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TAS Code Results for the Sixth Drag Prediction Workshop

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Outline

- Objective
- Flow Solver: TAS Code
- Case 1: NACA0012 Grids
- Cases 2 & 3: CRM Grids
  - Computational results
  - Comments on grids
- Concluding Remarks

Objective

- Evaluate our unstructured grid solver, TAS Code, with committee-provided grids.
  - Case 1: Verification Study (NACA0012 Airfoil)
    - Grid Family II on TMR
  - Case 2: CRM Nacelle-Pylon Drag Increment
    - unstructured_NASA_GeoLab.REV00
    - Boeing_Babcock_Unstructured_CC.REV00 (as reference)
  - Case 3: CRM WB Static Aero-Elastic Effect
    - unstructured_NASA_GeoLab.REV00
  - No optional test cases

Flow Solver: TAS Code

- TAS (Tohoku Univ. Aerodynamic Simulation) code
  - Originally developed by Nakahashi *et al*.
- Venkatakrishnan's limiter (1995. *JCP*, 118, 120-130.)
  - Constant K = **10**, 5, 1

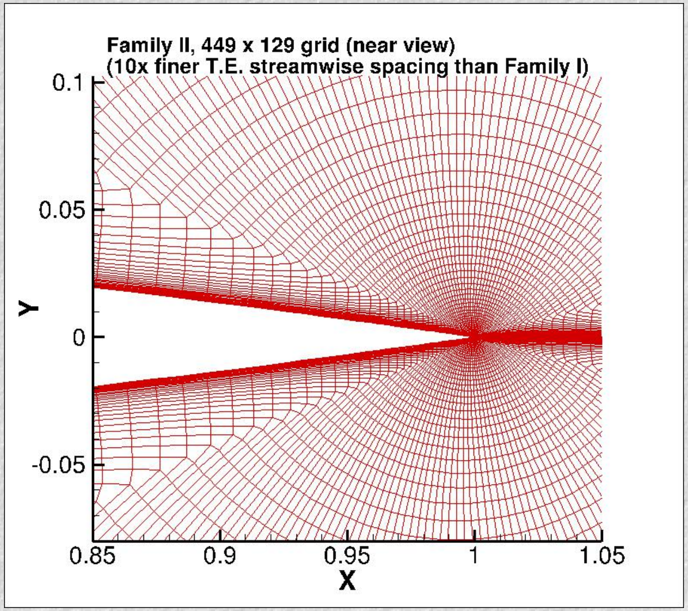
    Less ⟸ Limiter effect ⟹ More
  - 5 is recommended in the paper.

	TAS
Grid type	Unstructured hybrid grids
Discretization	Cell-vertex finite volume
Convection flux	HLLEW 2nd-order with Venkatakrishnan's limiter
Time integration	LU-Symmetric Gauss-Seidel
Turbulence model	SA-noft2 (Case 1) SA-noft2-R(C_{rot}=1)-QCR2000 (Cases 2 & 3)

Yamamoto, *et al.*
AIAA 2012-2895

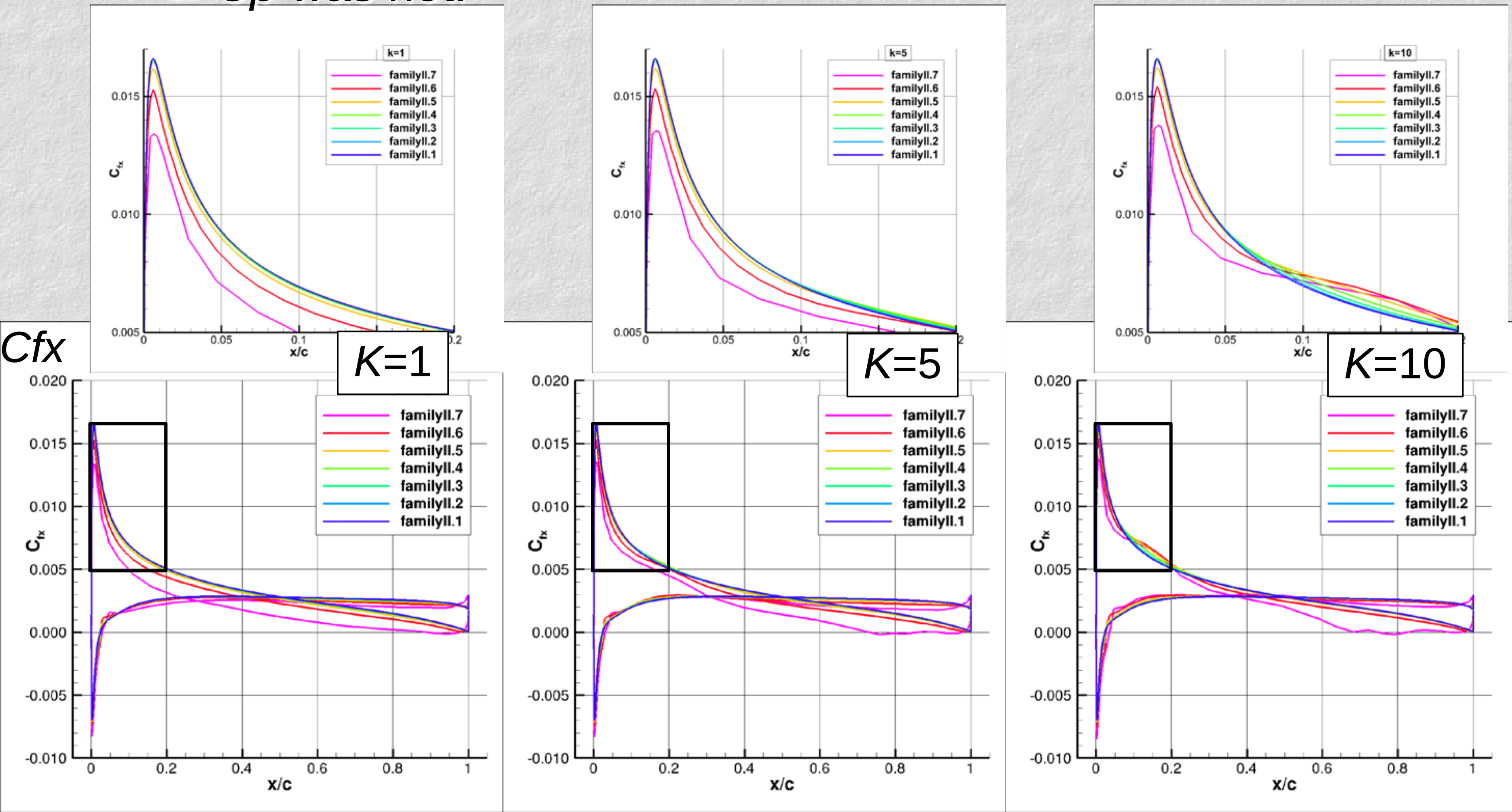
Case 1: NACA 0012 Grids

- Grid Family II http://turbmodels.larc.nasa.gov/naca0012numerics_grids.html
  - 7 structured grids: 1 (Finest) through 7 (Coarsest)
  - Converted to unstructured one-layer hexahedral grids
- Flow condition
  - M_∞ = 0.15, Re = 6M, AoA = 10°
  - Farfield: Dirichlet BC (not Riemann BC)



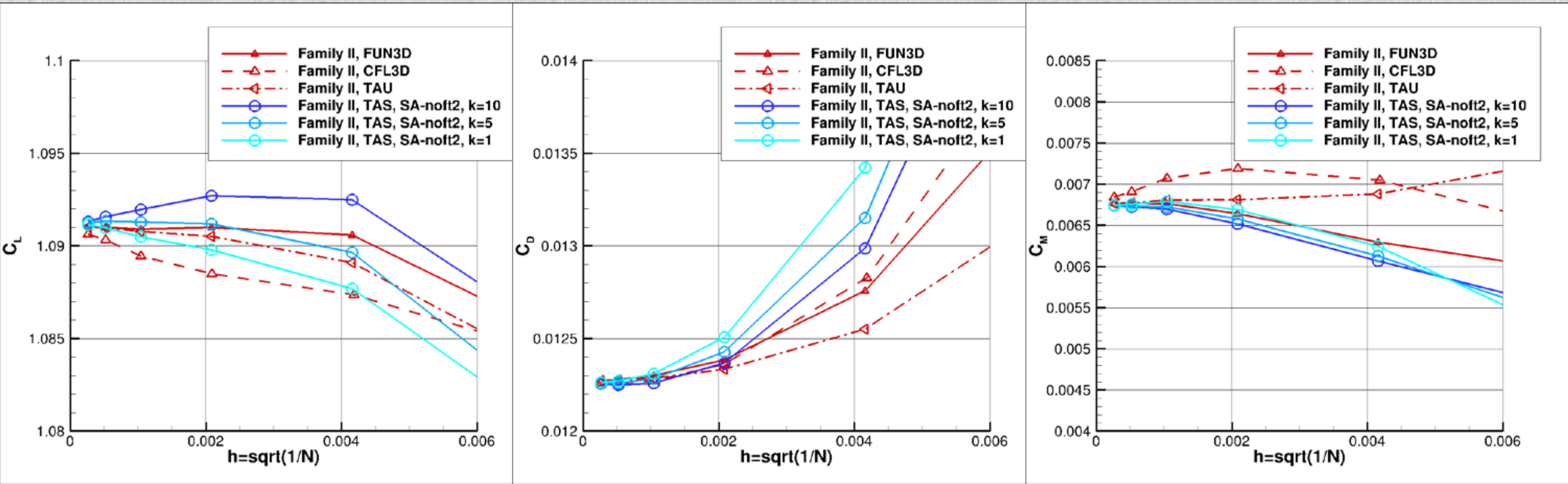
Case 1: *Cfx*

- *Cfx* was sensitive to *K* in Venkatakrishnan's limiter.
  - *Cp* was not.

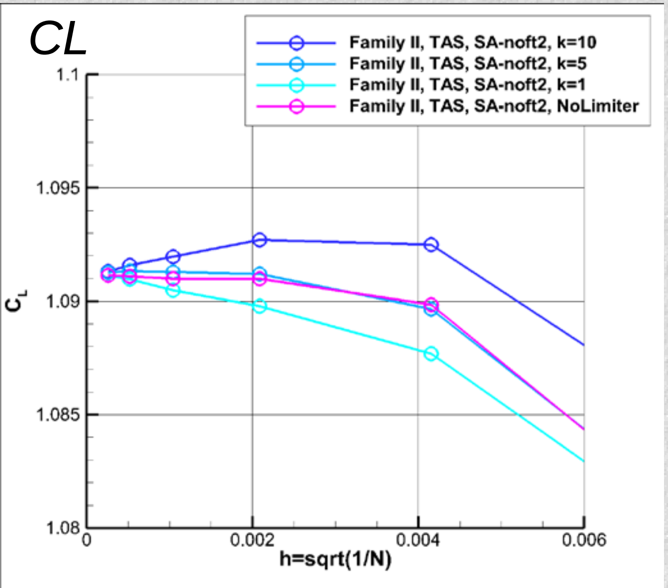


Case 1 Grid Convergence Study

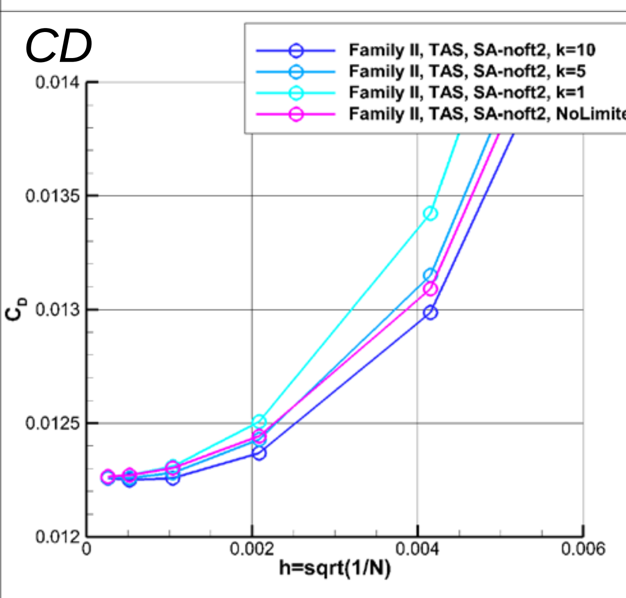
- Compared with results from other solvers, TAS code predicted similar converged coefficients.
- *K* in Venkatakrishnan's limiter created variations when the grids were coarse.

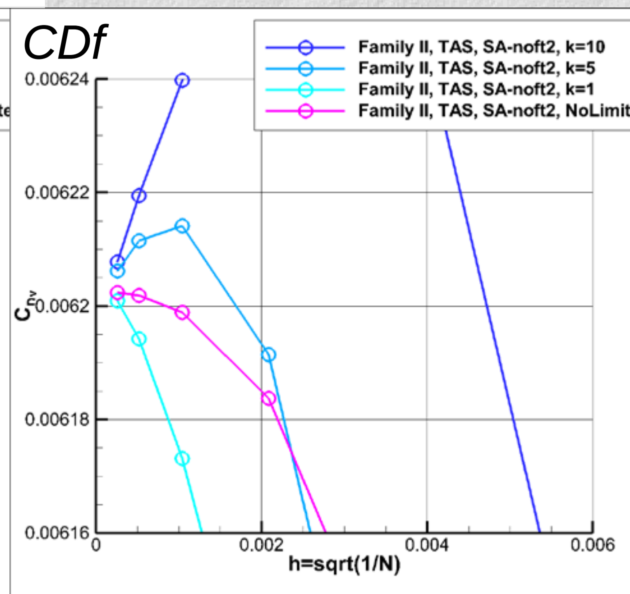


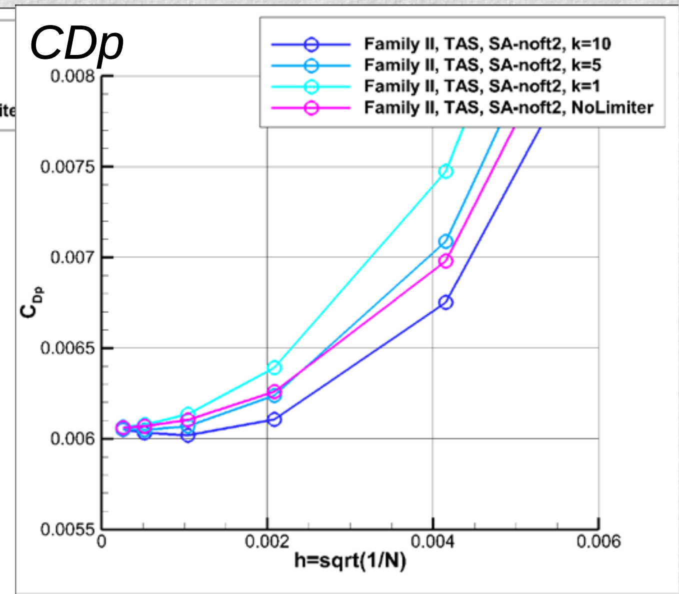
Case 1 Grid Convergence Study: *CL* & *CD*



- Compared with no limiter case, *CL* and *CD* predicted with *K* = 5 converged similarly.







Cases 2 & 3: CRM Grids

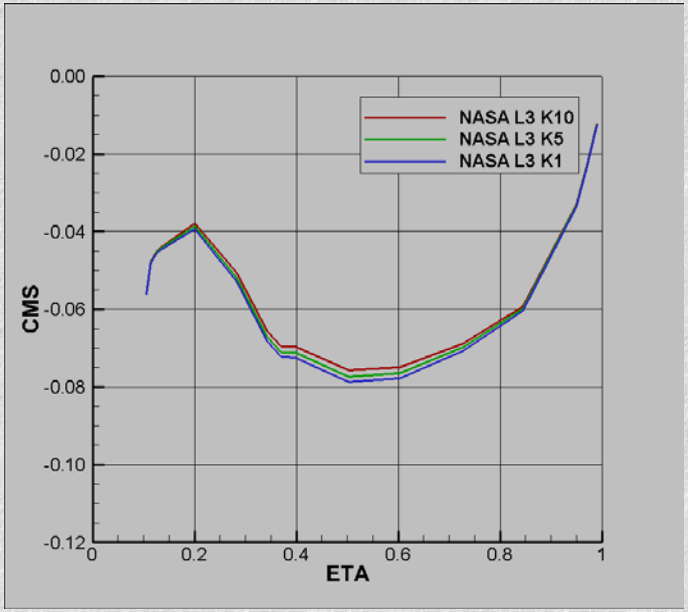
- Two unstructured grid families were used for WB & WBNP configurations
  - unstructured_NASA_GeoLab.REV00
    - Except WBNP Ultra-Fine due to limitation in grid partitioning
  - Boeing_Babcock_Unstructured_CC.REV00 (as reference)

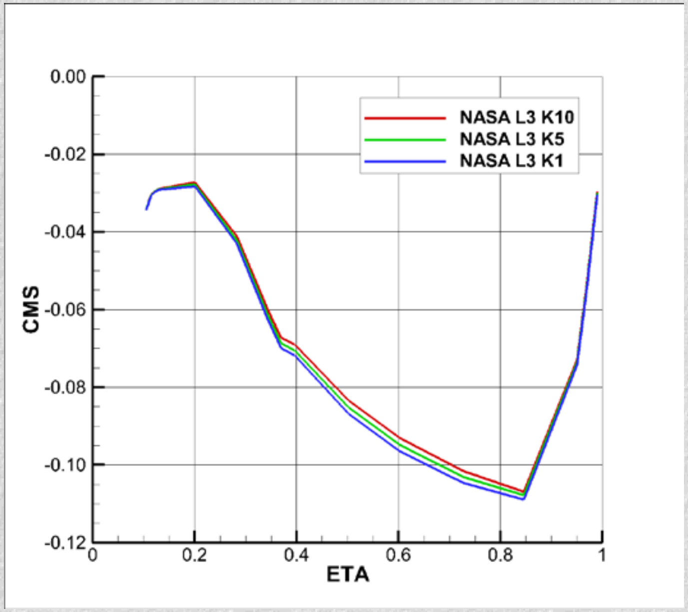
# nodes (million)	**NASA** GeoLab		**Boeing** Babcock	
	WB	WBNP	WB	WBNP
Tiny	20	28	8.0	Not used
Coarse	30	41	10	
Medium	44	61	13	
Fine	66	91	17	
eXtra fine	101	138	22	
Ultra fine	151	~~209~~	28	

Correction – Case 2A CMS

- The method to calculate CMS in our submitted data (sectional lift and moment) was incorrect.

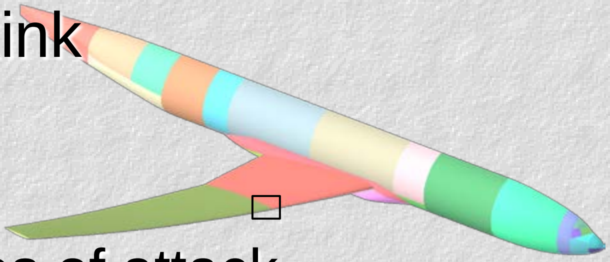
Medium Grid Case

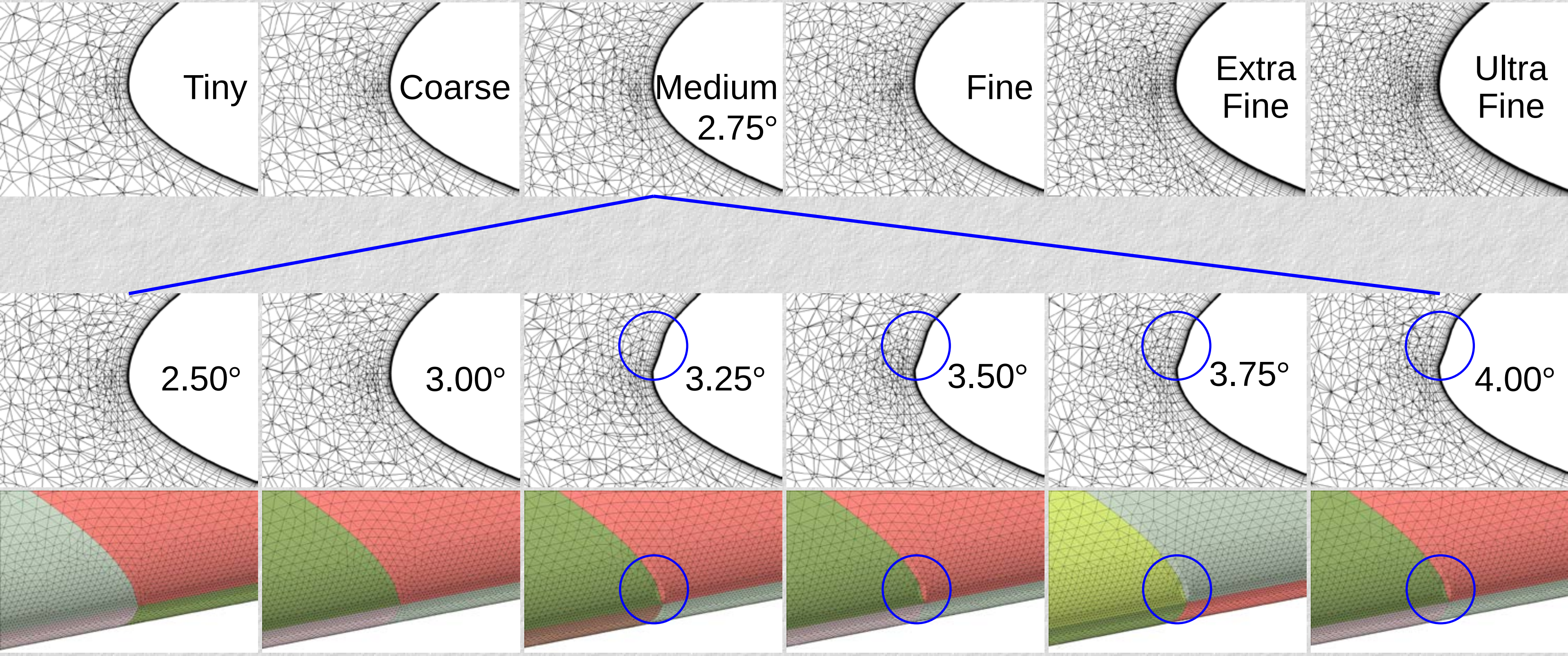




NASA GeoLab WB Grid Family (1)

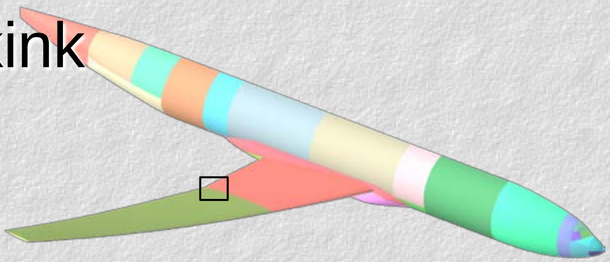
- Cross-sections around LE through the kink
  - Dense surface grids
  - Relatively a small # of prismatic layers
  - Dents on medium grids for several angles of attack

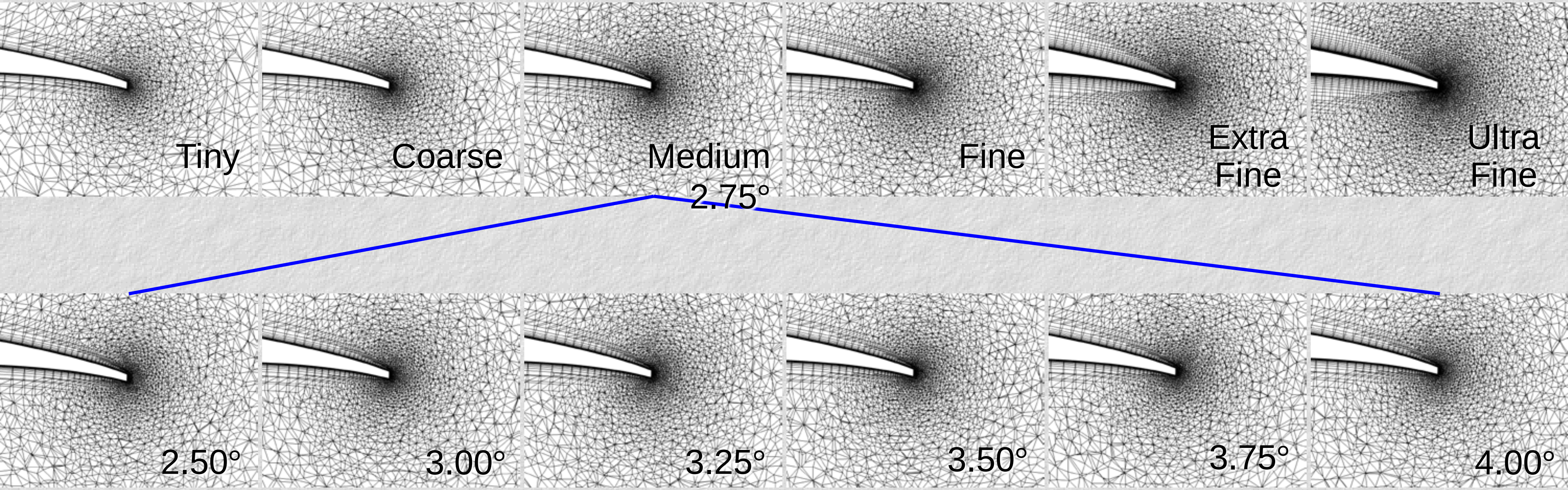




NASA GeoLab WB Grid Family (2)

- Cross-sections around TE through the kink

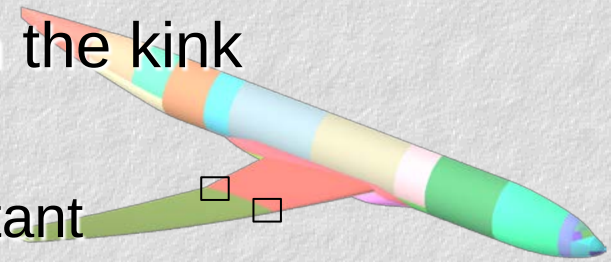


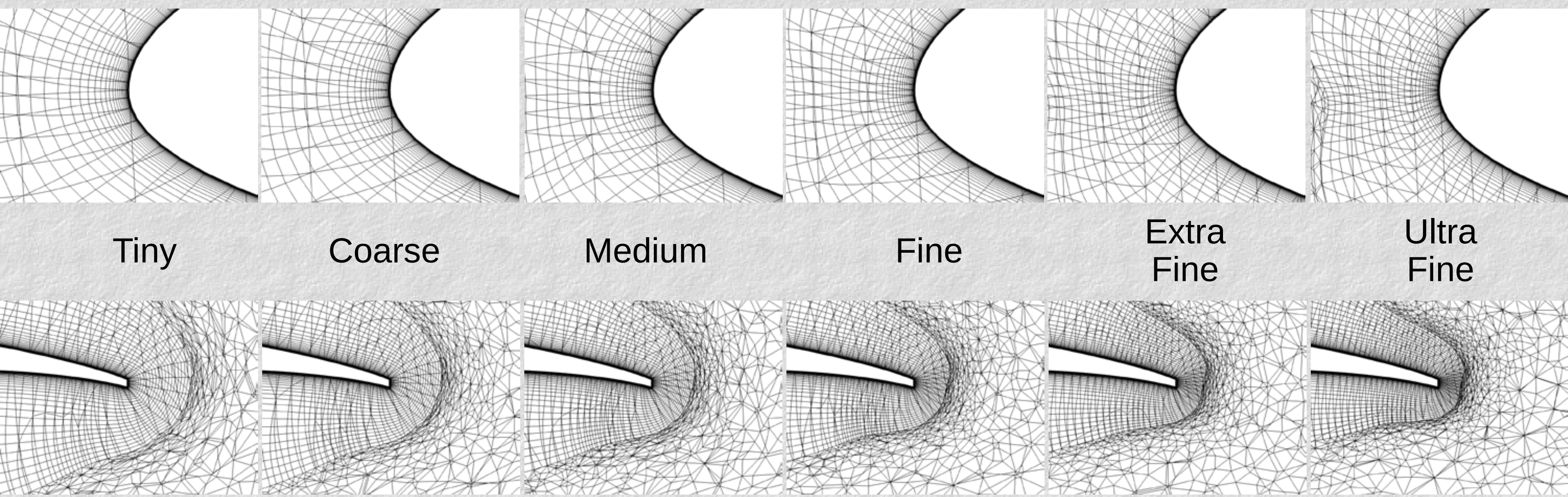


- Small # of extreme slivers close to TE in several grids were fixed to properly run TAS code.

Boeing Babcock Grid Family

- Cross-sections around LE & TE through the kink
  - A large # of prismatic layers
  - The # of prismatic layers is almost constant
- Only grid convergence study with this Boeing WB grid family.

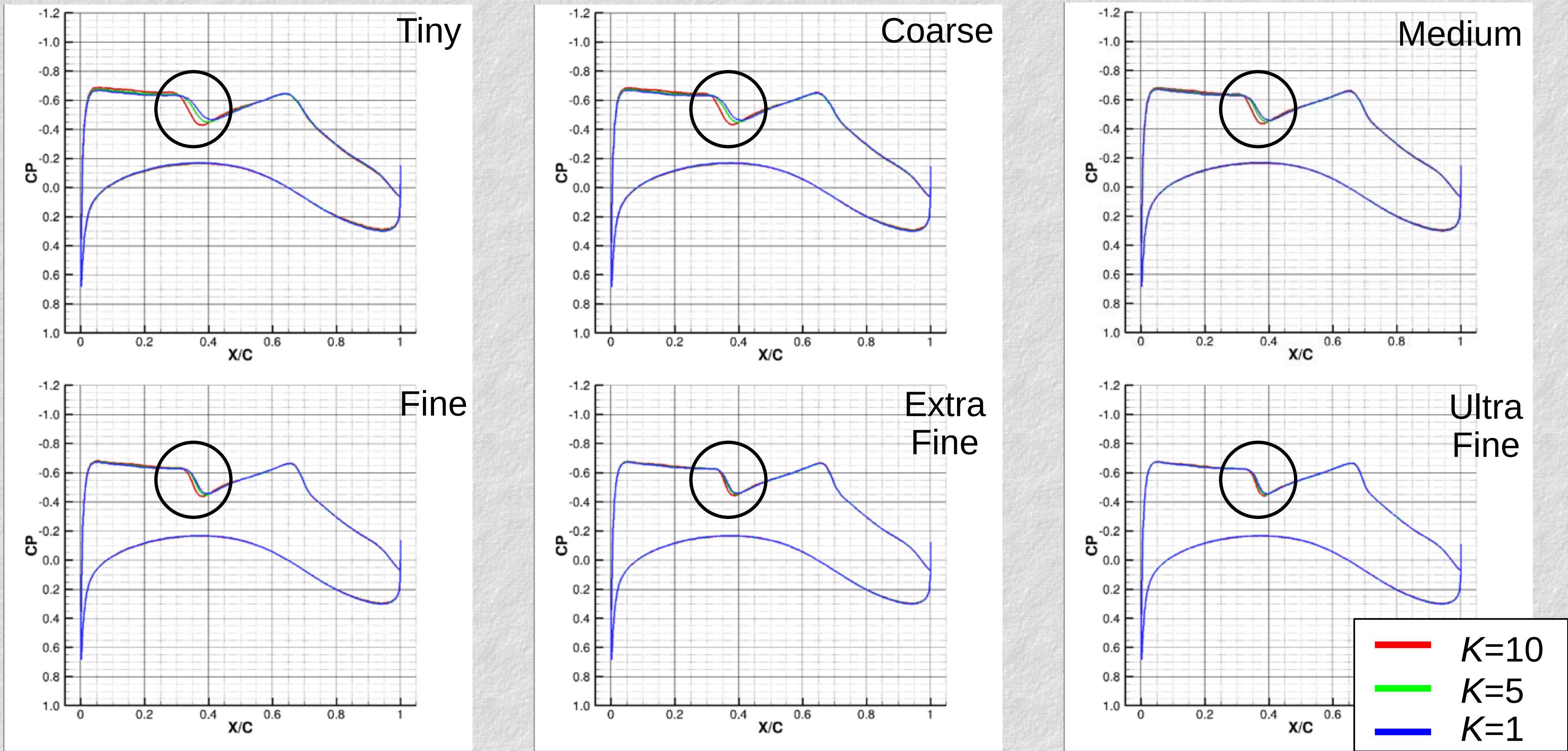




Case 2 Grid Convergence Study: *Cp*

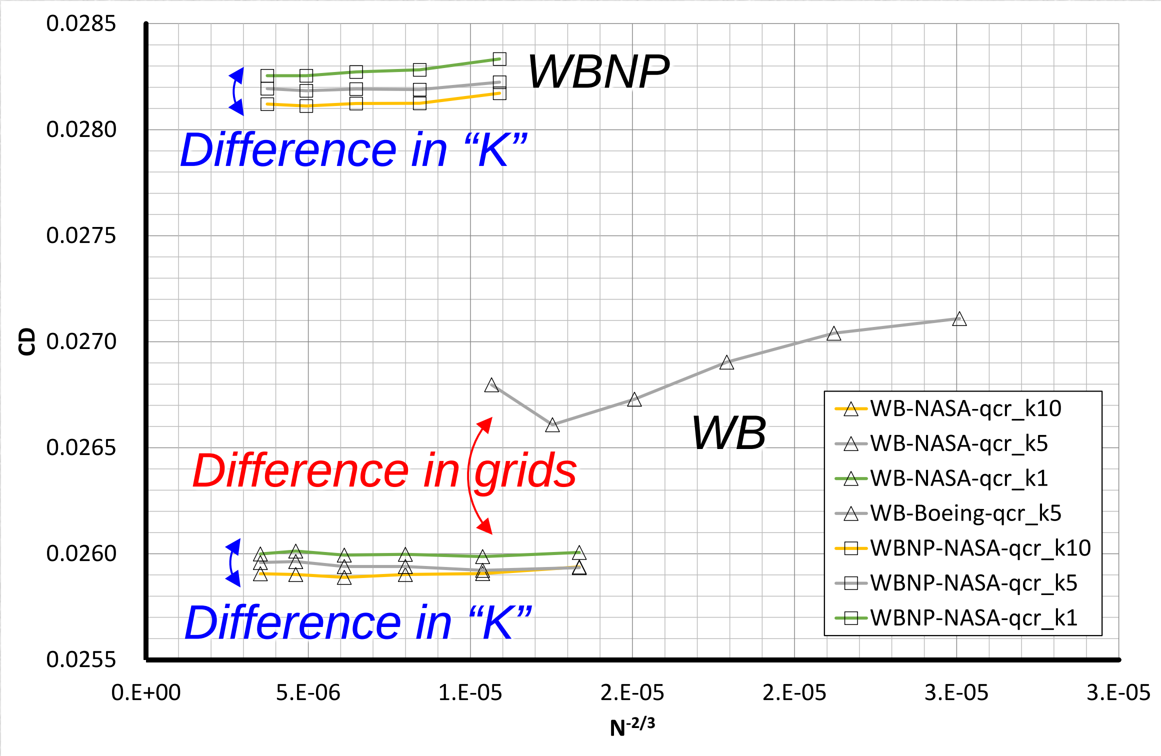
η = 0.8456

- *K* in Venkatakrishnan's limiter affected the shock location especially when the grids were coarse.
- *K* = 5 appeared to provide the most consistent result.



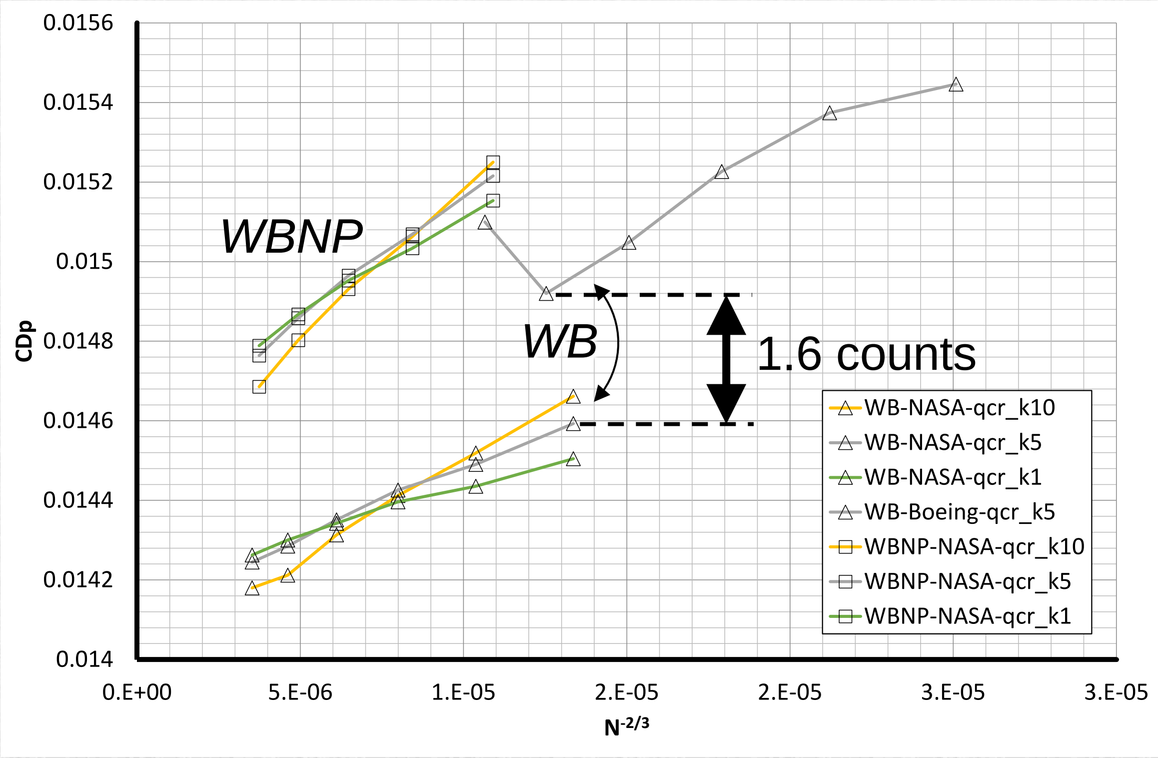
Case 2 Grid Convergence Study: *CD*

- *K* in Venkatakrishnan's limiter affected CD by 1-2 counts.
- The two grid families provided different results for the WB case.



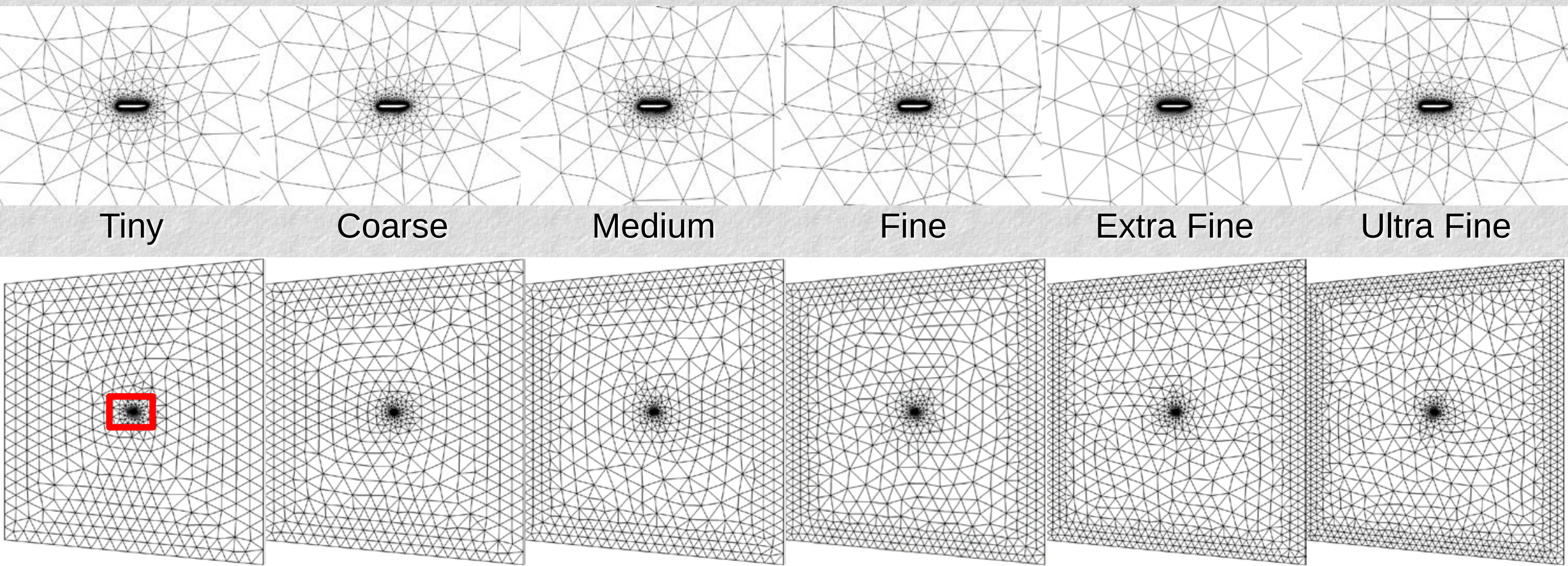
Case 2 Grid Convergence Study: *CDp*

- Boeing Ultra-Fine grid showed a different trend.
- Boeing Extra-Fine & NASA Tiny grids were similar in size, but produced a difference in drag count.
  - Due to relatively coarse tetrahedra around CRM in the Boeing grid family.



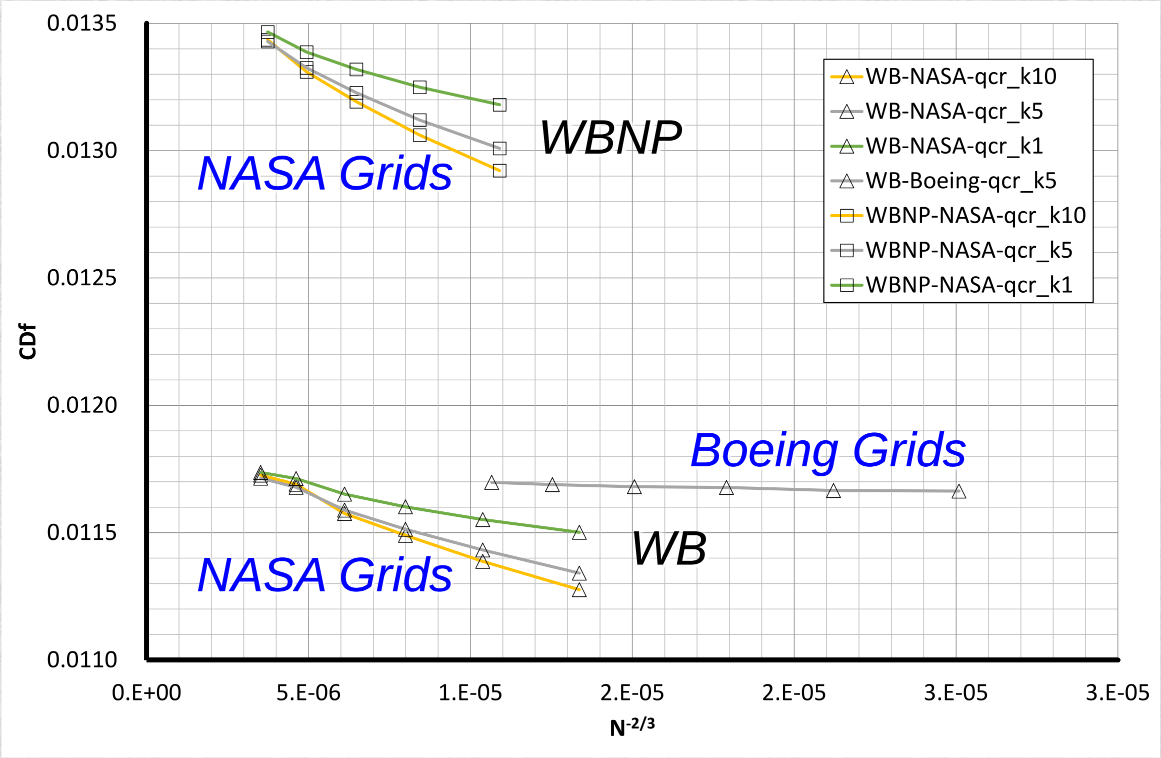
Boeing Grids on Symmetry Plane

- To check the size of tetrahedra, surface grids on the symmetry plane were visualized.
- Grid density was controlled on the CRM and the farfield boundary, but was not well controlled in the middle.
  - The Ultra-Fine grid still had relatively coarse tetrahedra.



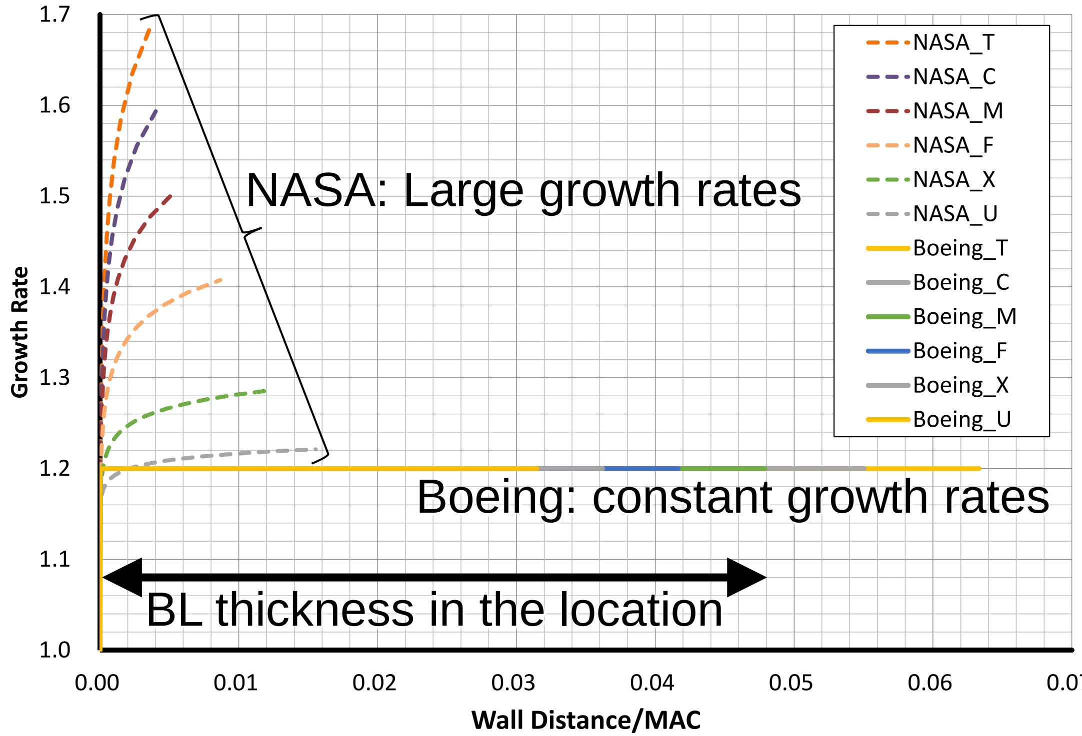
Case 2 Grid Convergence Study: *CDf*

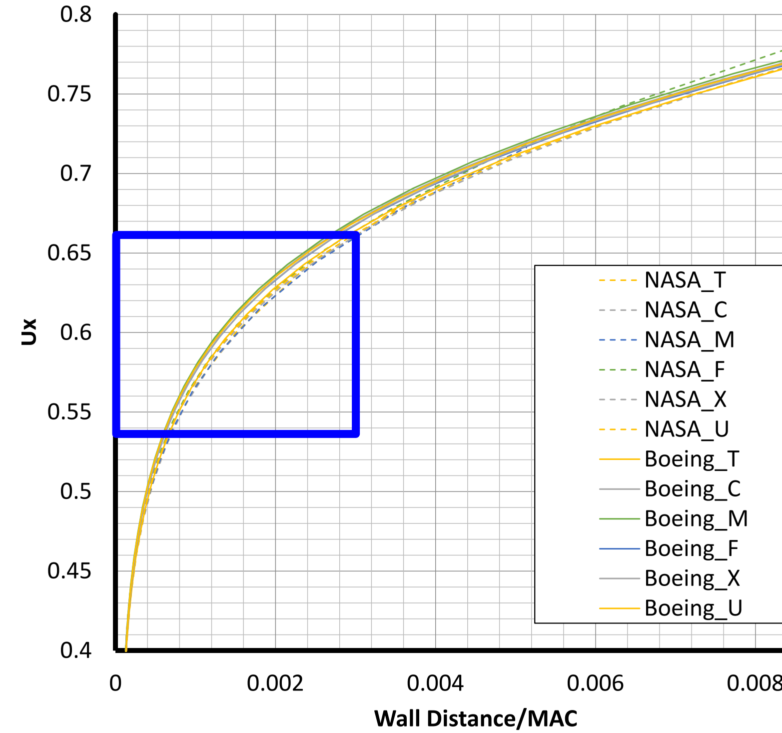
- CDf estimated by TAS code with SA was usually not sensitive to grid density, but a different trend was observed with the NASA grids.
  - Due to unexpected growth rates for the near-field grids.



Prism Growth Rates & Ux

- To check boundary layer profile in the near-field grids, nodes with the same coordinates on the junction of the fuselage and the symmetry plane were selected.
  - According to the Gridding Guidelines, “Growth Rates < 1.2X Normal to Viscous Walls”
  - The large growth rates of the NASA grids made the friction drag by TAS code grid dependent.





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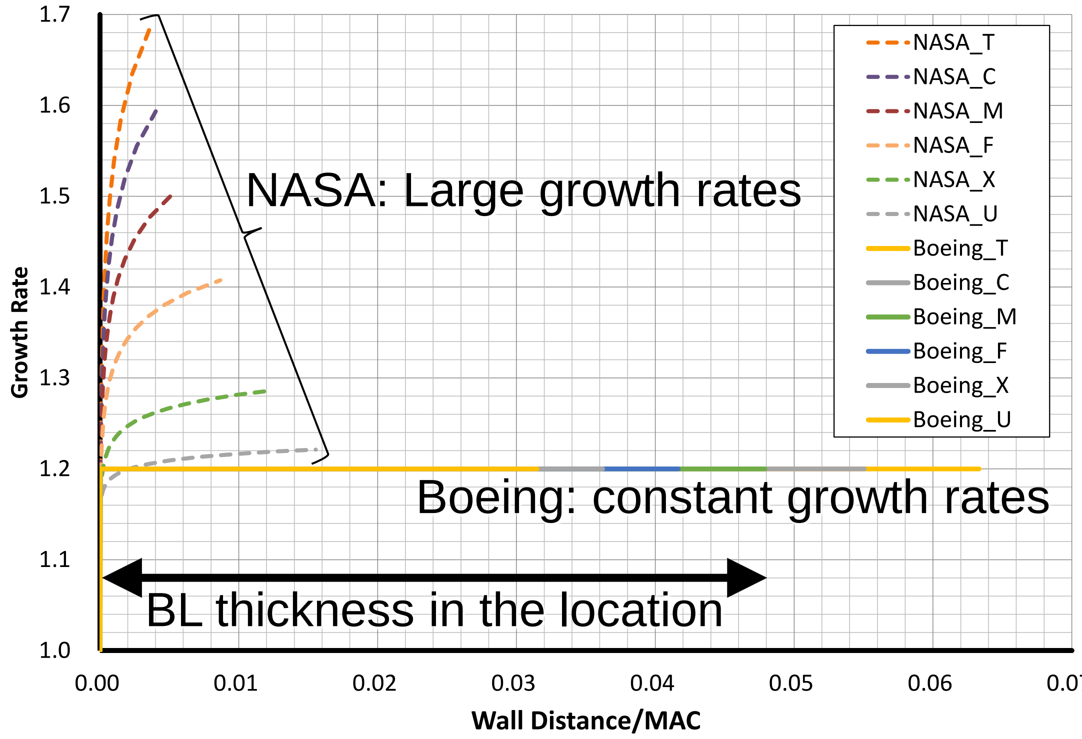
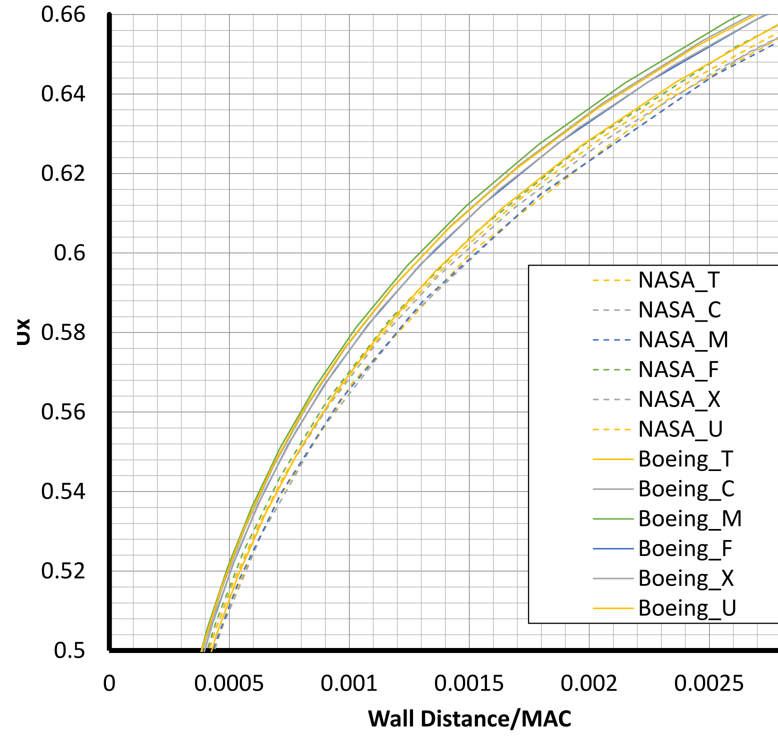
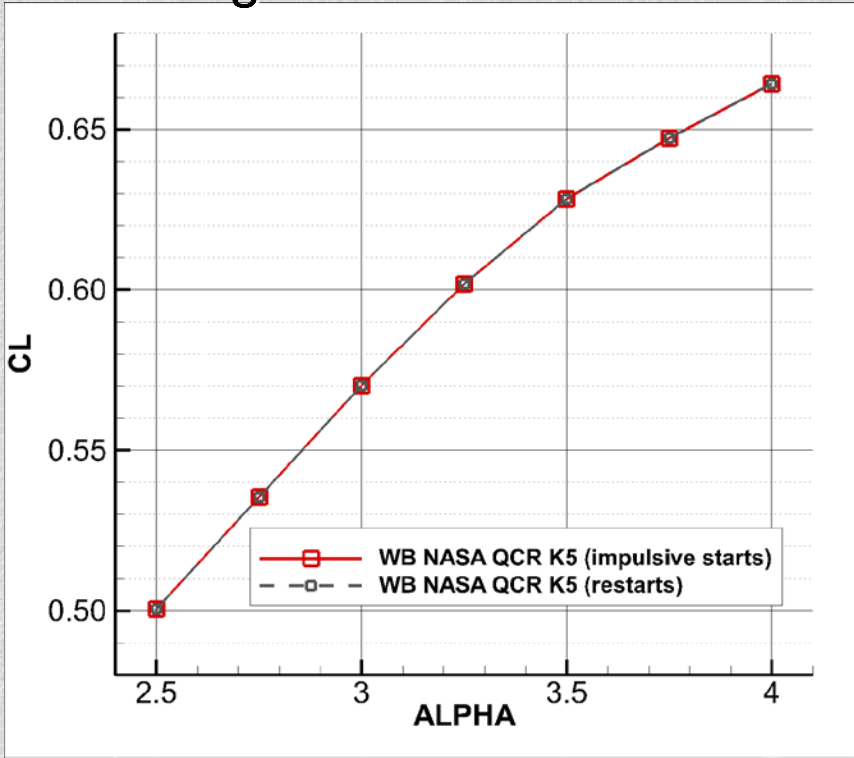


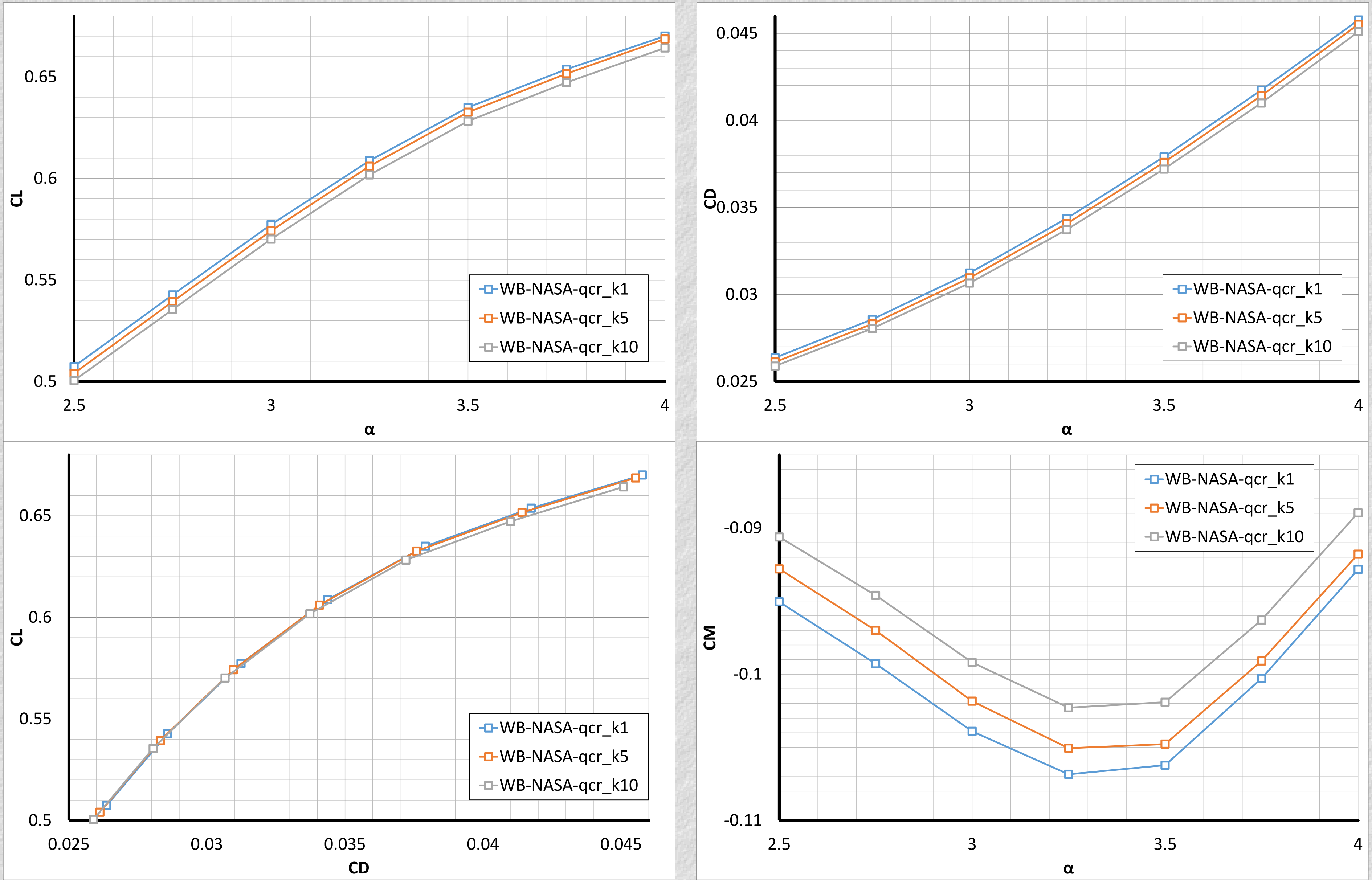


Case 3: α Sweep

- To perform α sweep, there is a set of grids that do not have the same element connectivity.
  - Should we restart a CFD simulation based on a solution at a lower α (= 2.75°) even for this case?
  - Can we use an impulsive start for each grid?
- For NASA WB grids, the two approaches gave almost the same result.
  - Impulsive starts were selected for other cases.

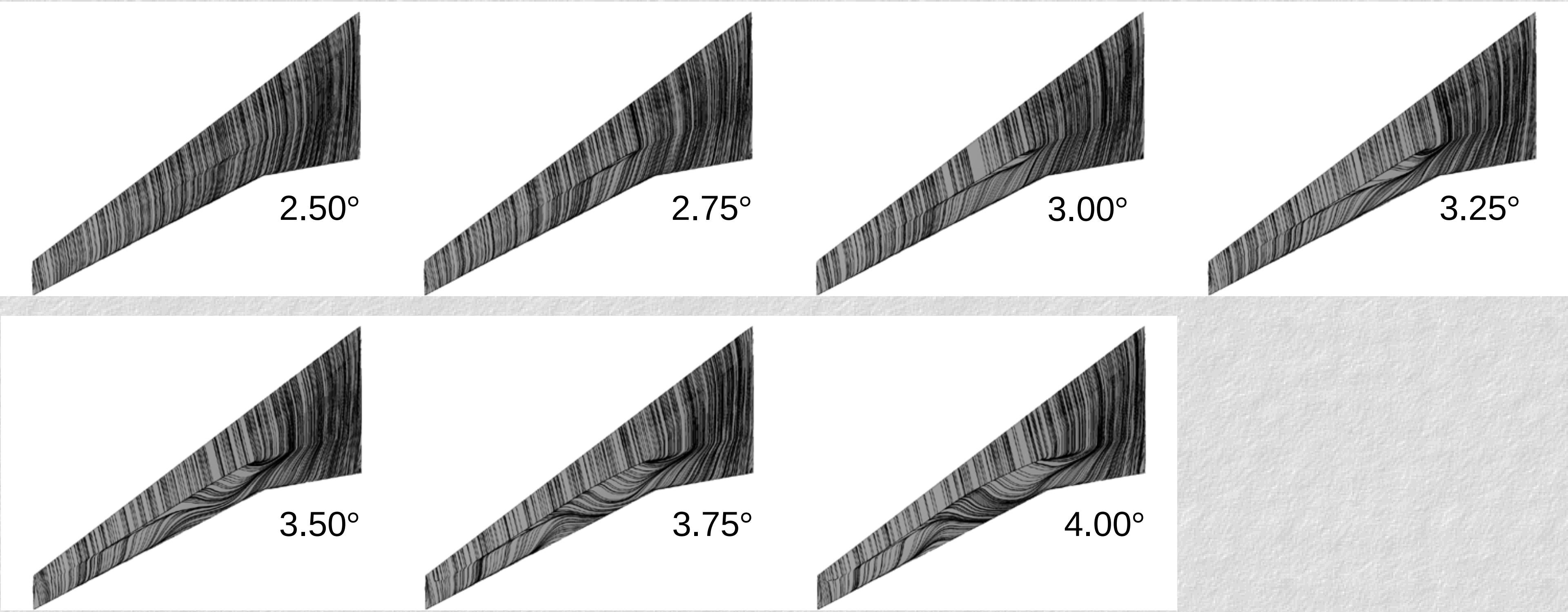


Case 3: Result of α Sweep



Surface Stream Lines

- No significant side-of-body separation found on the wing upper surface.



Concluding Remarks

- In Case 1, *K* in Venkatakrishnan's limiter was evaluated by using three constants, 10, 5 and 1.
  - *K* = 5 recommended in the original paper was the best.
- In Cases 2 & 3, grids had a great impact on TAS code in terms of prism growth rates & farfield grid density.
  - We will generate our own grids and run TAS code to see if a difference is found in the grid convergence study.
- Impulsive starts and restarts based on a solution at α = 2.75° gave almost no difference.