissipation
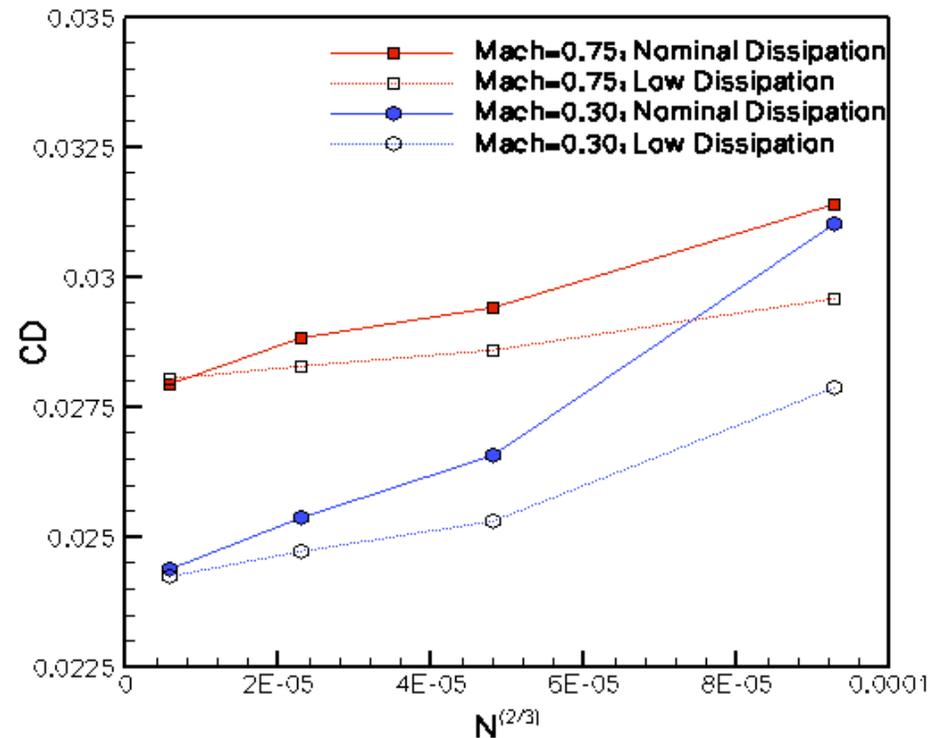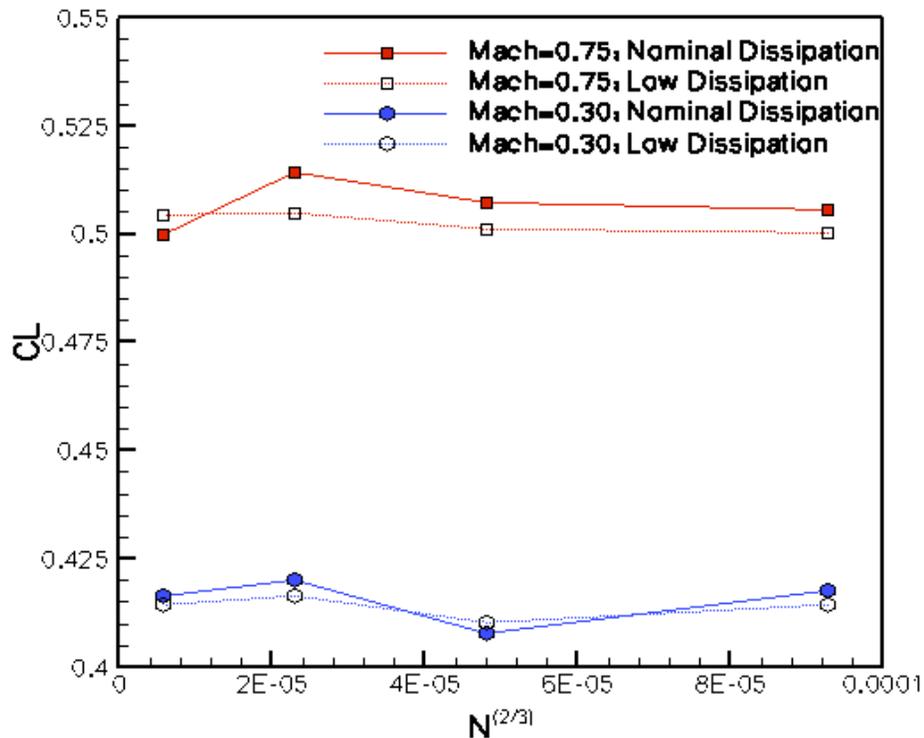
- Drag is grid converging
- Lift is somewhat erratic:
  - better grid convergence at lower dissipation values
- Sensitivity to dissipation decreases as expected

65M pt mesh Results
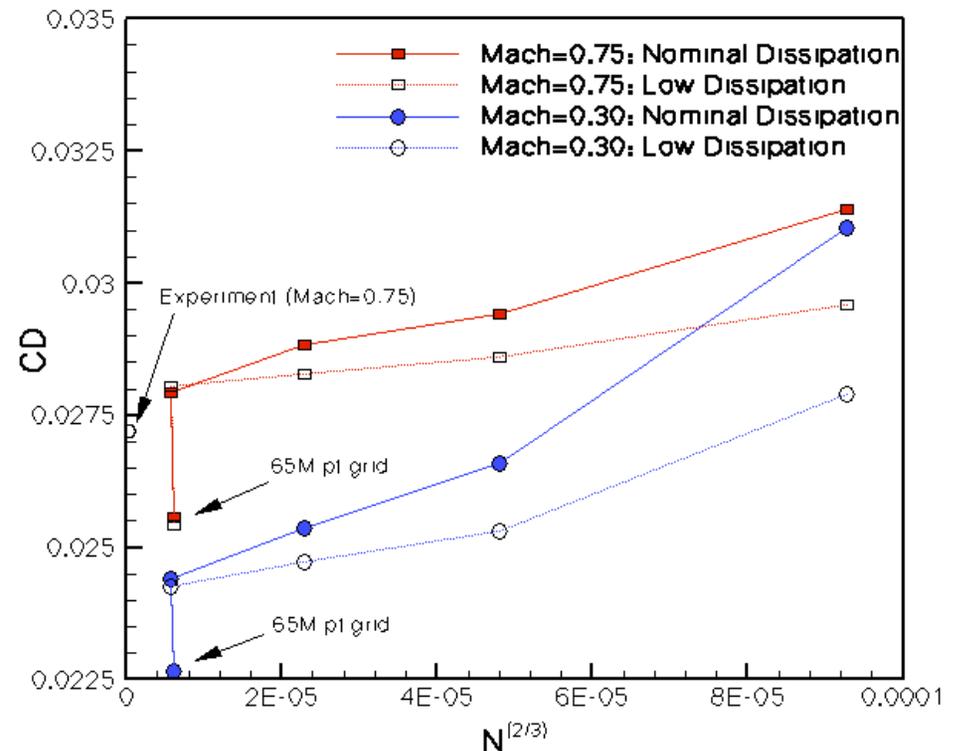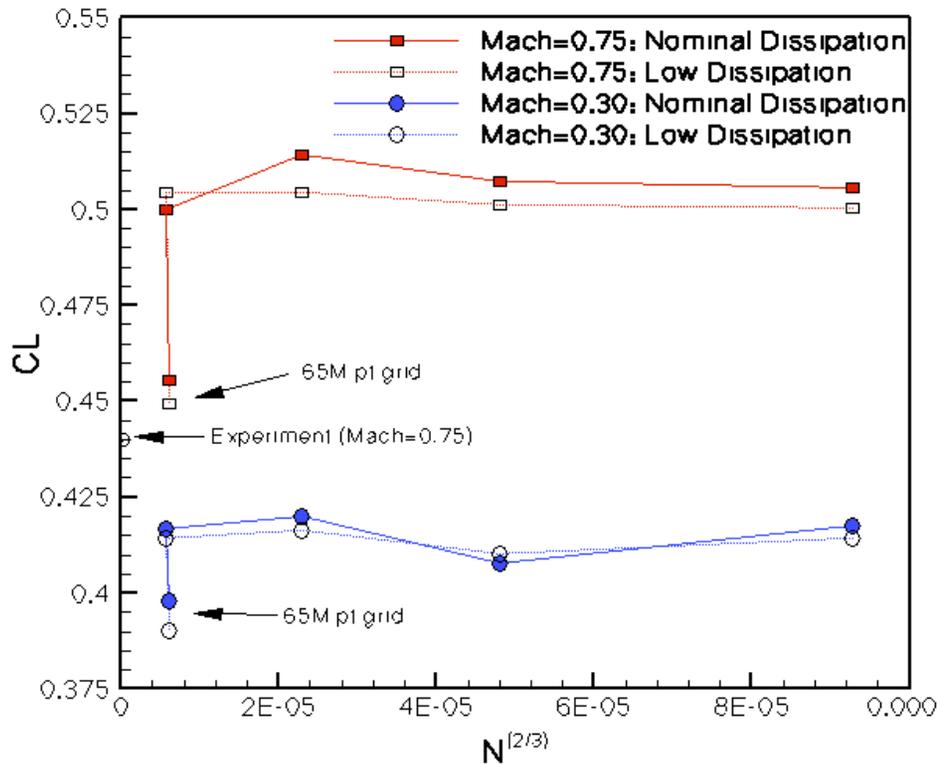
- 10% drop in C_L at AoA=0°: closer to experiment
- Drop in C_D: further from experiment
- Same trends at Mach=0.3
- Little sensitivity to dissipation

65M pt Mesh Results
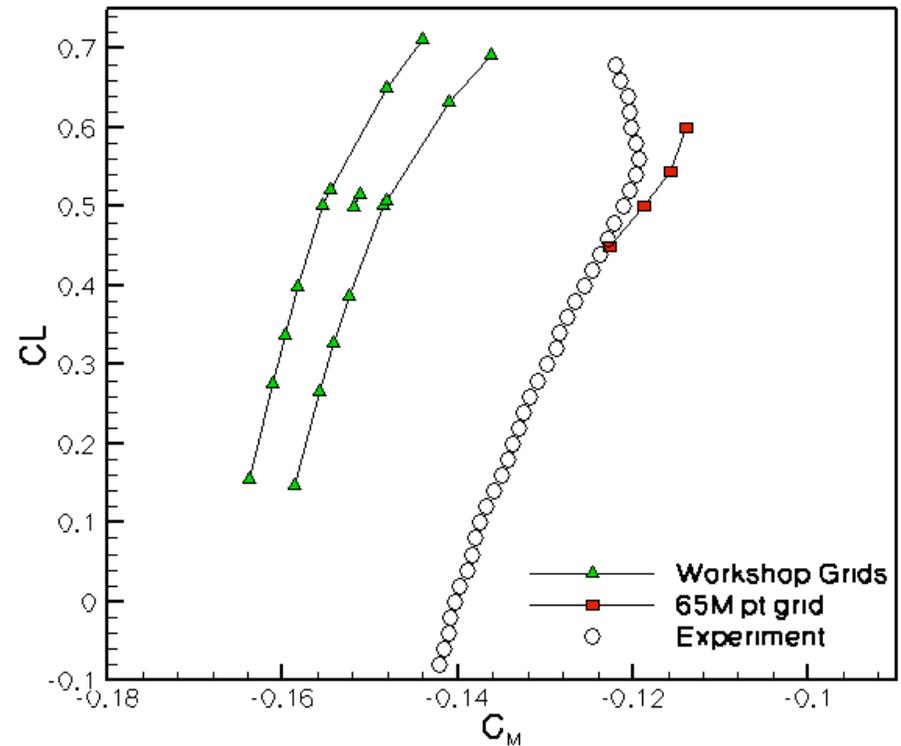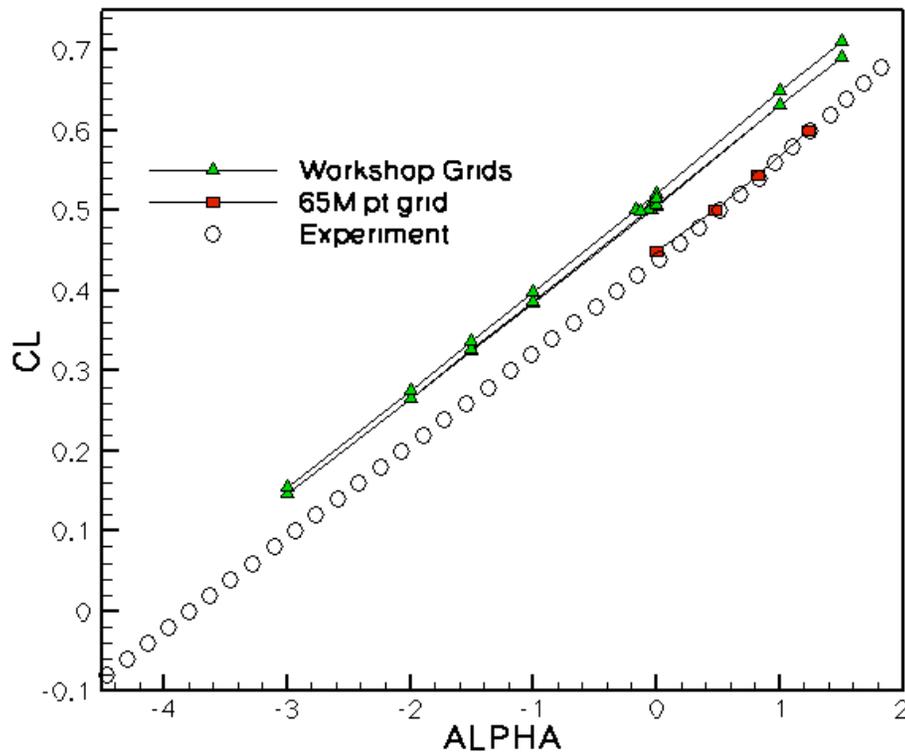
- Much better agreement with experiment(C_L and C_M)

Grid Specifications
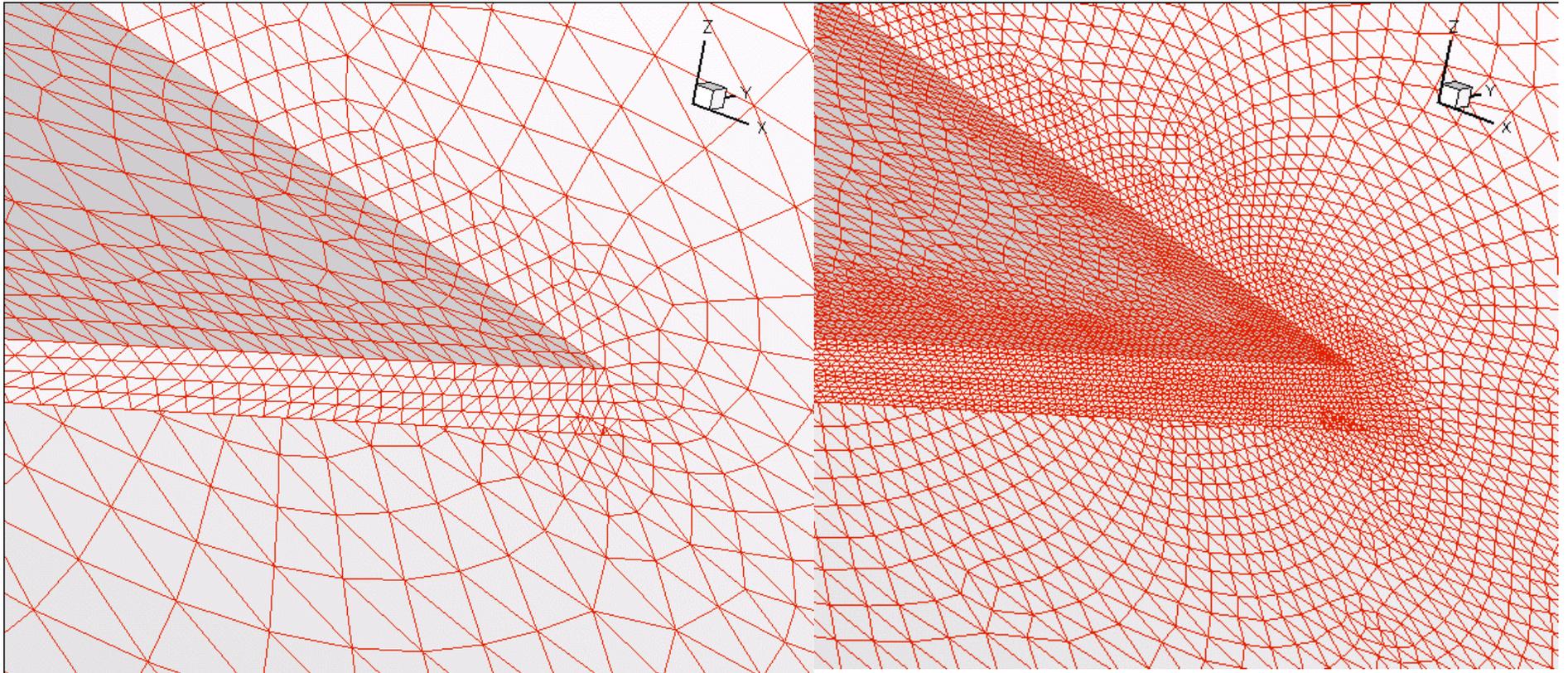
3.0 million pt grid

72 million pt grid
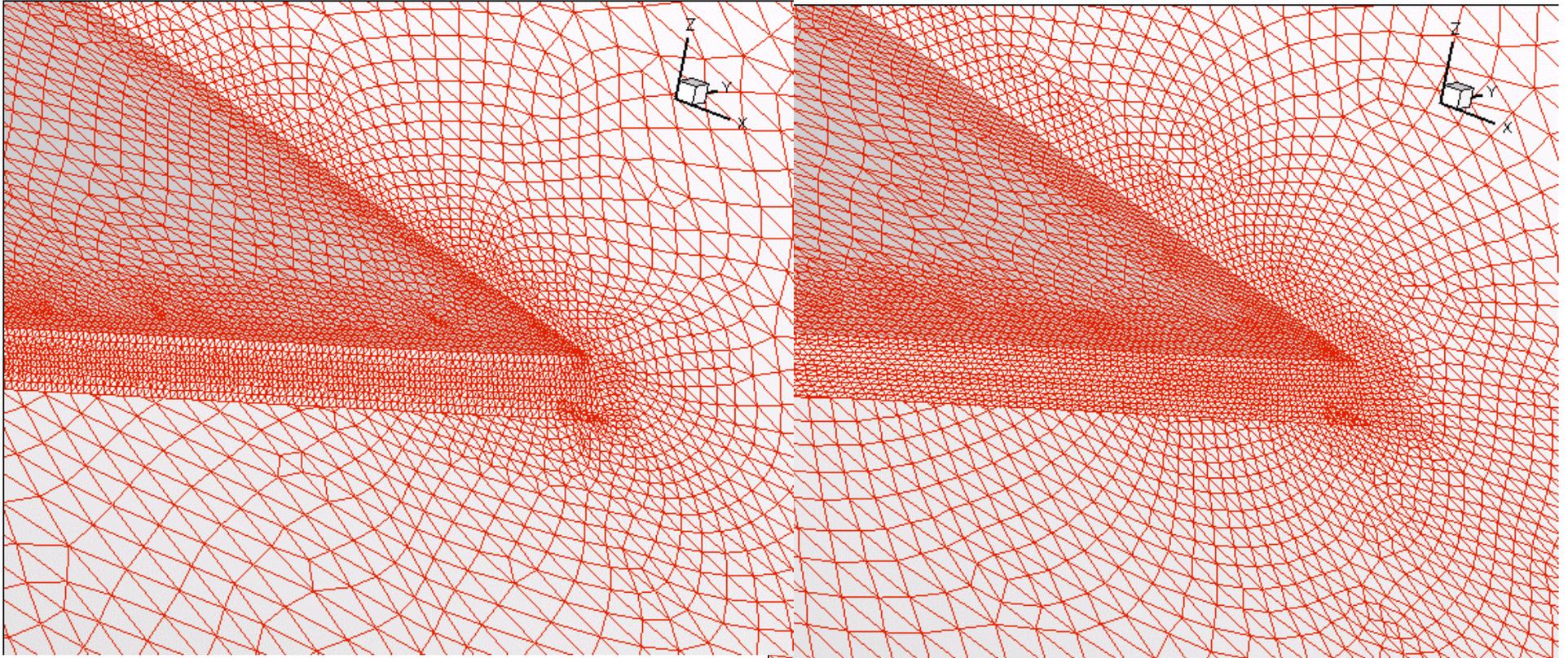
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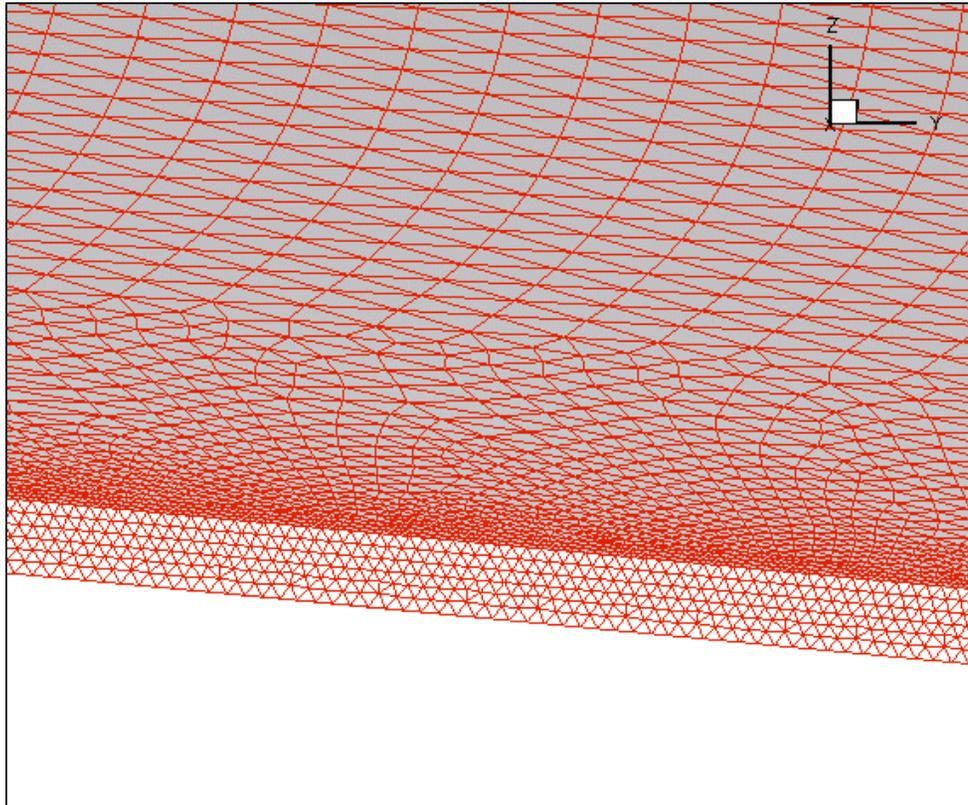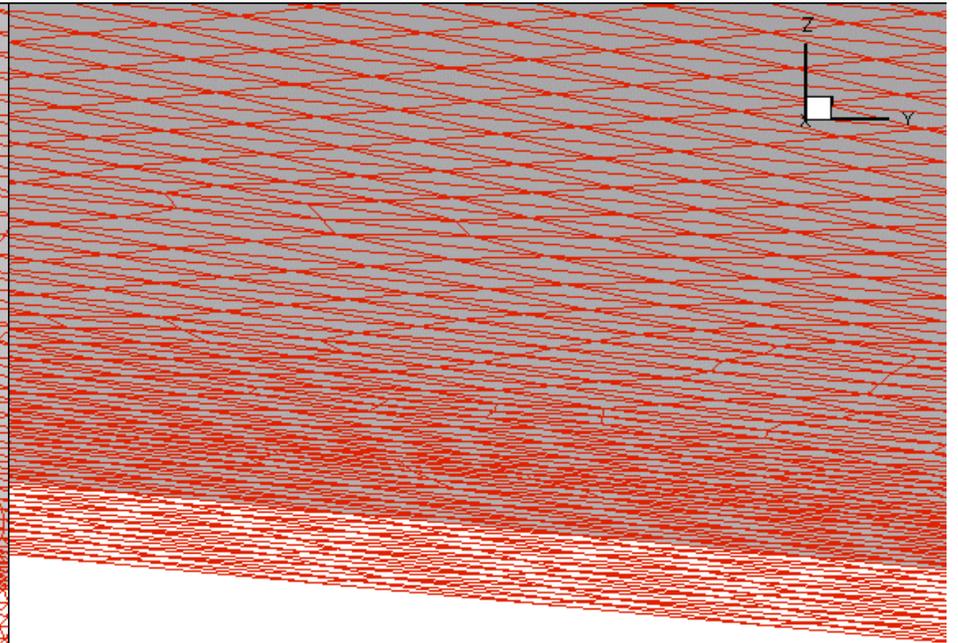
65 million pt grid

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WB Convergence (fixed alpha)
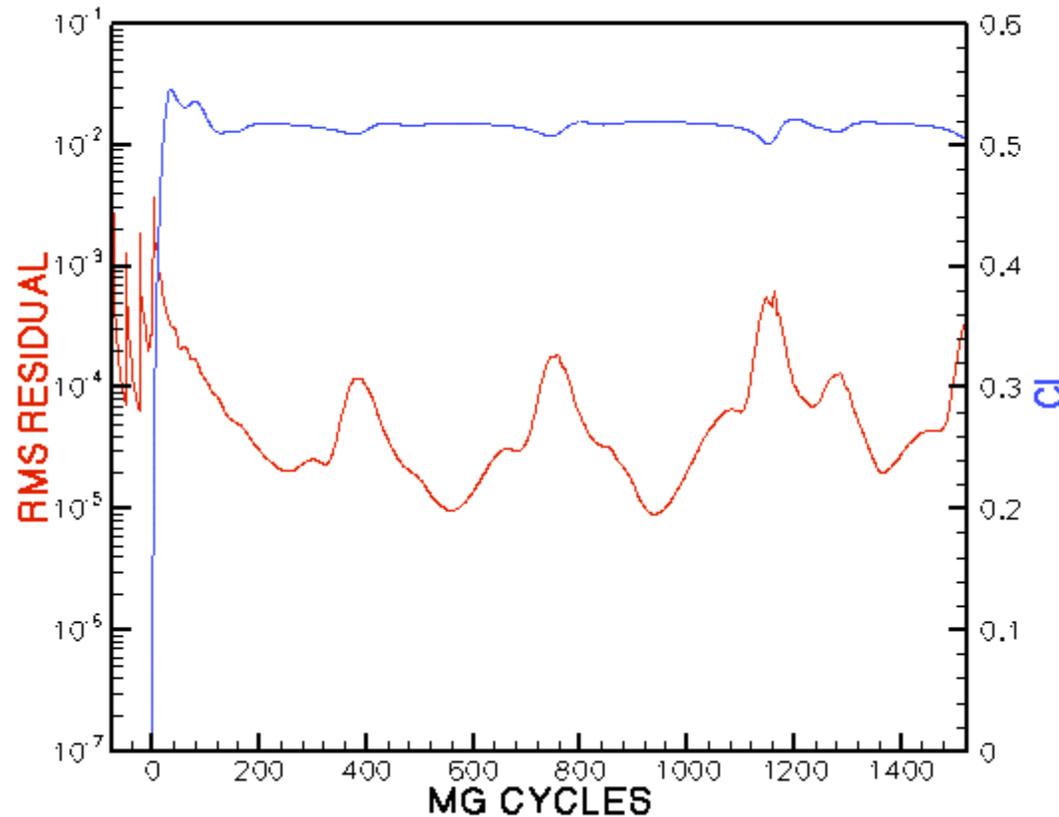
- Separated Flow, unsteady shedding pattern
- Smaller residual excursions with fewer MG levels
- Moderate CL variations

WB Medium Grid
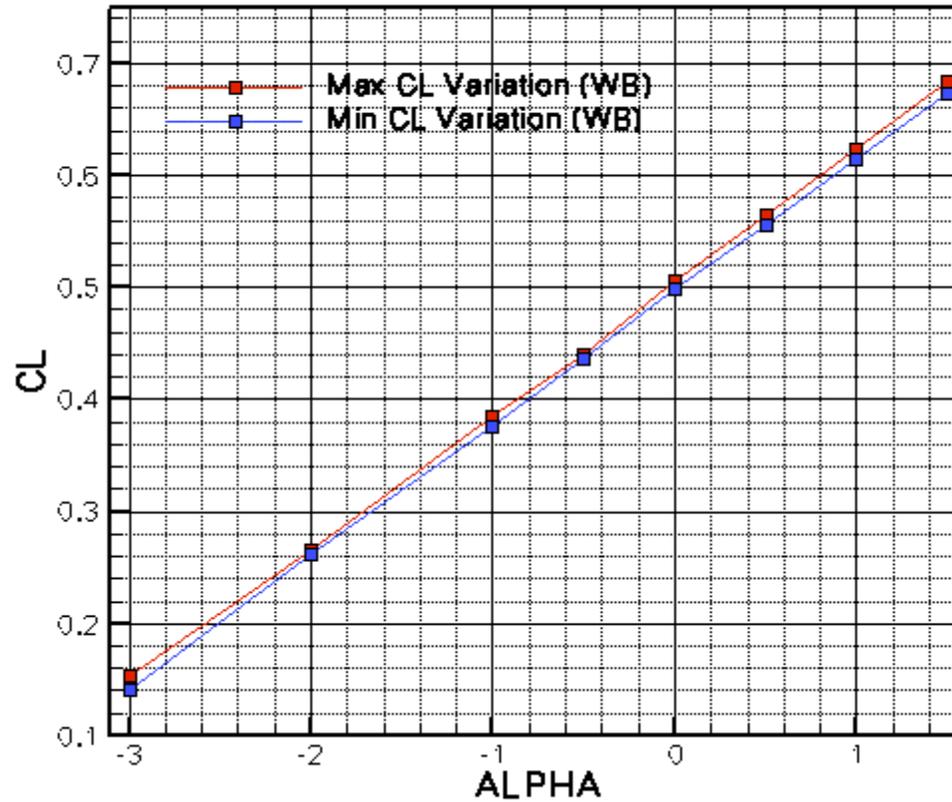
- Plot Min and Max unsteady CL values

WB Medium Grid
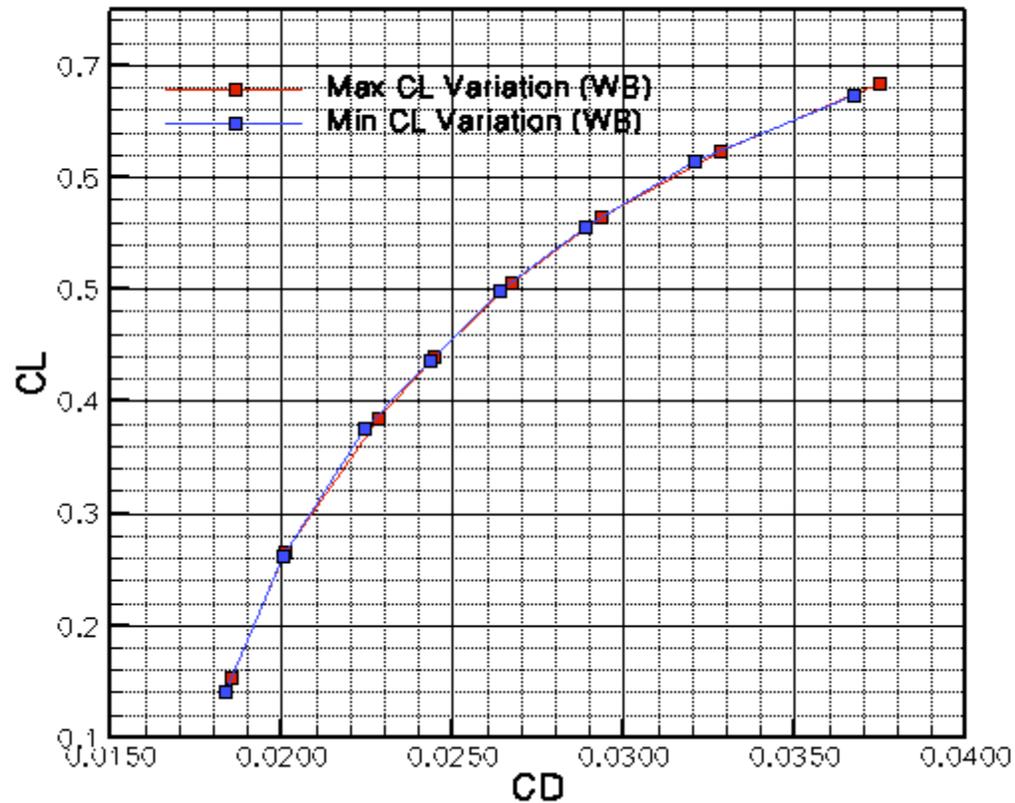
- Plot Min and Max unsteady CL values
- Good overlap in polar– suitable drag values

WB Medium Grid
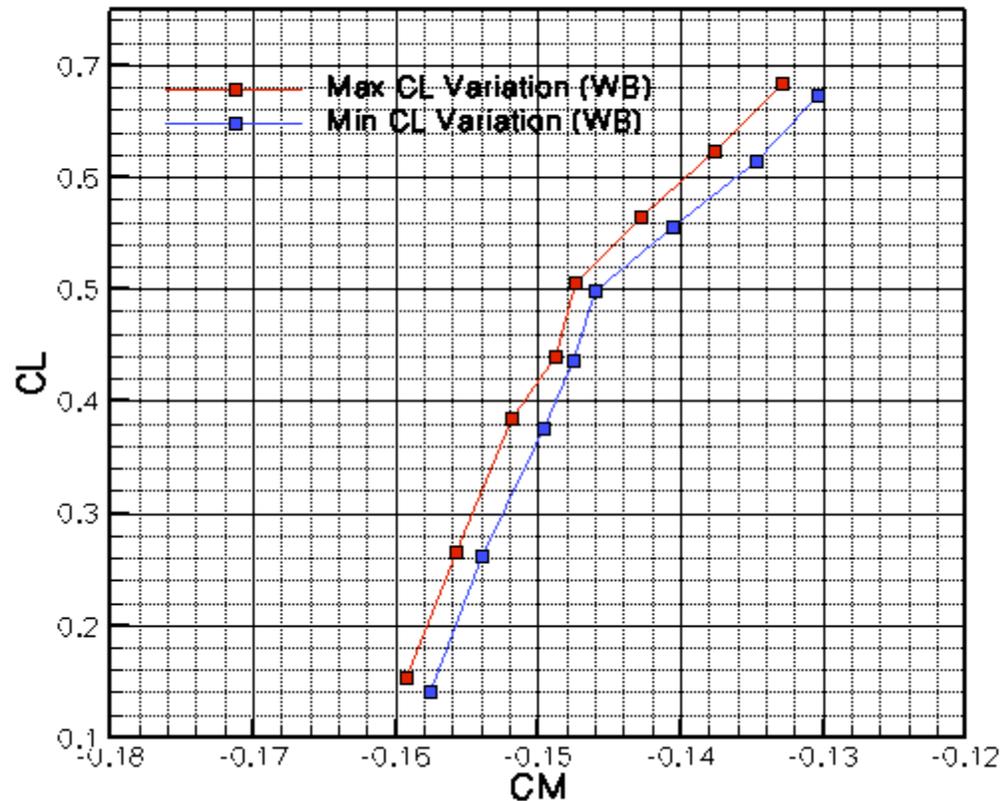
- Plot Min and Max unsteady CL values
- Less overlap in CM

WB Medium Grid
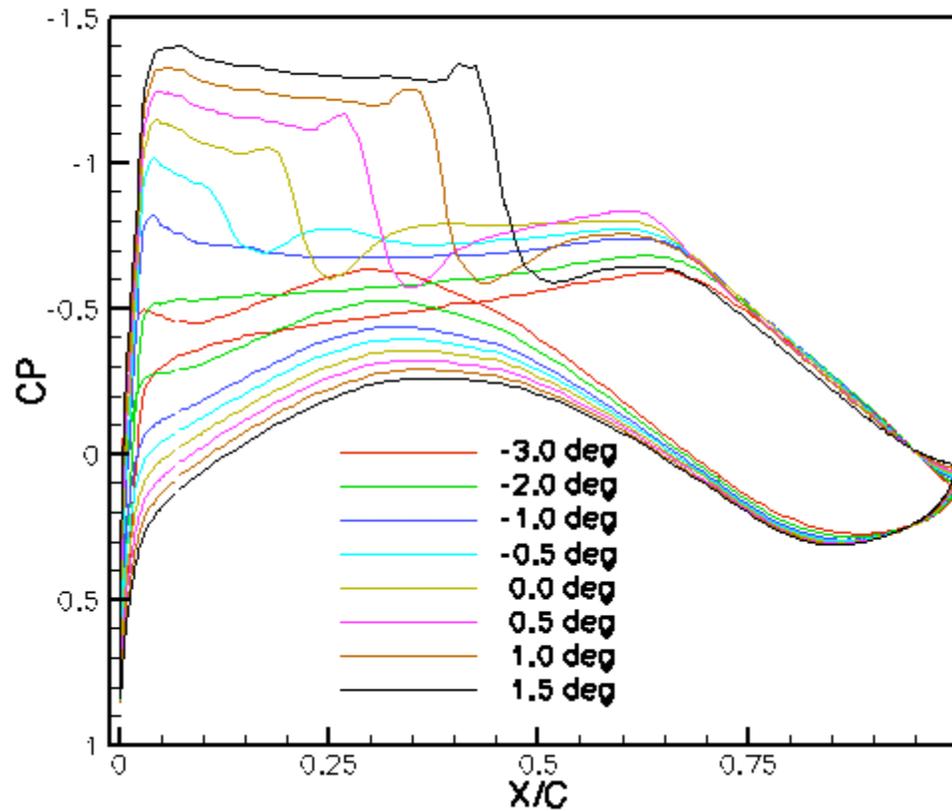
- CP Values at Break Station (y/b=0.411)

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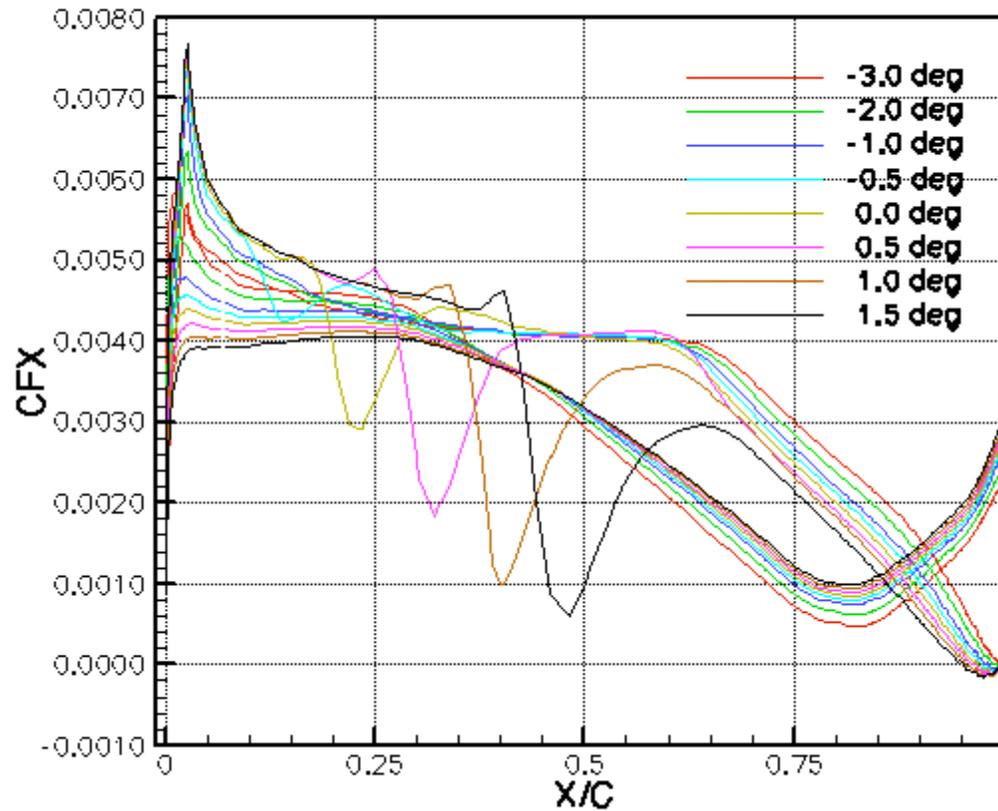
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WB Grid Convergence
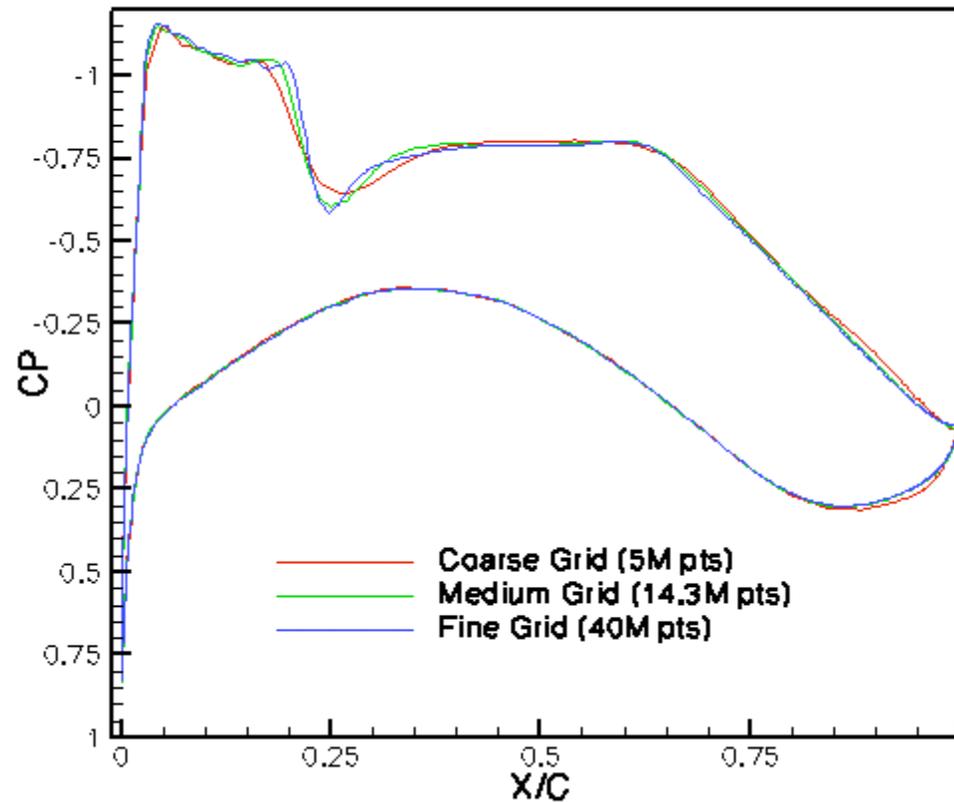
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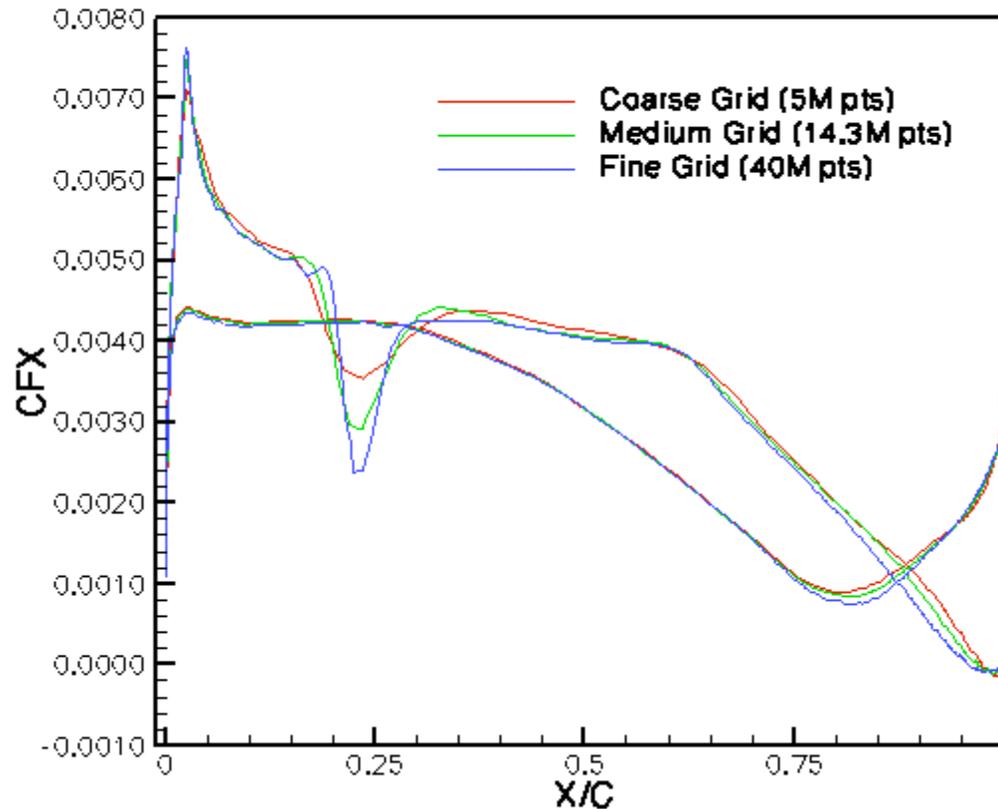
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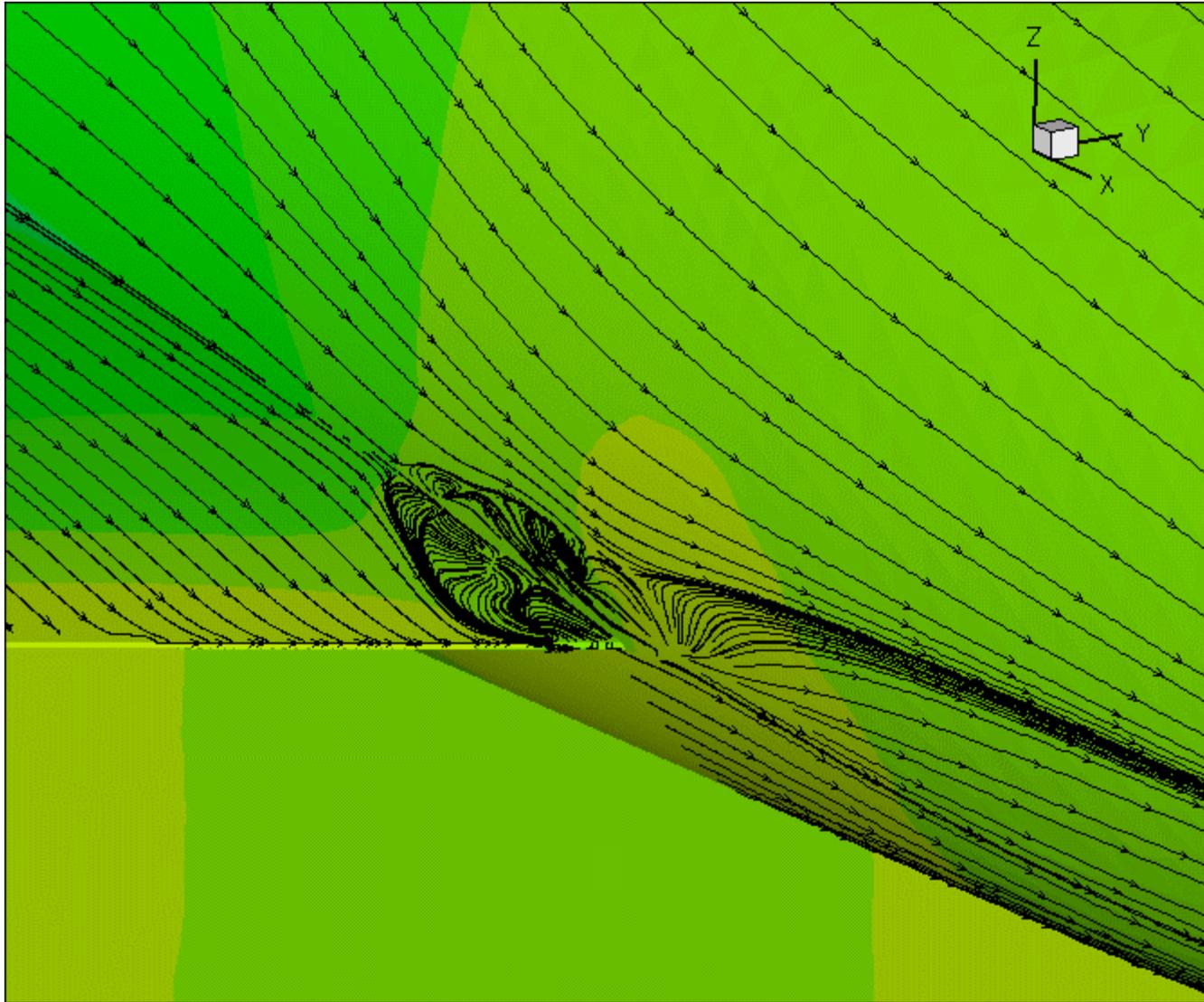
- Separation Pattern (Coarse grid : 5M pts)

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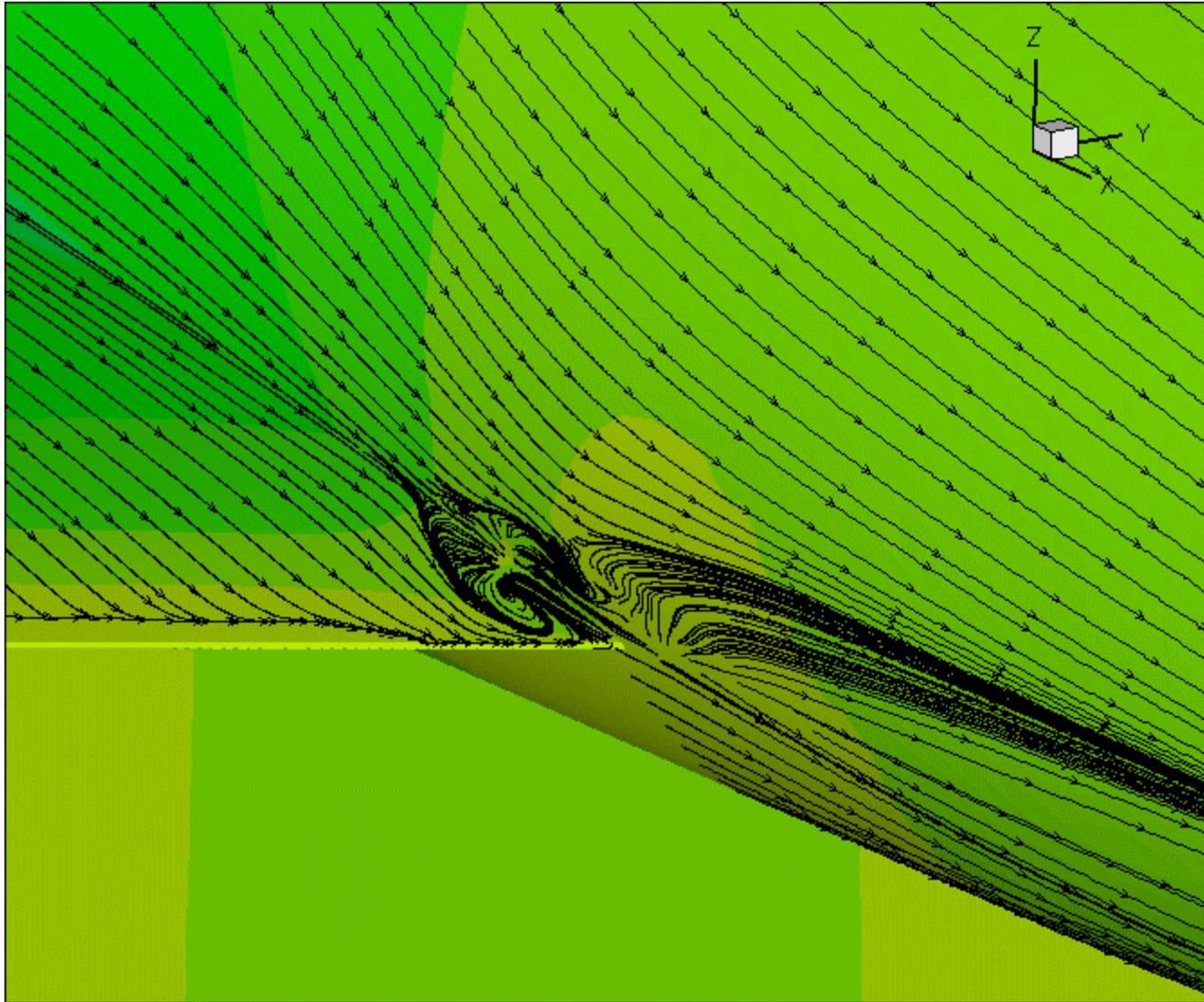
- Separation Pattern (Medium grid : 5M pts)

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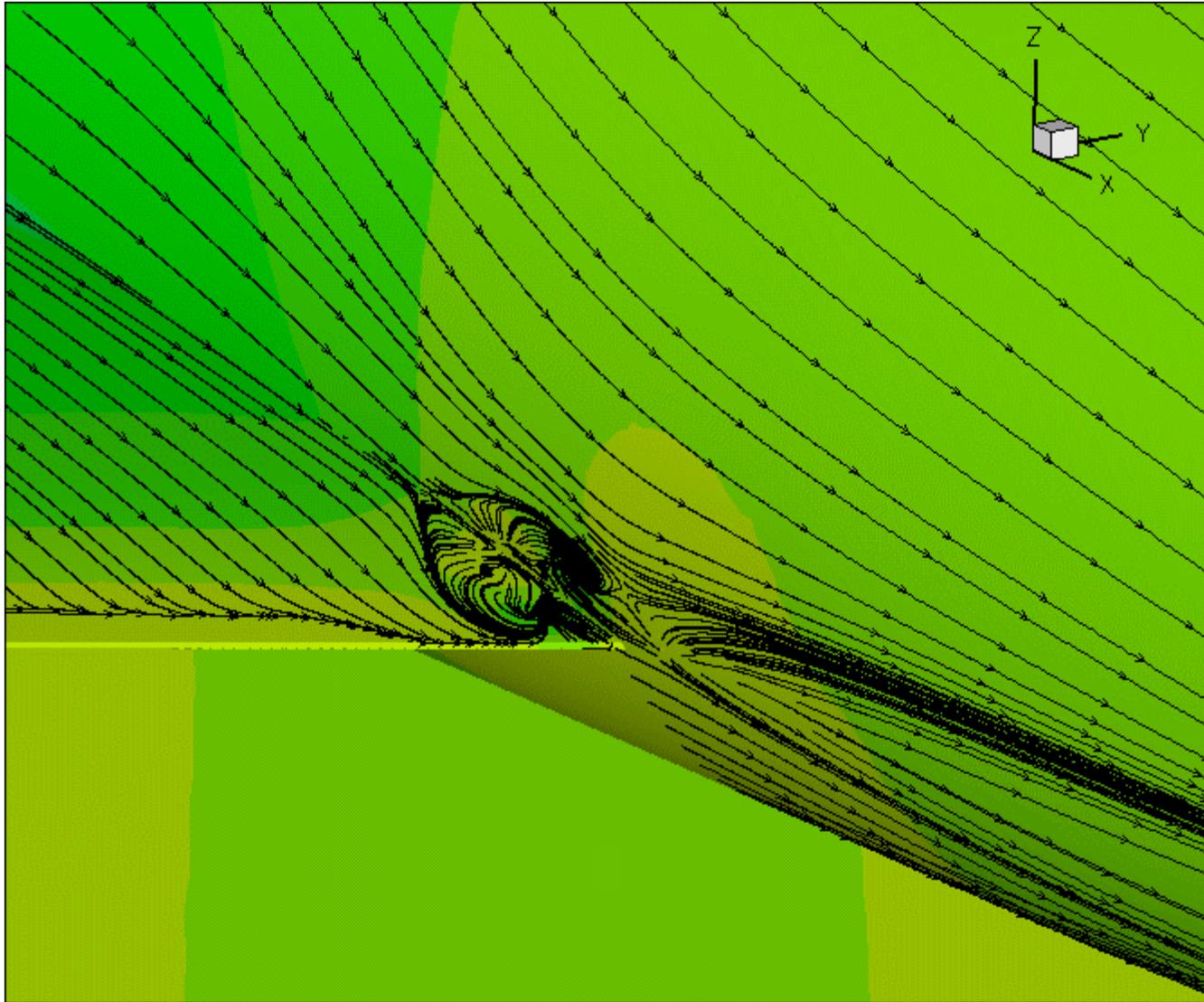
- Separation Pattern (Fine grid : 40M pts)

WB TE Separation Pattern
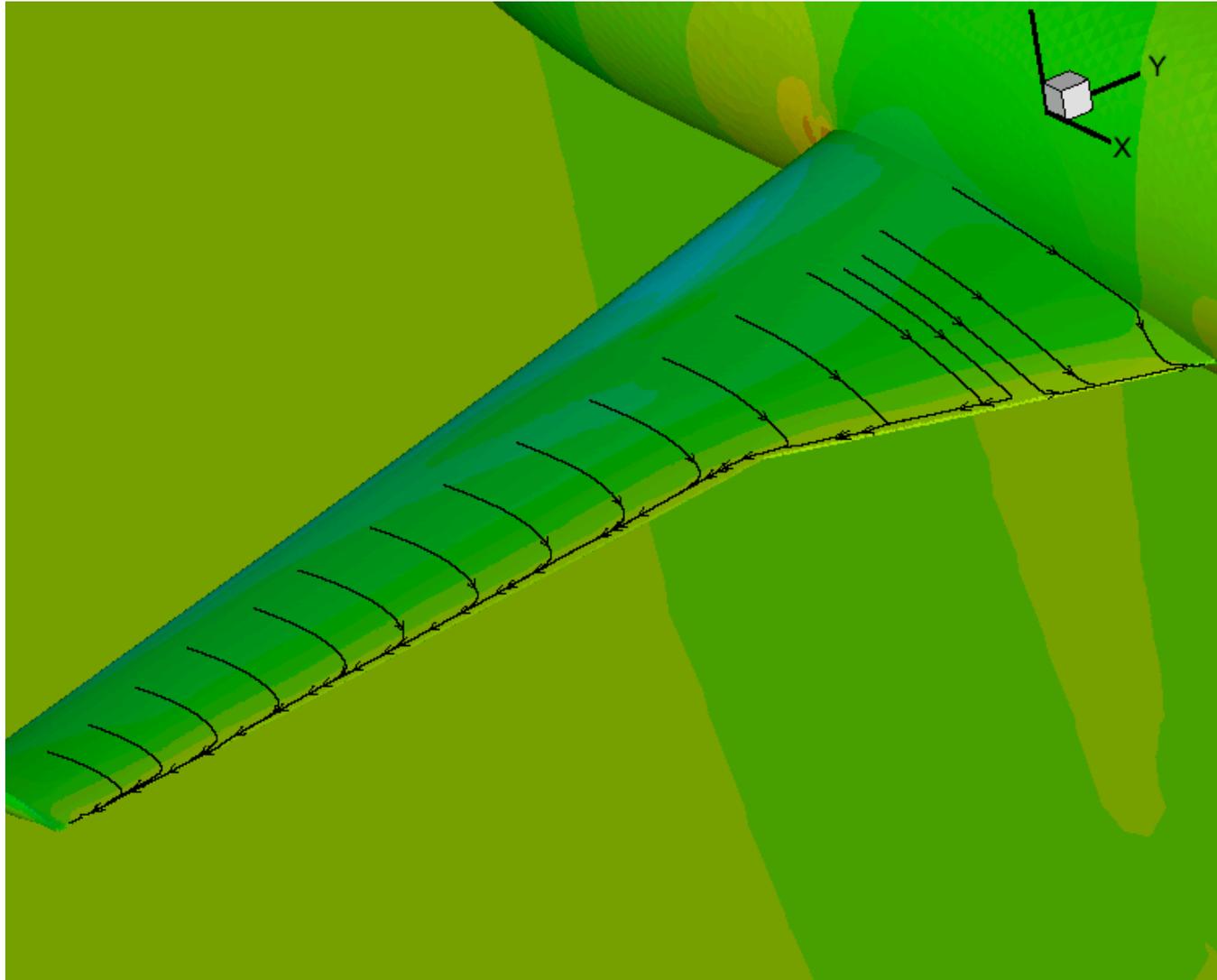
- (Coarse grid : 5M pts)

Grid Convergence (WB+WBF)
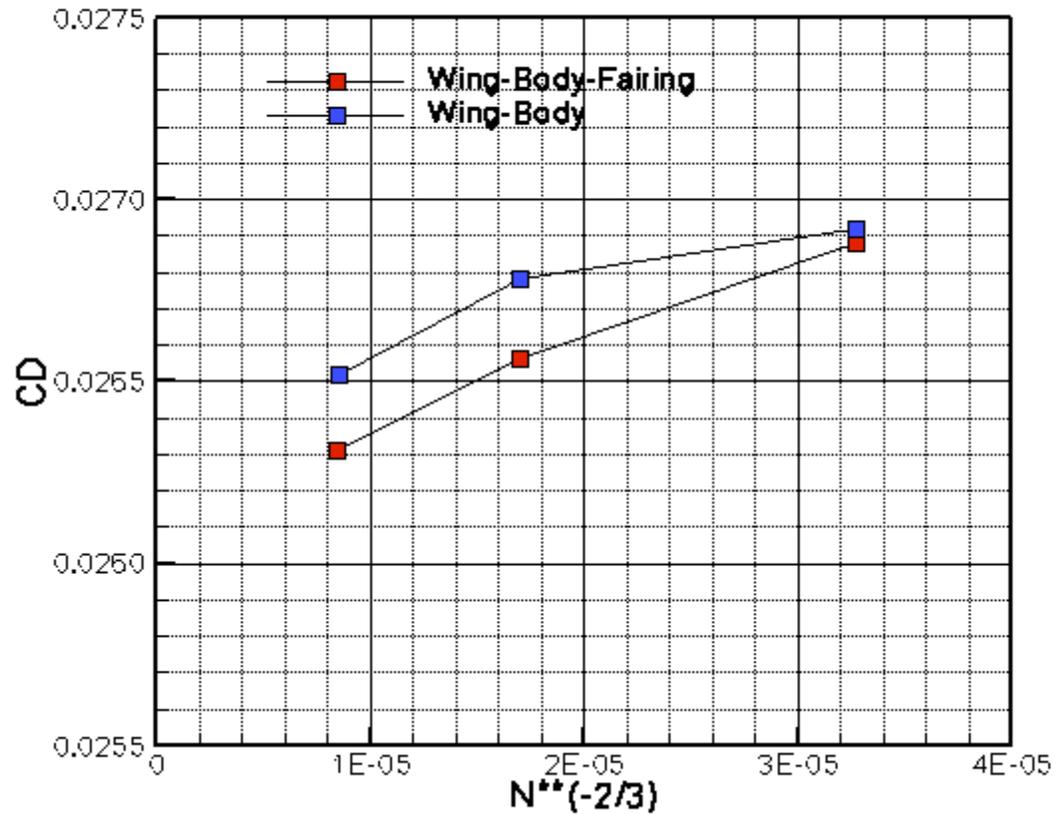
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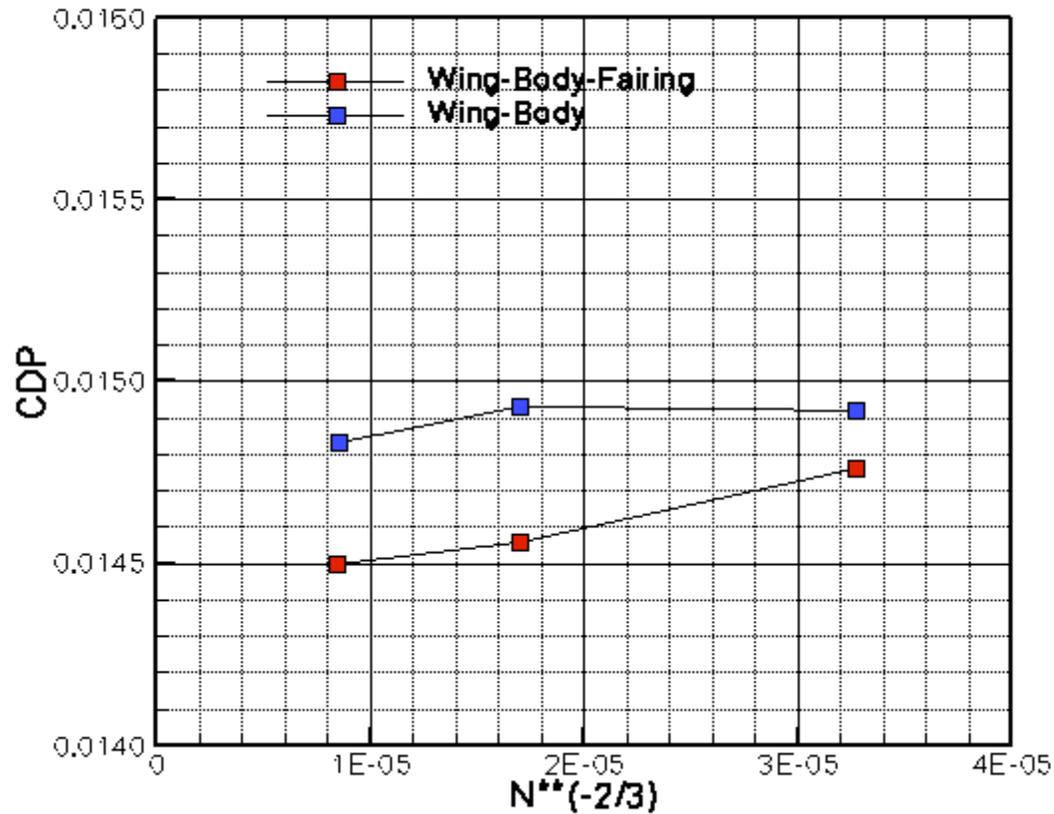
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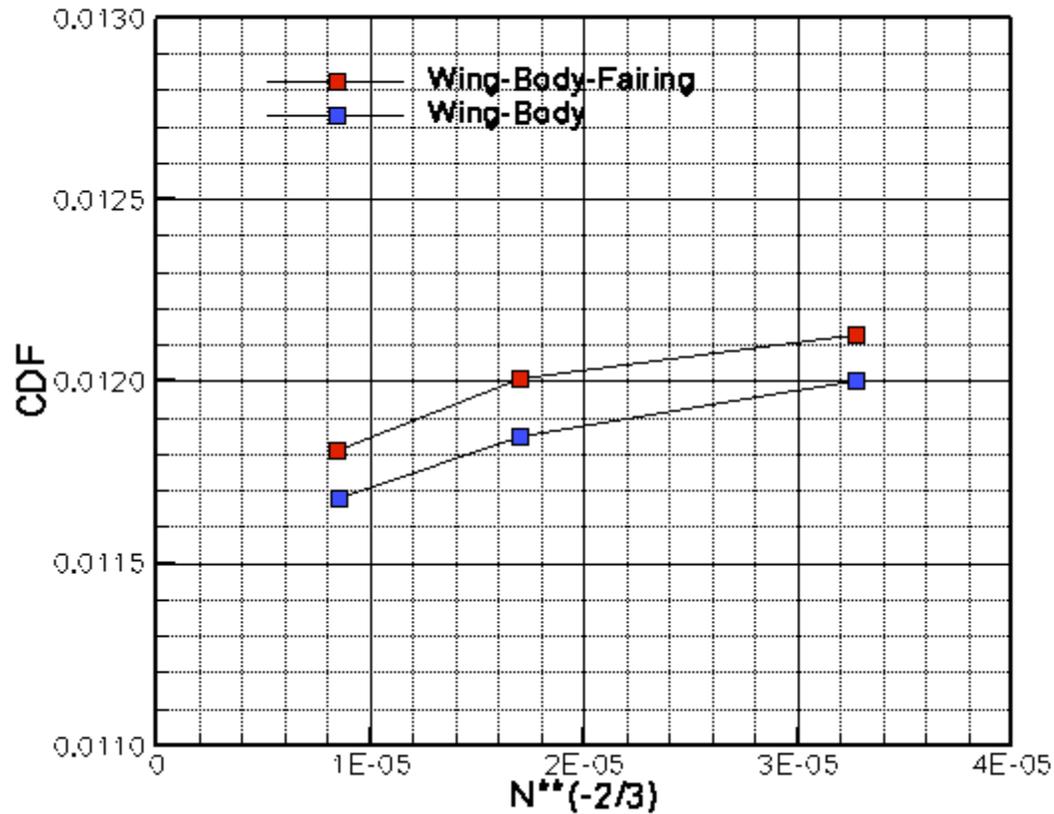
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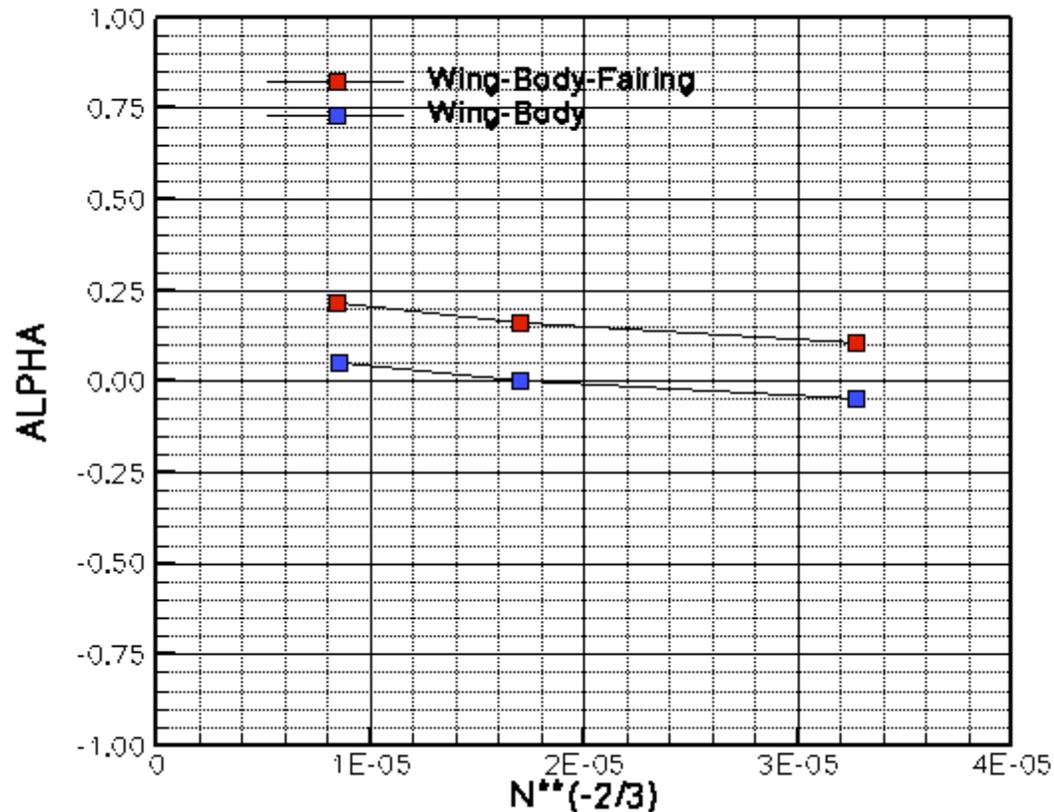
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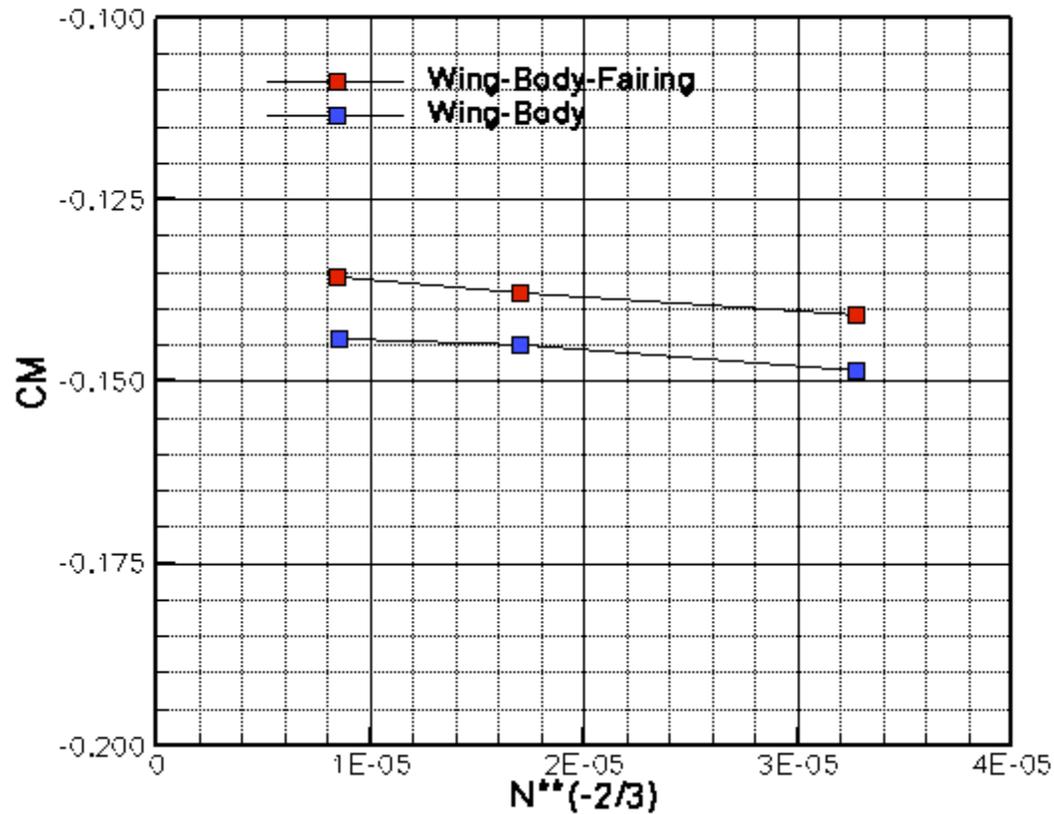
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WBF-WB Differences
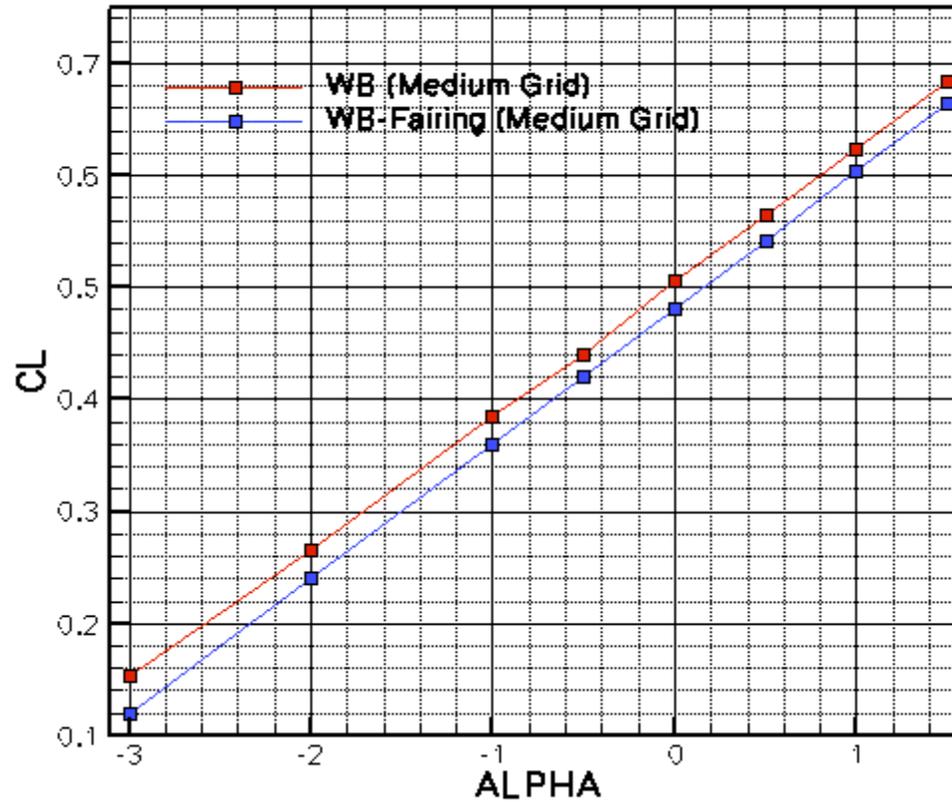
- Medium grid comparisons
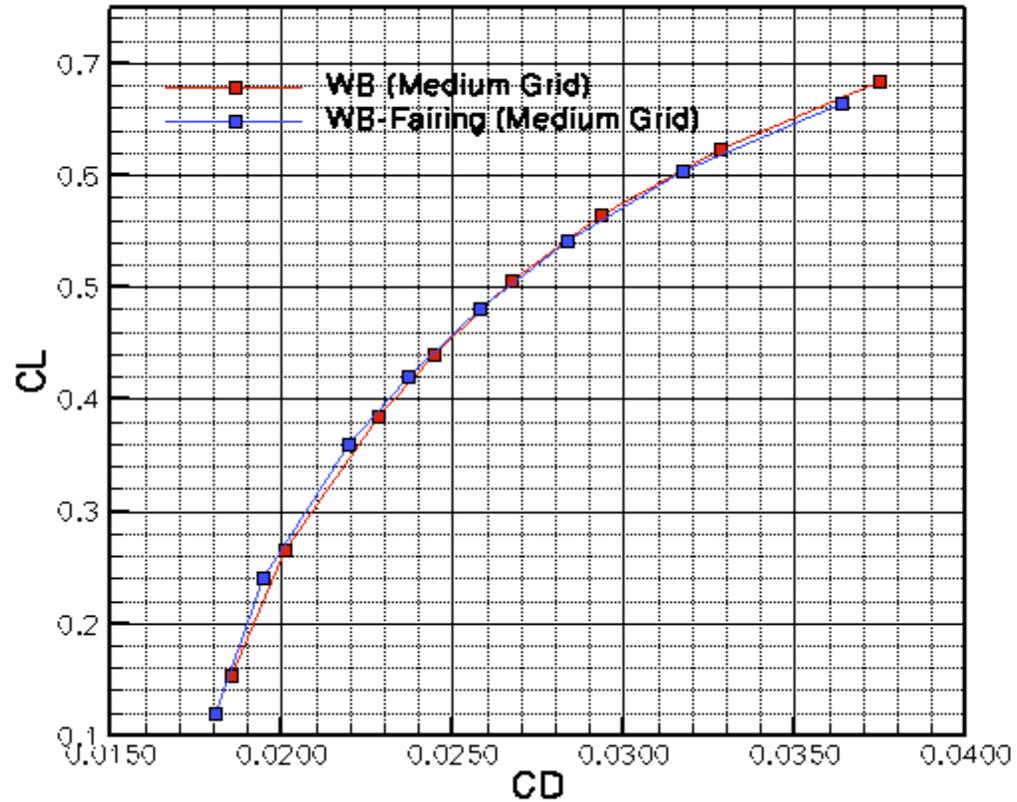
WBF-WB Differences

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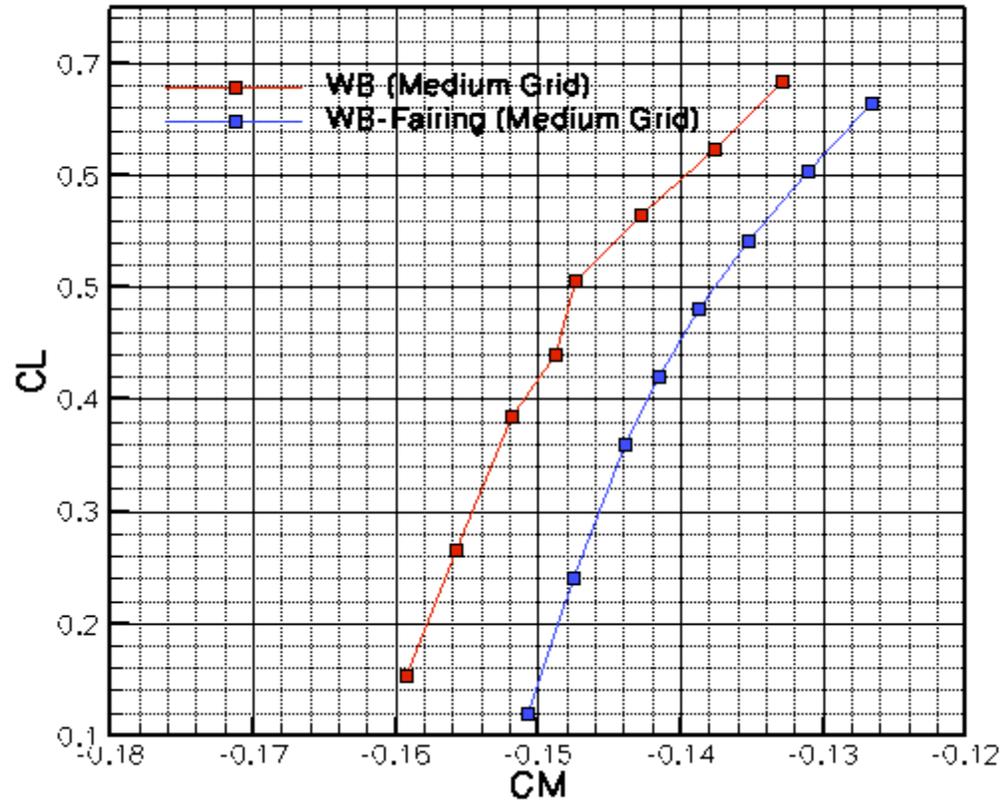
- Medium grid comparisons

Conclusions

- WBF appears to be grid converging
- WB case is complex
  - Previous results showed importance of grid topology
  - New DPW3 grids are once again different
  - Same trends as FUN3D on same meshes (different results)
- WB/WBF delta CD is converging to ~2 counts
- DPW1,2,3 pushing s.o.f of grid resolution
  - DPW1: 1.6M pts
  - DPW2: 3M pts to 10M
  - DPW3: 5M to 40M pts