# FaSTAR Results of Sixth Drag Prediction Workshop

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Kenji Hayashi, Keiji Ueshima (Ryoyu Systems)

# Summary of FaSTAR results

- Flow Solver : FaSTAR (unstructured-grid solver)

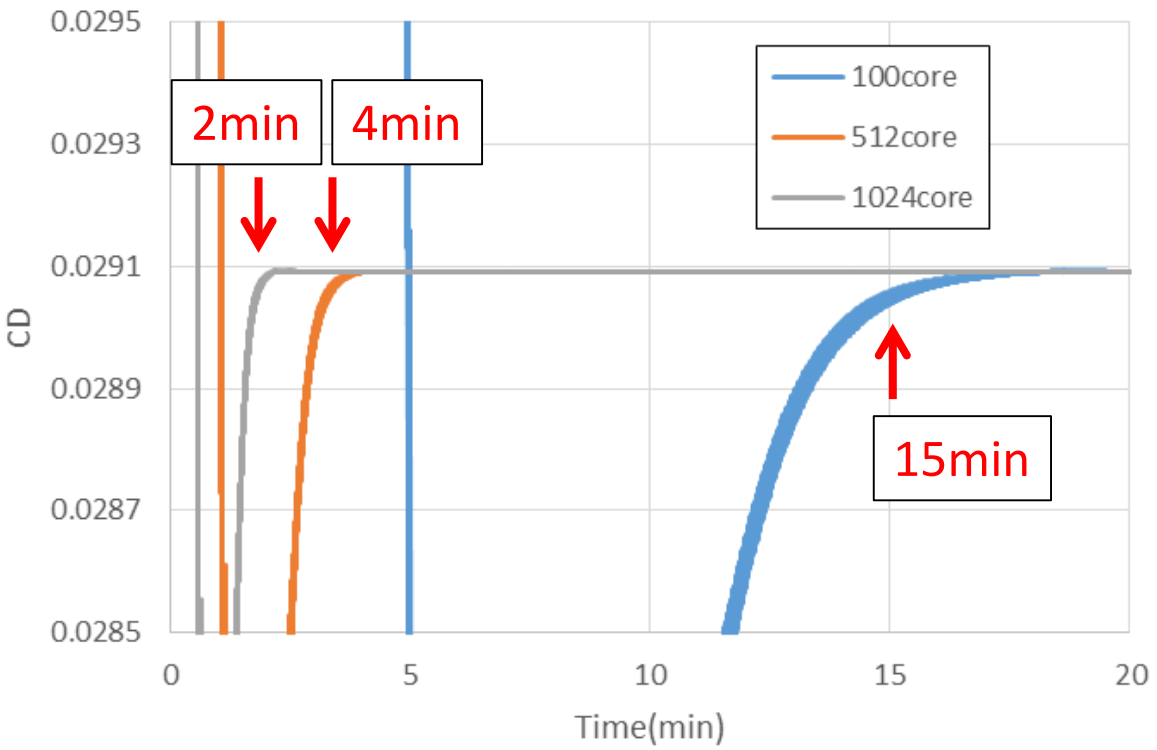
- Results
  - **Case 1: Verification Study of 2D NACA0012 airfoil**
    - Grid: Family II
    - Turbulence model: SA
    - Discretization: Cell-center/Node-center
  - **Case 2: CRM Nacelle-Pylon Drag Increment**
    - Grid: unstructured_NASA_GeoLab.REV00
    - Turbulence model: SA-noft2-R-QCR2000
    - Discretization: Node-center
  - **Case 3: CRM WB Static Aero-Elastic Effect**
    - Grid: unstructured_NASA_GeoLab.REV00
    - Turbulence model: SA-noft2-R-QCR2000
    - Discretization: Node-center

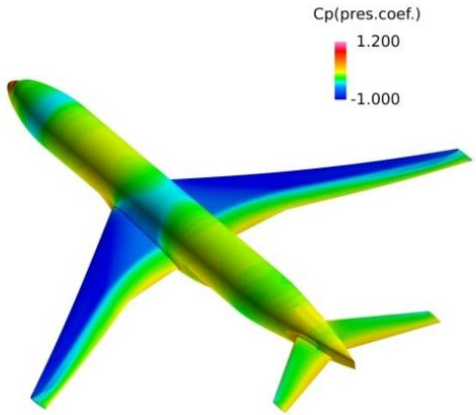
# Computational Scheme

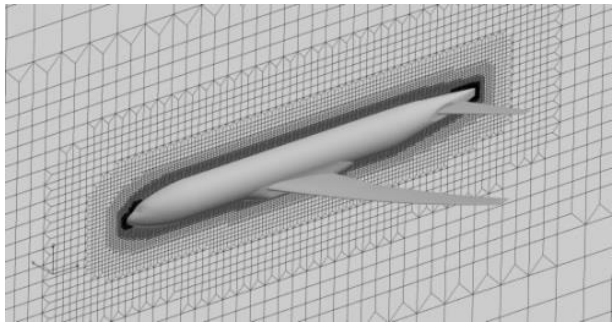
- Full compressible Navier-Stokes equations with the Spalart-Allmaras model
- Finite volume method (FVM)
- HLLEW for inviscid flux
- U-MUSCL reconstruction
- GLSQ for gradient computation
- van Leer-type Hishida limiter
- LU-SGS for time integration
- Wall distance code of TAS

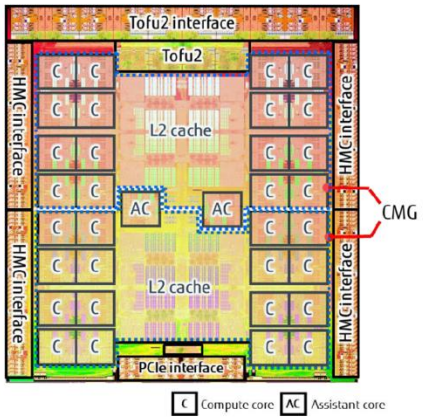
# Computational time with JSS2

JSS2, Fujitsu FX100 100, 512, 1024 cores,
Medium grid (10M) , Multigrid



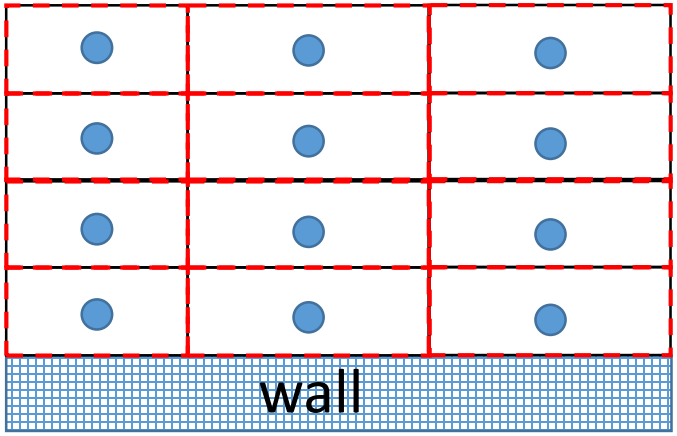





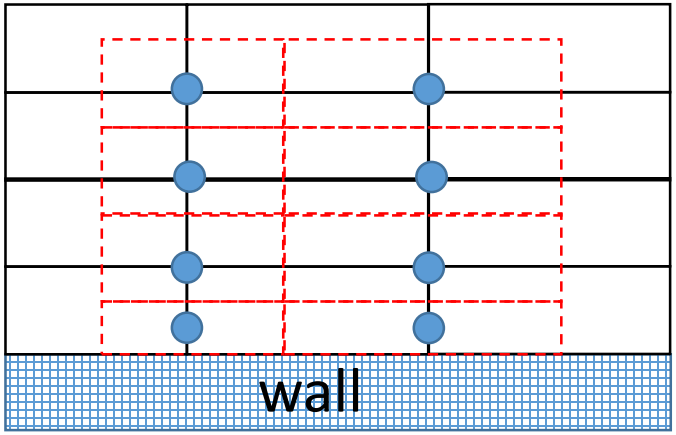

FaSTAR can compute aerodynamic forces in 2 minutes with 10M grid and 1024 CPU cores of JSS2.
1024cores(=32CPUs) are only 1% of the total system.

# Cell center/ Node center

- Both cell-center and node-center discretization methods are supported in FaSTAR
  - Solver is common, but pre/post are different
  - Only neighboring cell information is stored. We switch the discretization method due to the grid type (tetra or hexa)
  - Cell-center method was used for DPW5 problems. We validate node-center method for DPW6 problems.




Cell center




Node center

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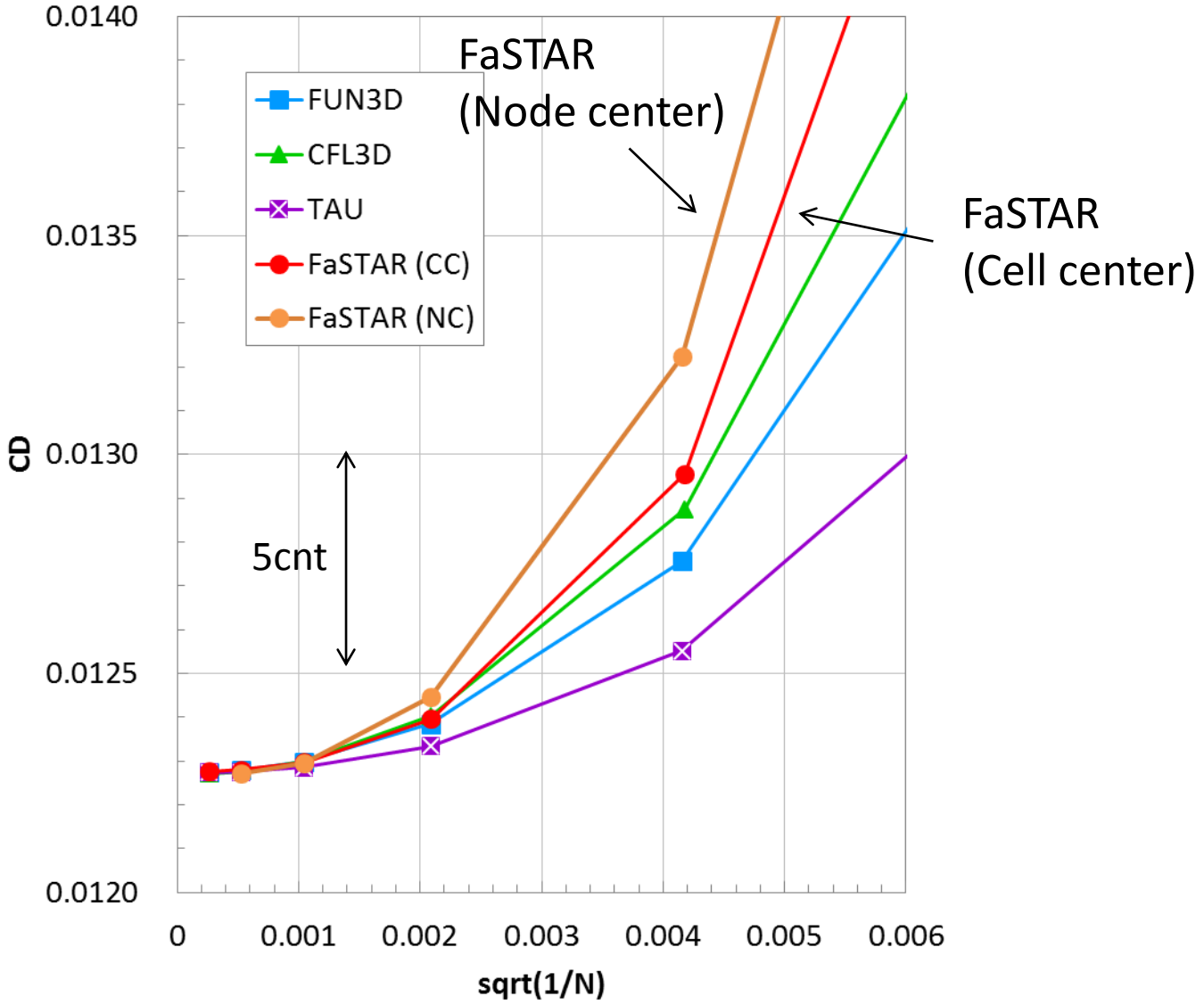
# Grid convergence of $C_D$



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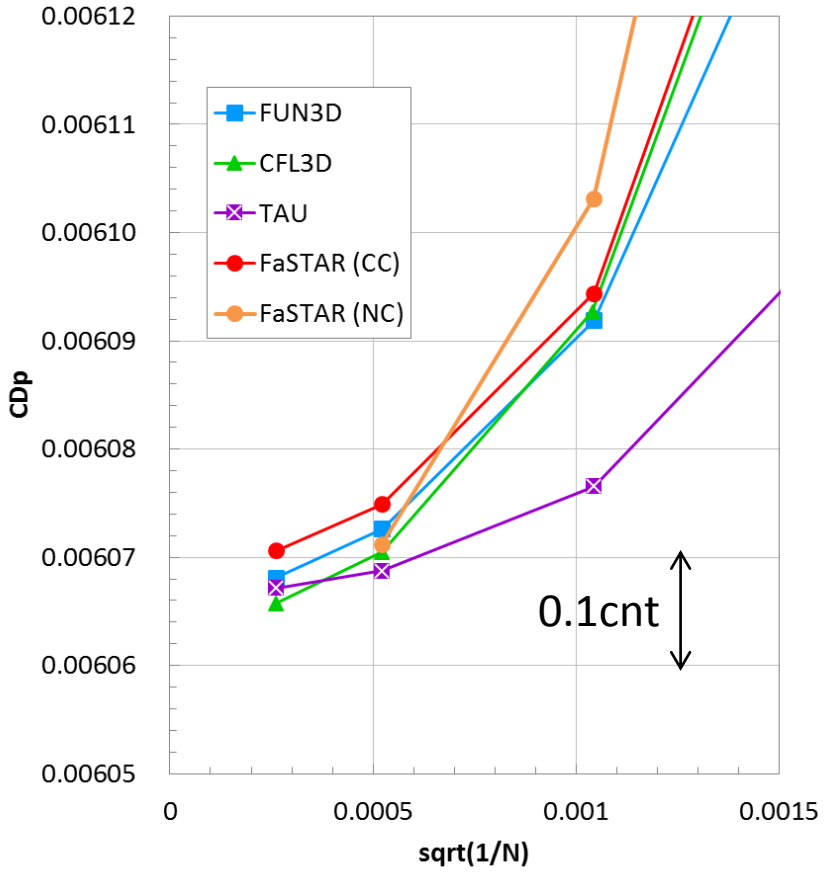
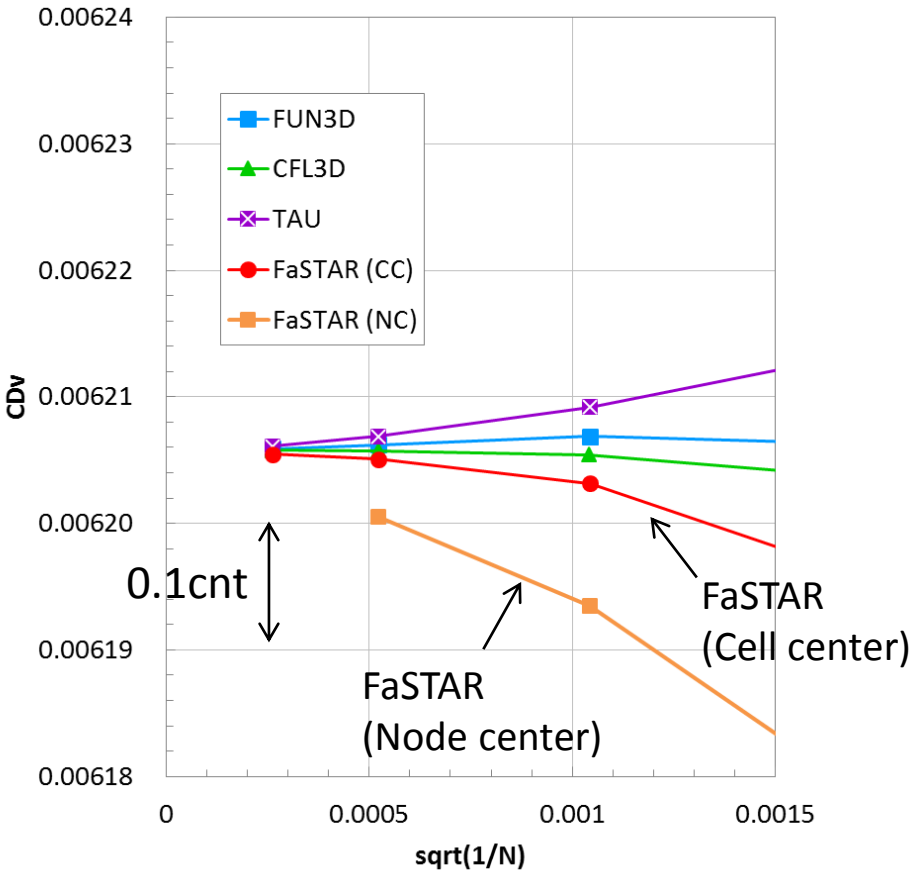
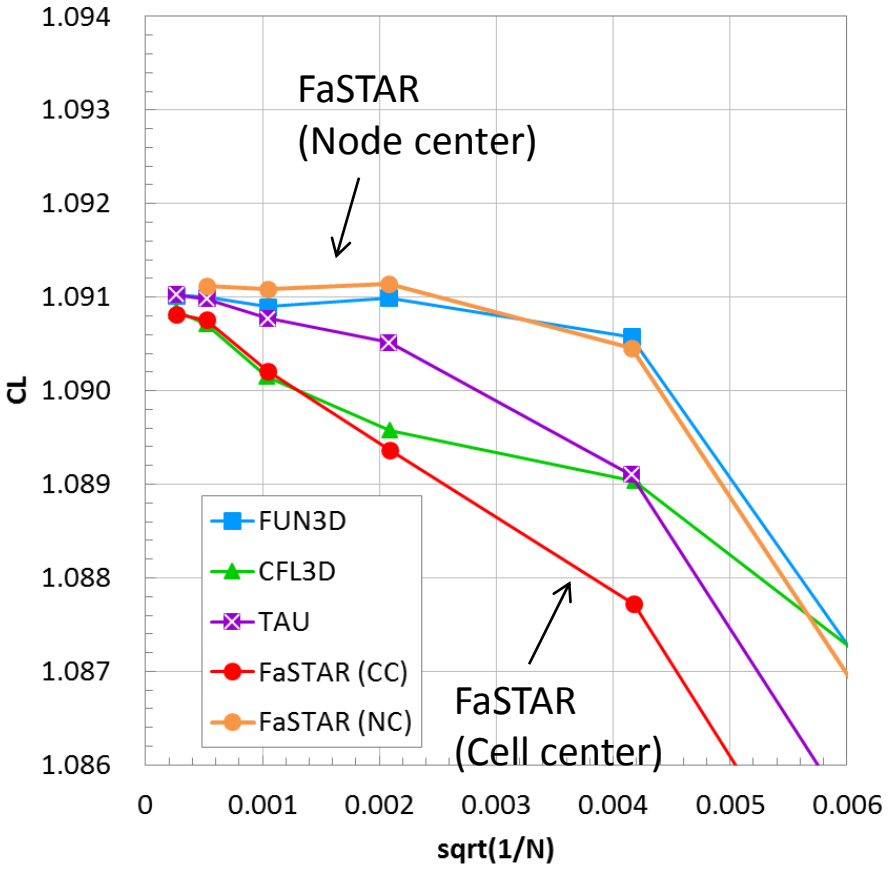



Pressure drag

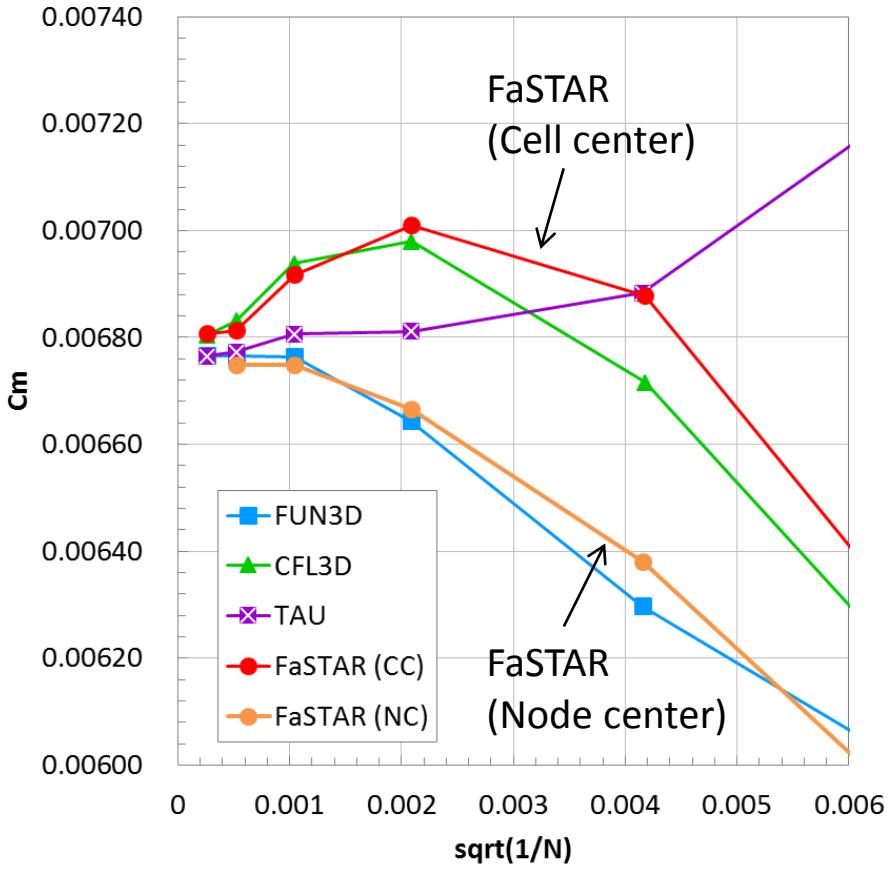



Friction drag

# Grid convergence of $C_L$ and $C_m$



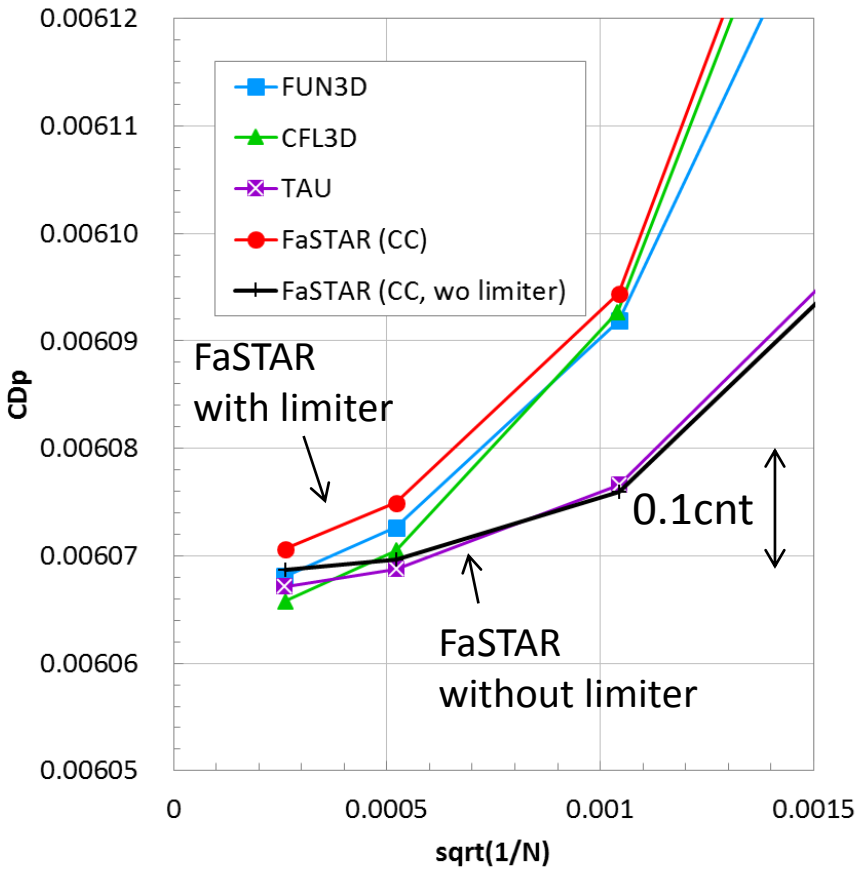

Lift



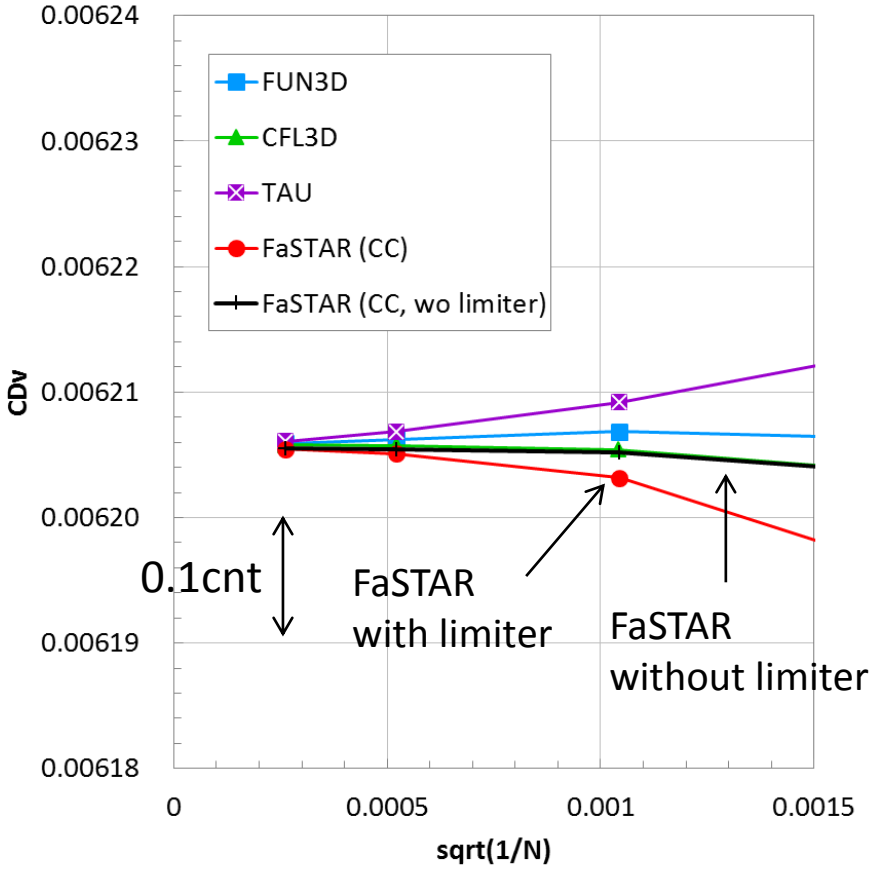

Pitching moment

# Slope limiter effect

## Grid convergence of $C_{Dp}$, $C_{Df}$




Pressure drag




Friction drag

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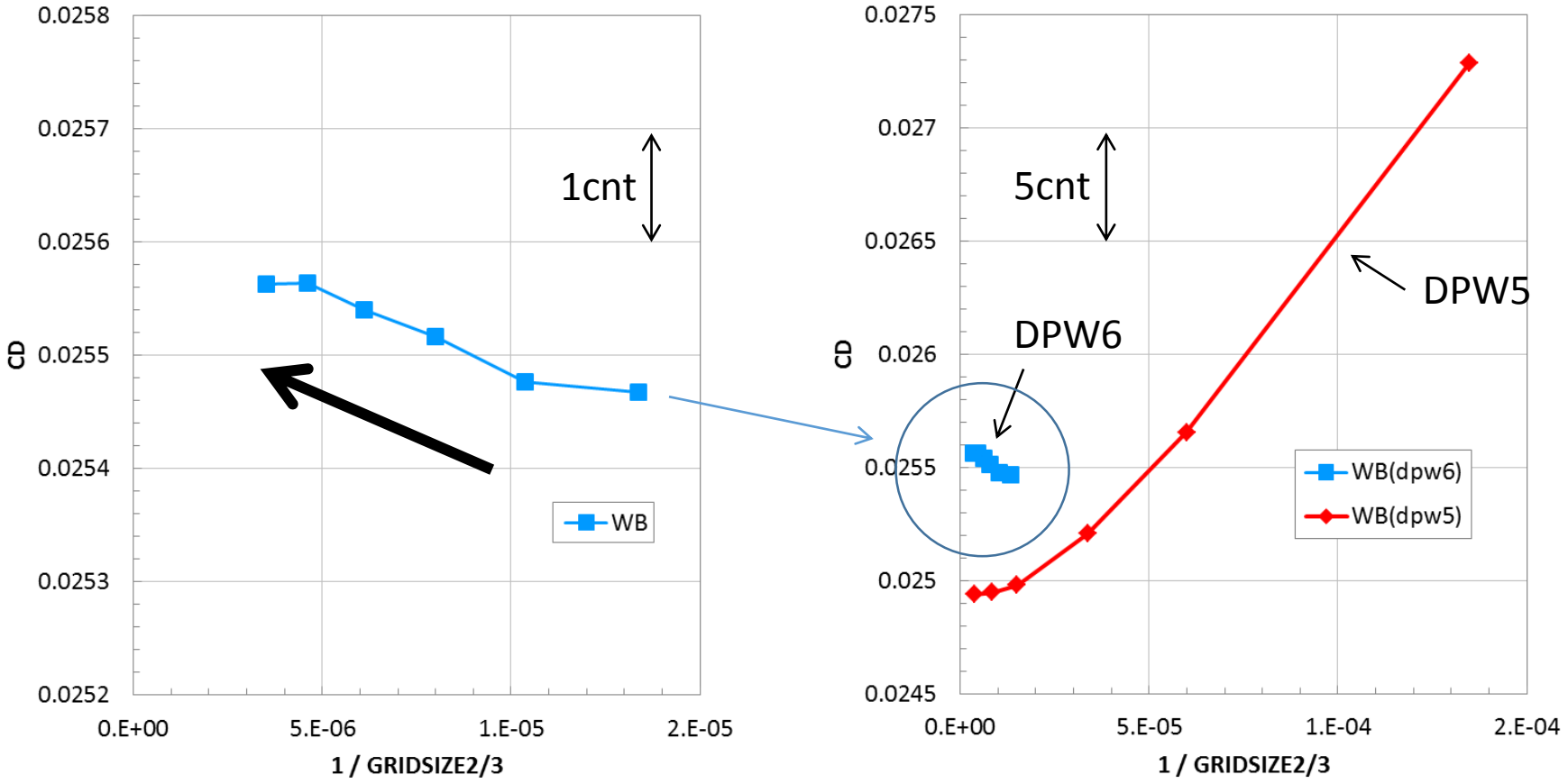
# Grid convergence of $C_D$

Wing-Body (WB) configuration



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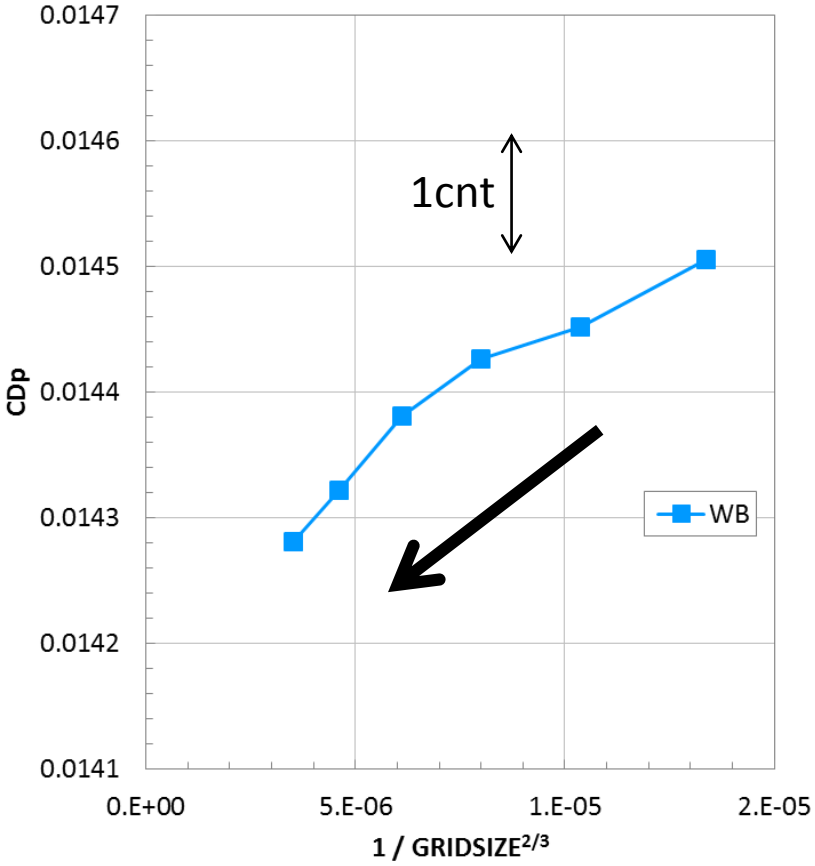
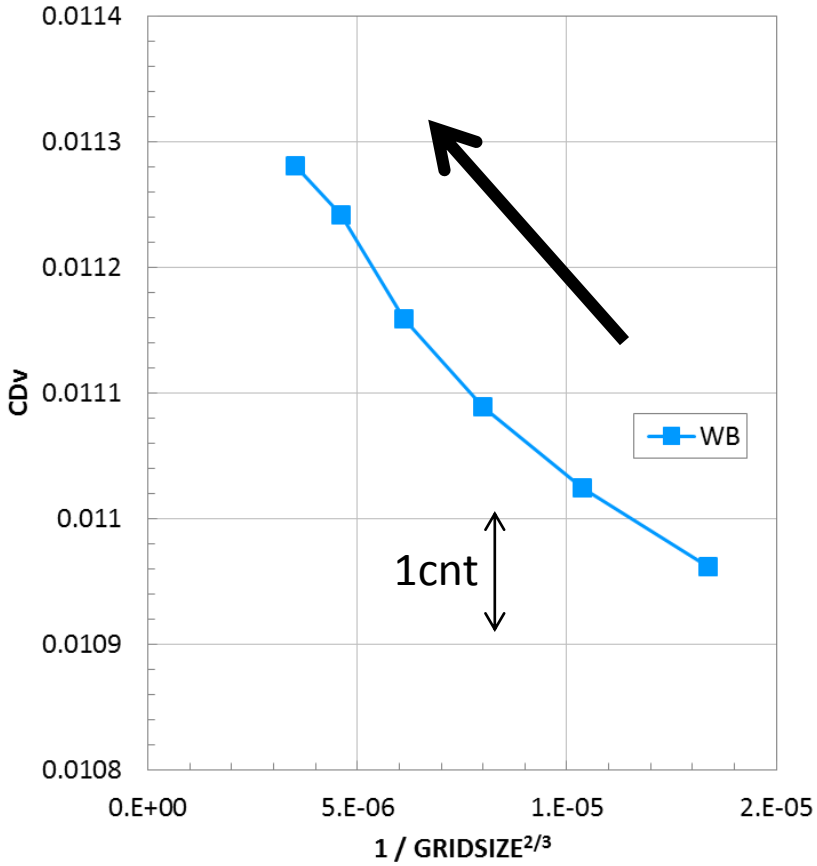


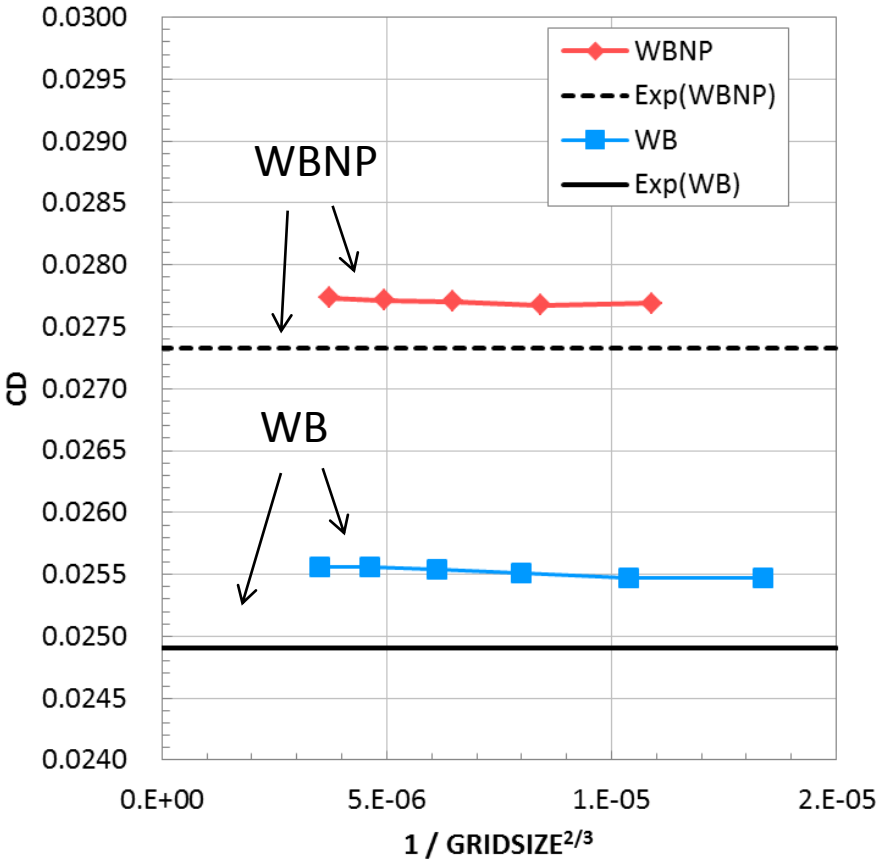




Pressure drag

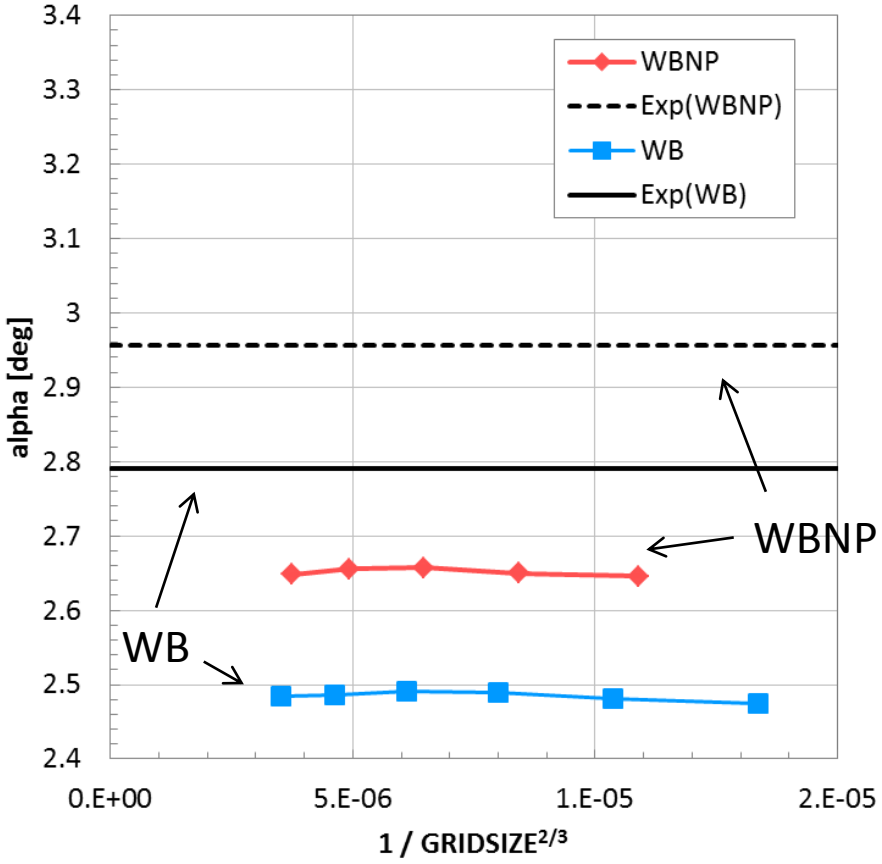
Friction drag

# Grid convergence of WB and WBNP

EXP: NTF data t197R44, t197R79




Drag




Alpha(~Lift)

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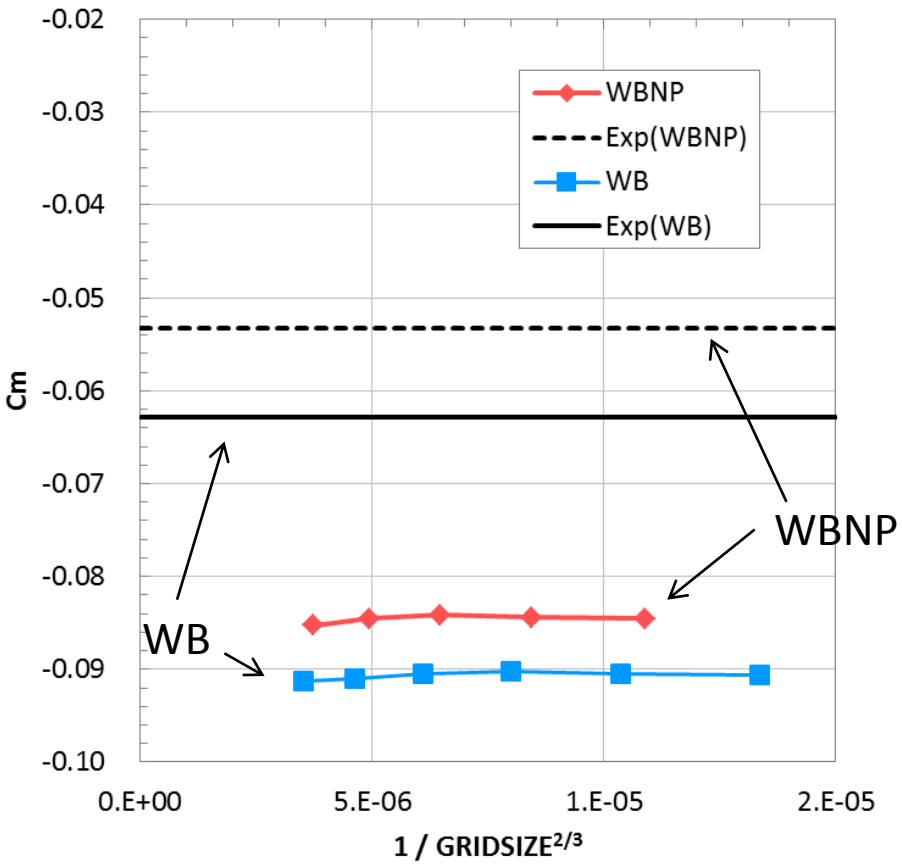
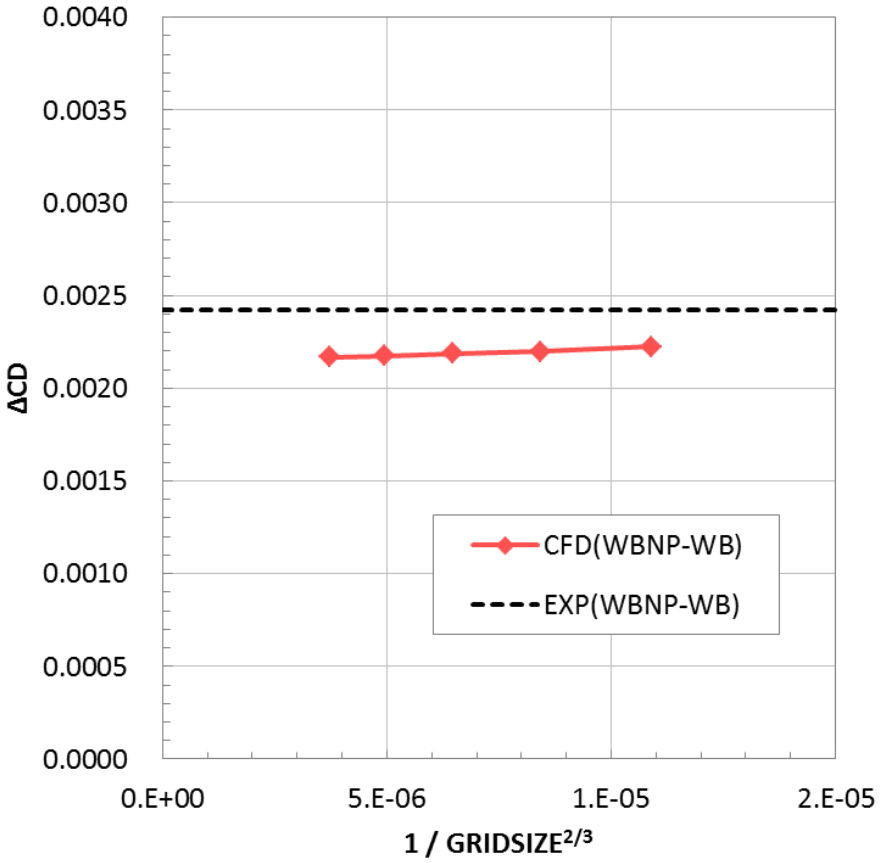
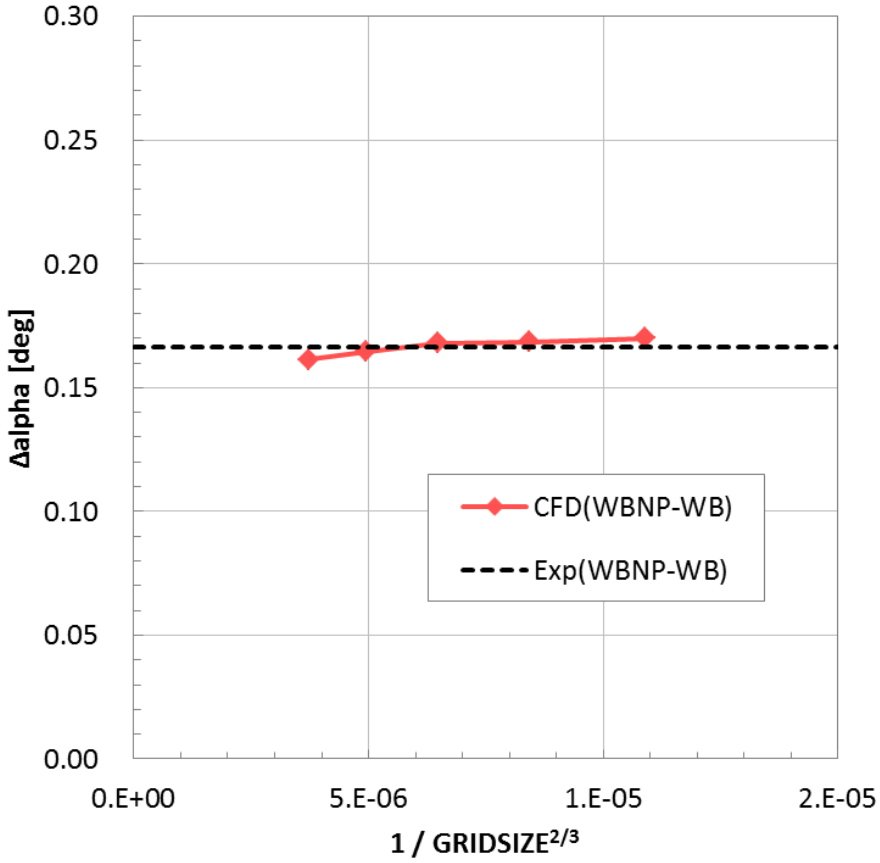



Pitching moment

# Grid convergence of NP interference

EXP: NTF data t197R44, t197R79




ΔDrag

ΔAlpha(~Lift)

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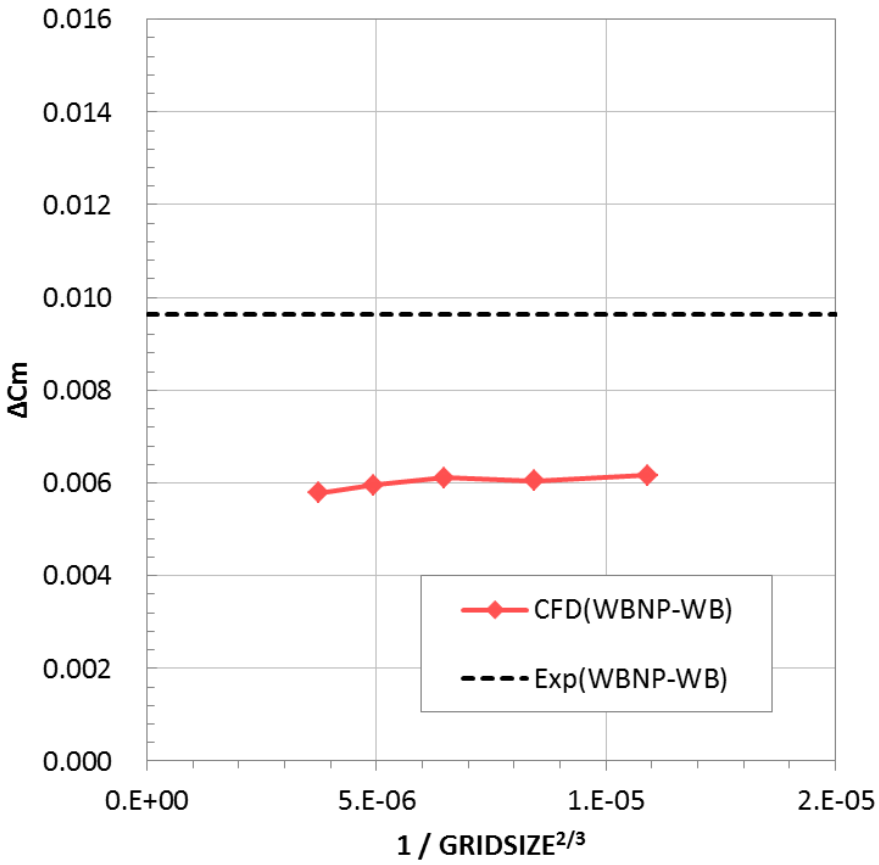
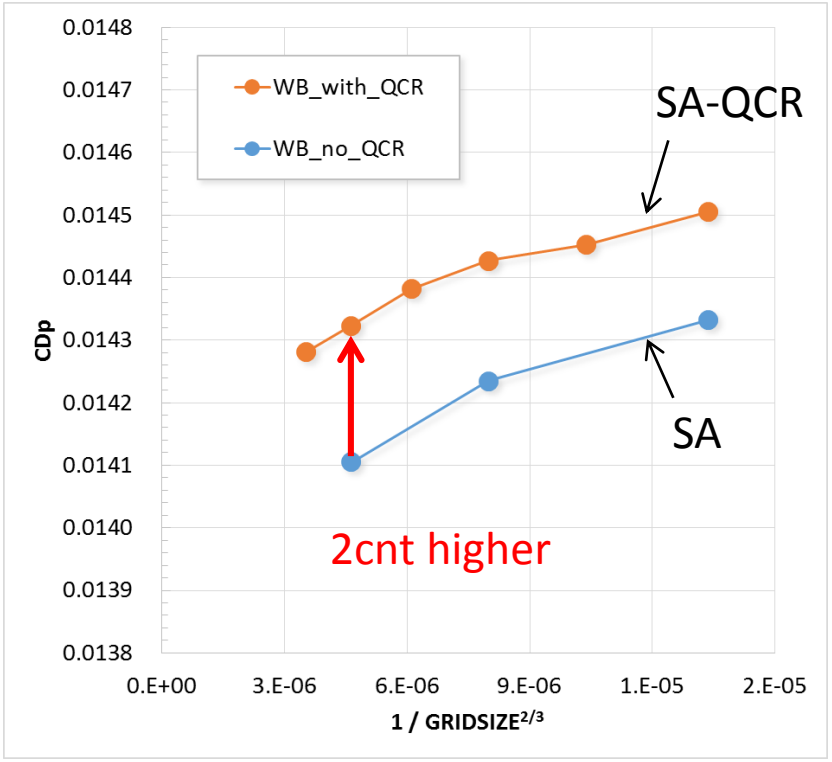
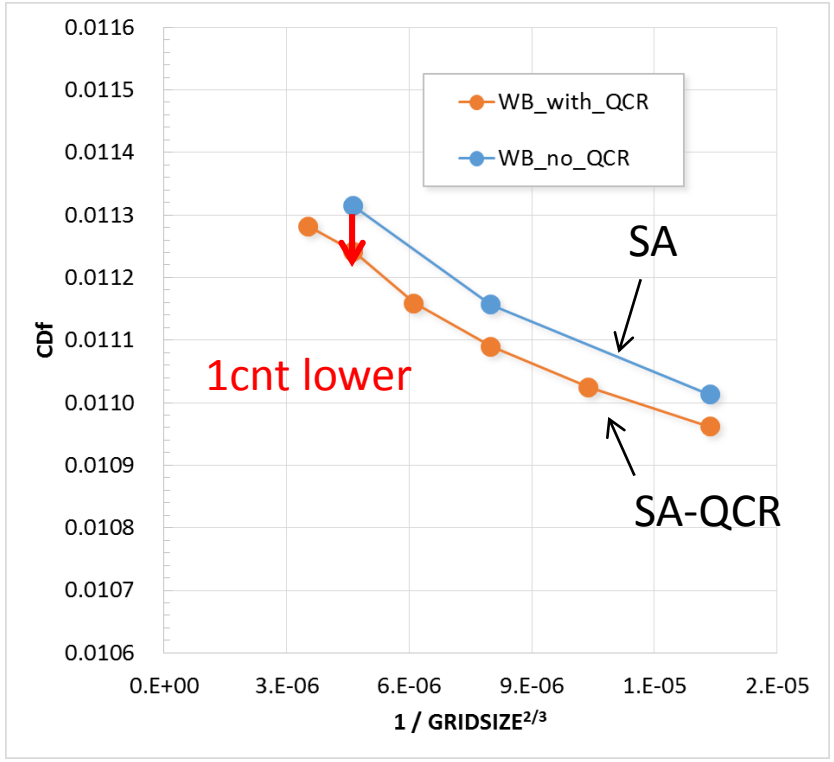



## Δ Pitching moment

# QCR model effect




Pressure drag




Friction drag

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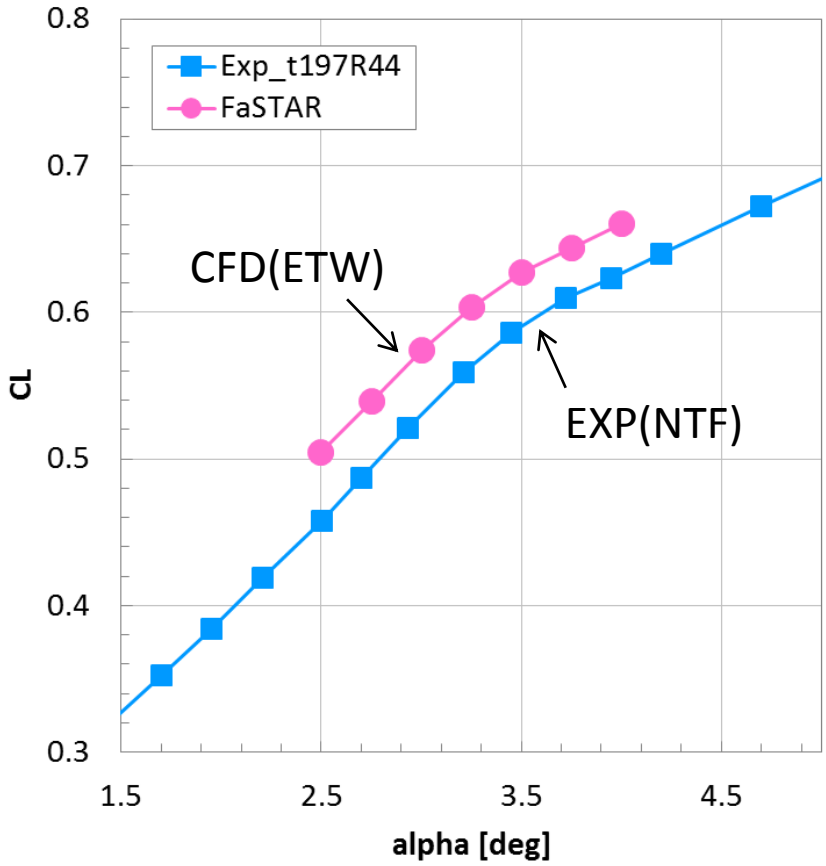
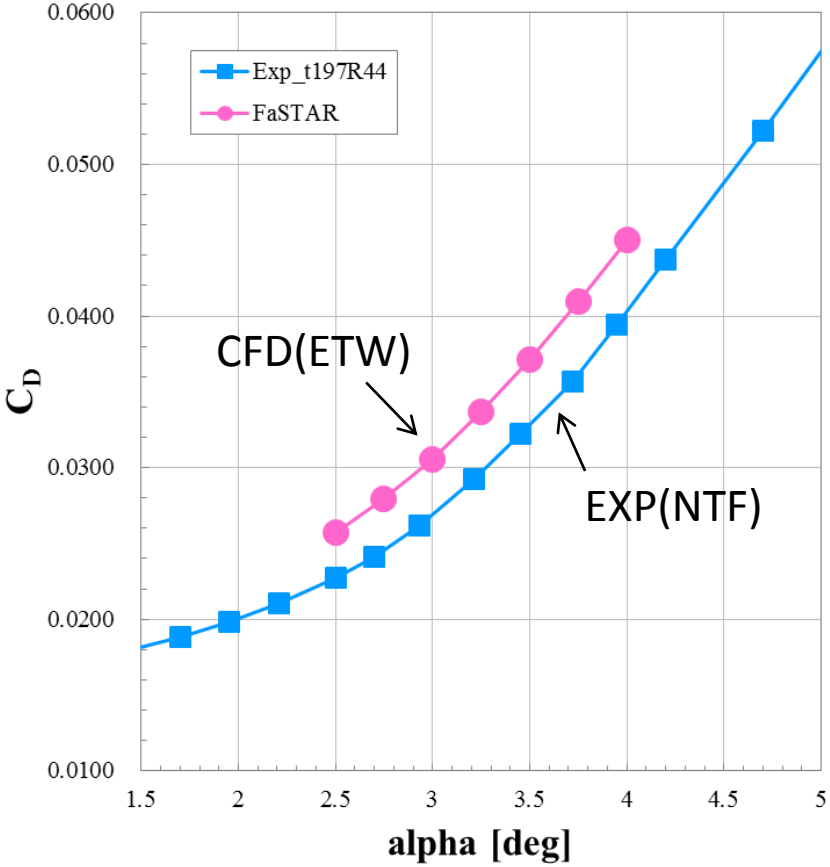
# Alpha-sweep (CL and CD)

EXP: NTF data t197R44

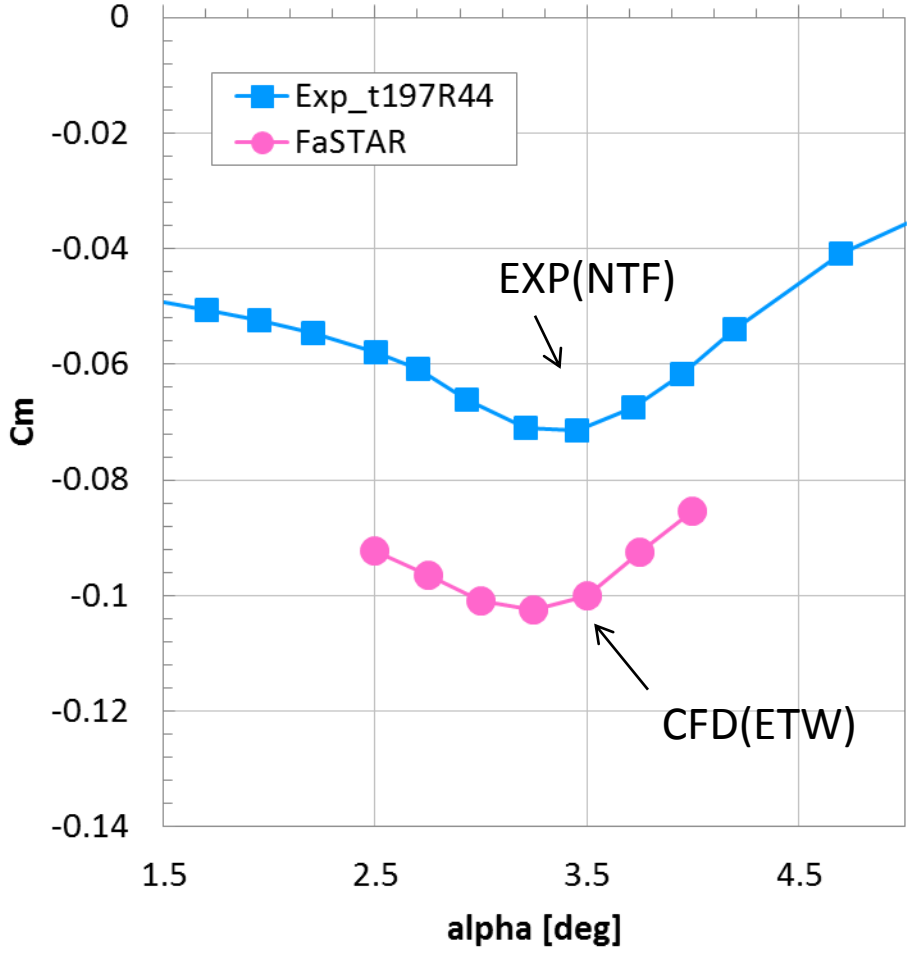



CL-alpha




CD-alpha

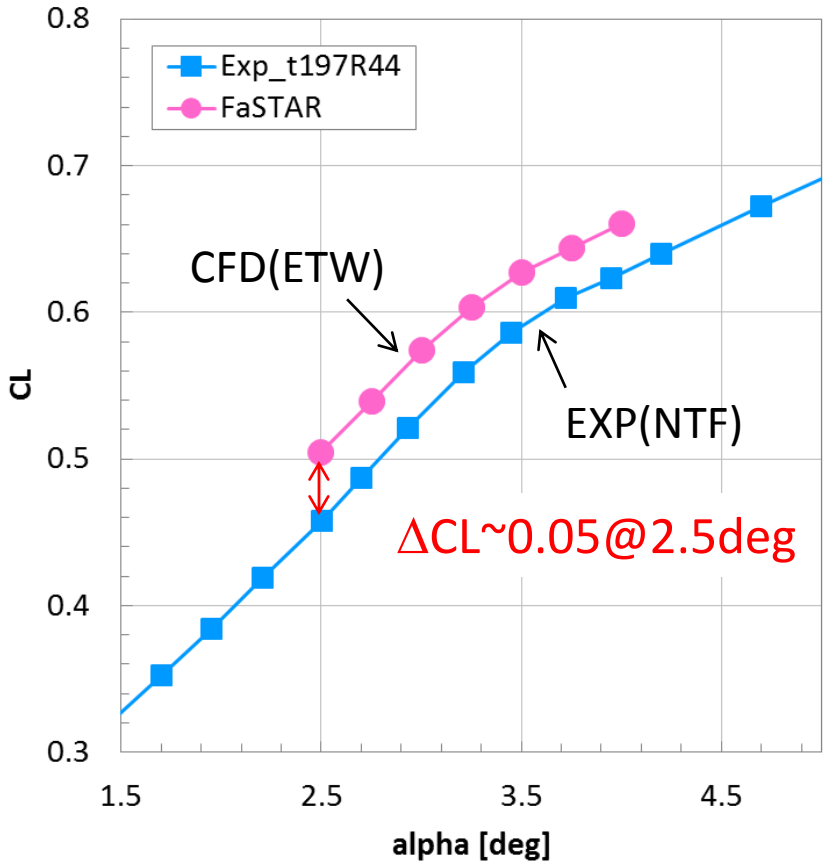
# Alpha-sweep (Cm)



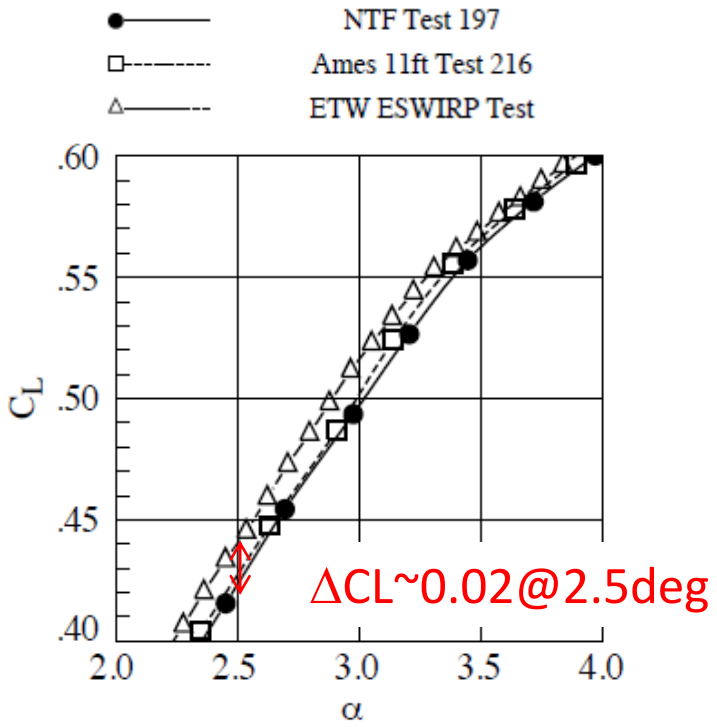

ΔCm=0.025-0.030

# Alpha-sweep (CL and CD)

EXP: NTF data t197R44




CL-alpha




Rivers, et al., AIAA2015-1093

Support interference is
ΔCL~0.024@2deg, WBT0

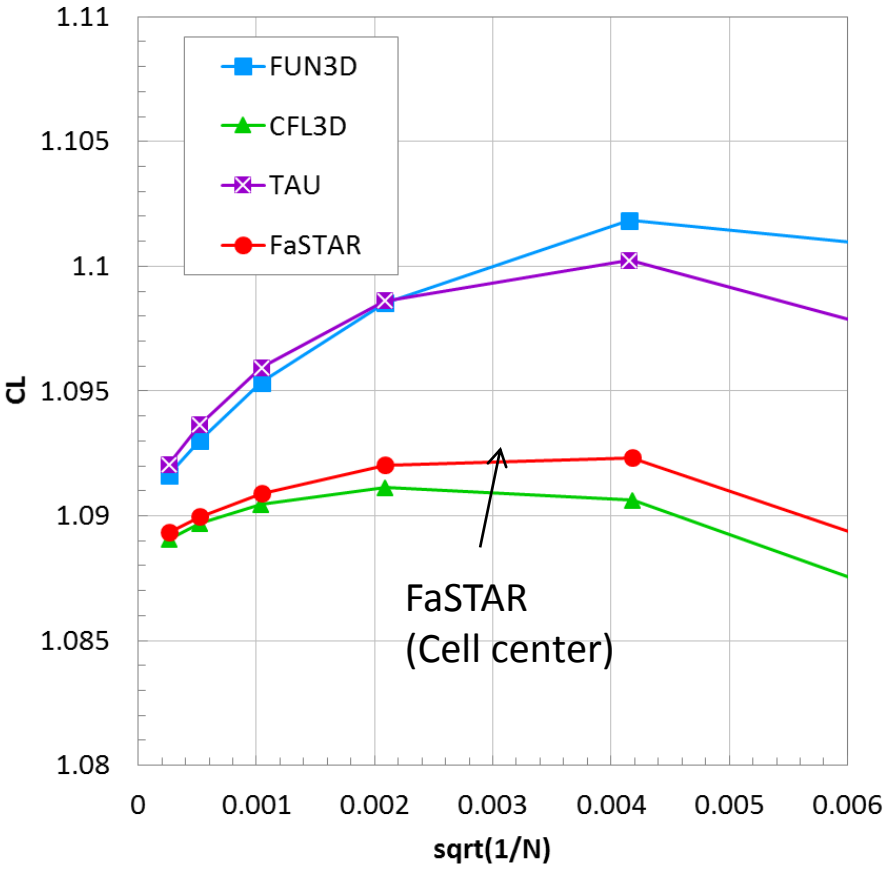
Rivers, et al., AIAA2012-3209

# Summary

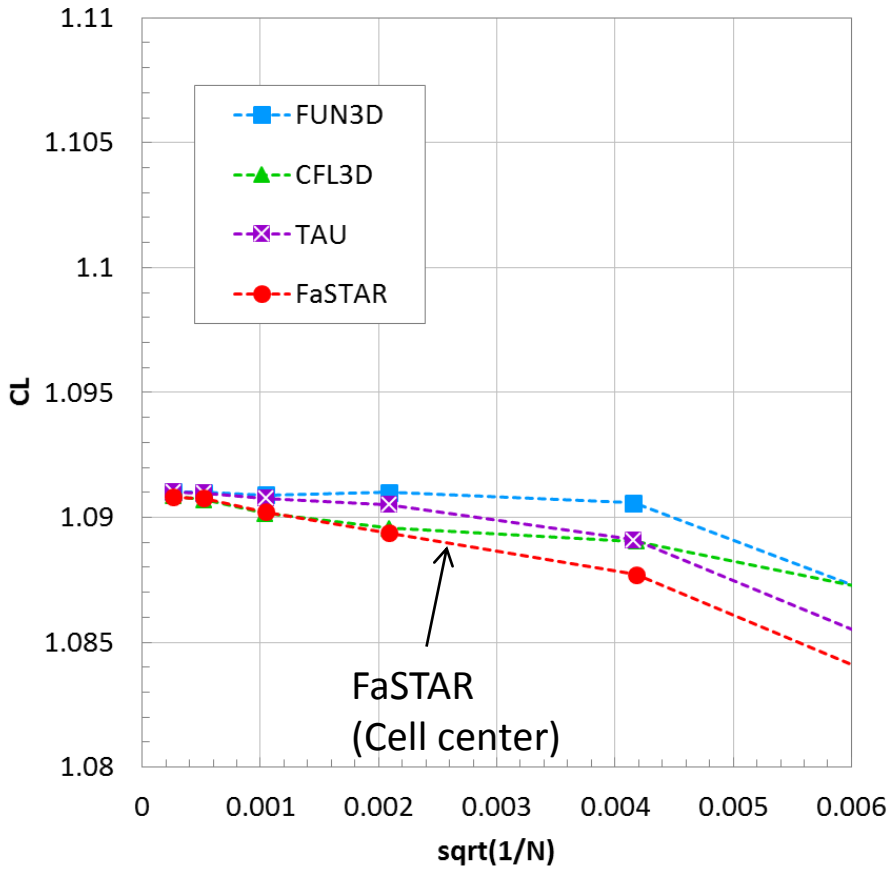
- **Case 1: Verification Study of 2D NACA0012 airfoil**
  - The FaSTAR results agree with the FUN3D, CFL3D, and TAU results
  - The cell center method is close to the CFL3D, whereas the node center method is close to the FUN3D. This difference is caused by the discretization method.
- **Case 2: CRM Nacelle-Pylon Drag Increment**
  - Drag increase with number of grid due to the skin-friction.
  - The nacelle-pylon increment is almost same as the NTF data.
- **Case 3: CRM WB Static Aero-Elastic Effect**
  - Overall trend is same as the NTF experiment.
  - It seems that the difference is caused by the wing deflection and support interference.

# Grid type dependency

## Grid convergence of $C_L$



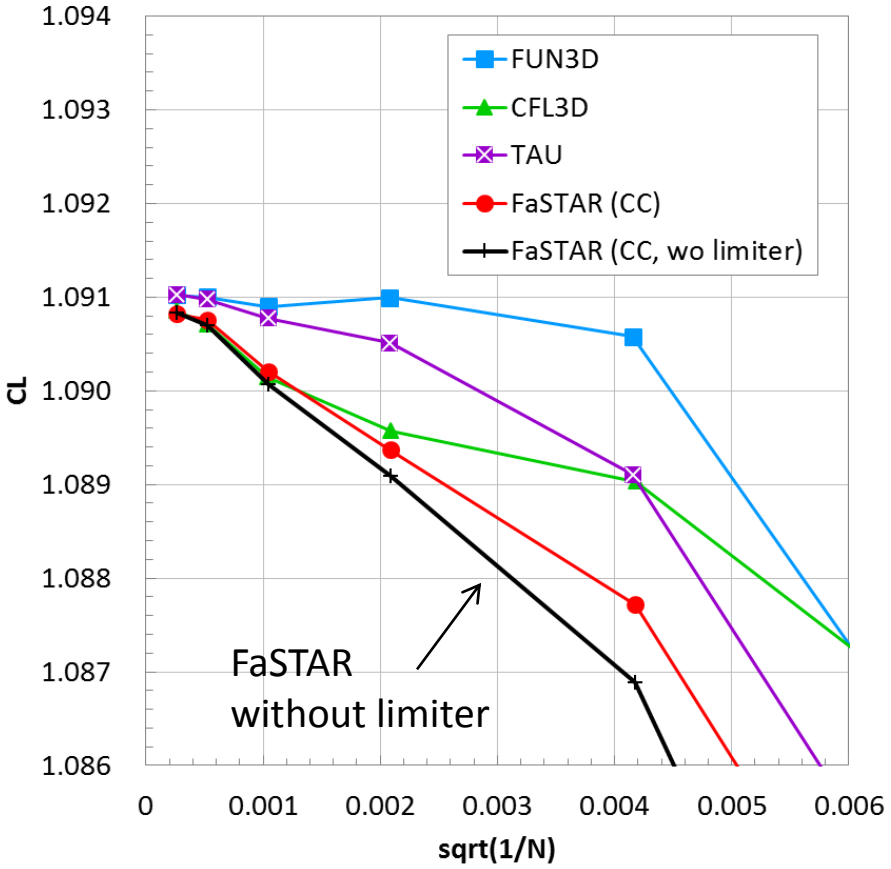

Family I grid



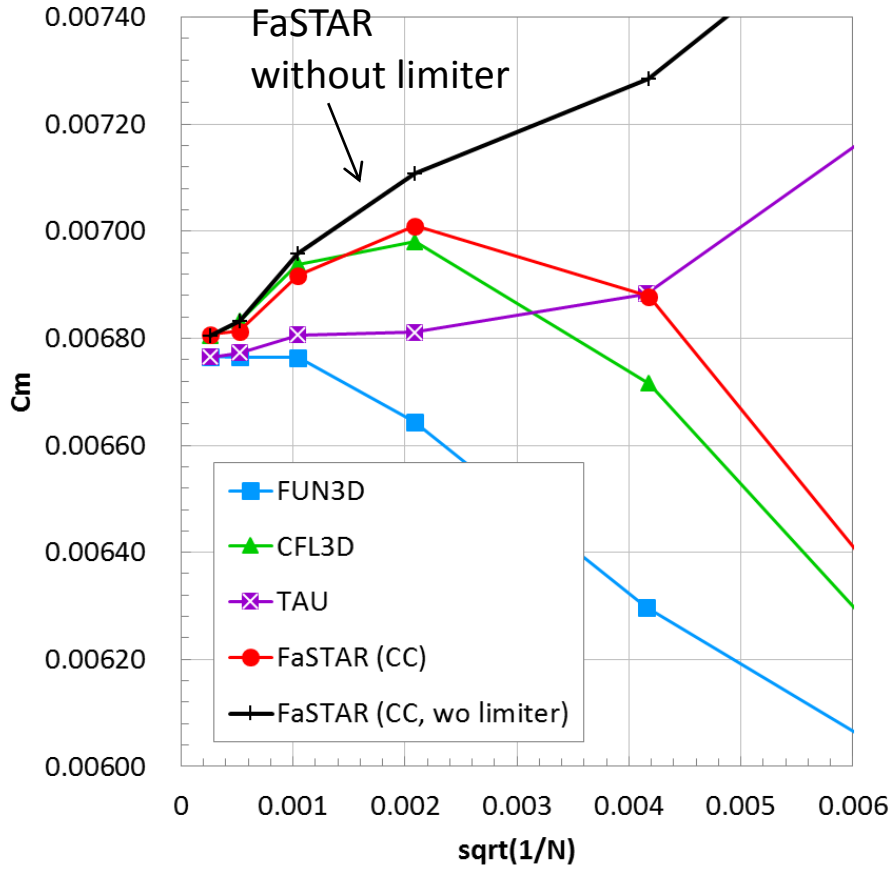

Family II grid

# Slope limiter effect

## Grid convergence of $C_L$, $C_m$

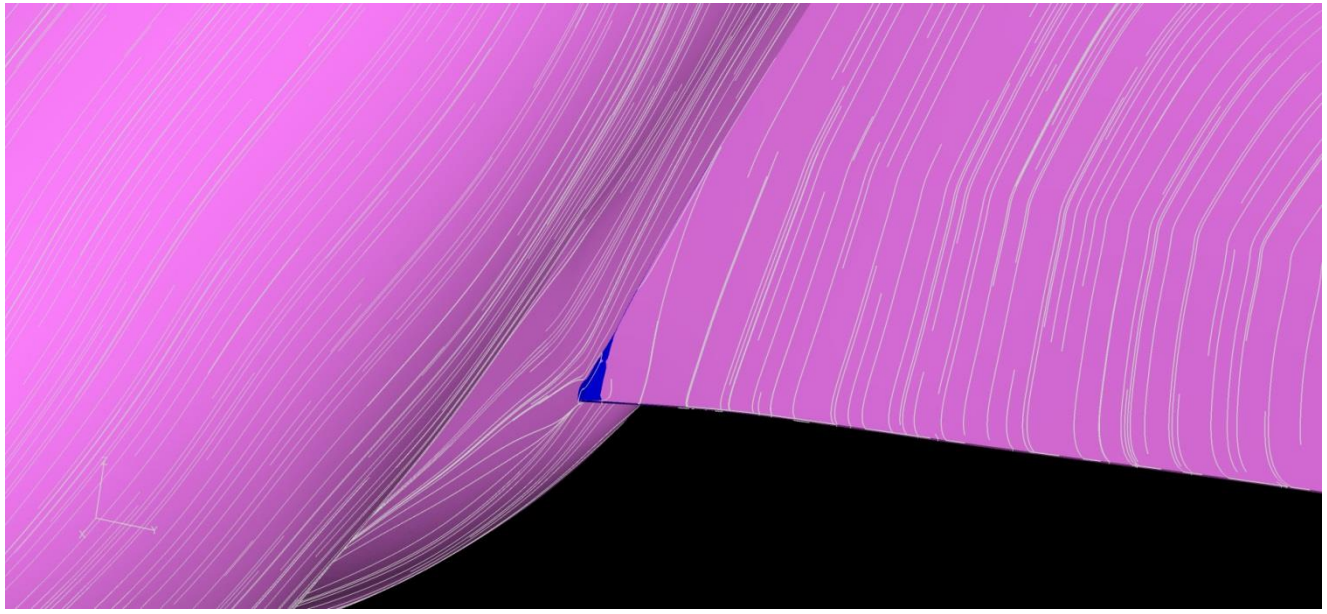



Lift

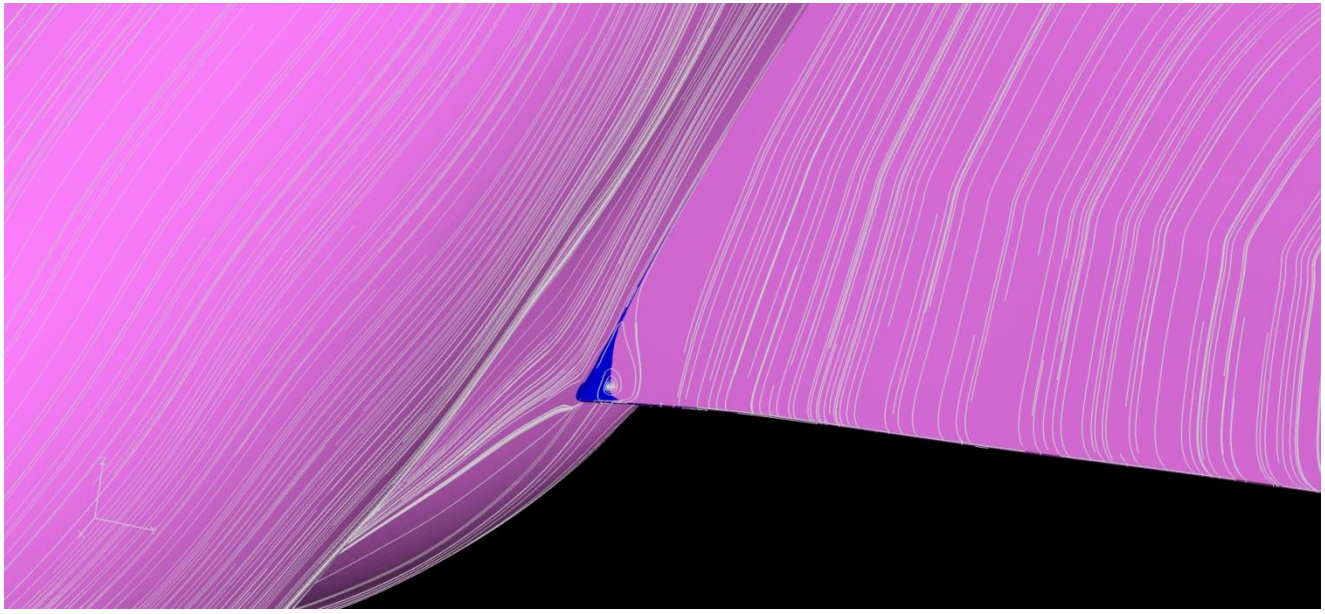



Pitching moment

# SOB (case2)

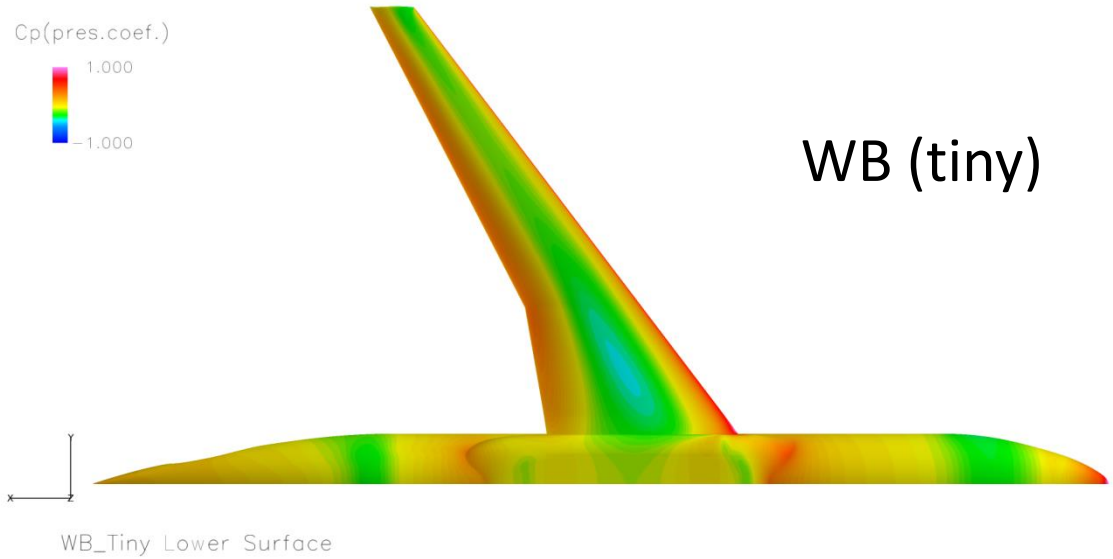


WB (ExtraFine)

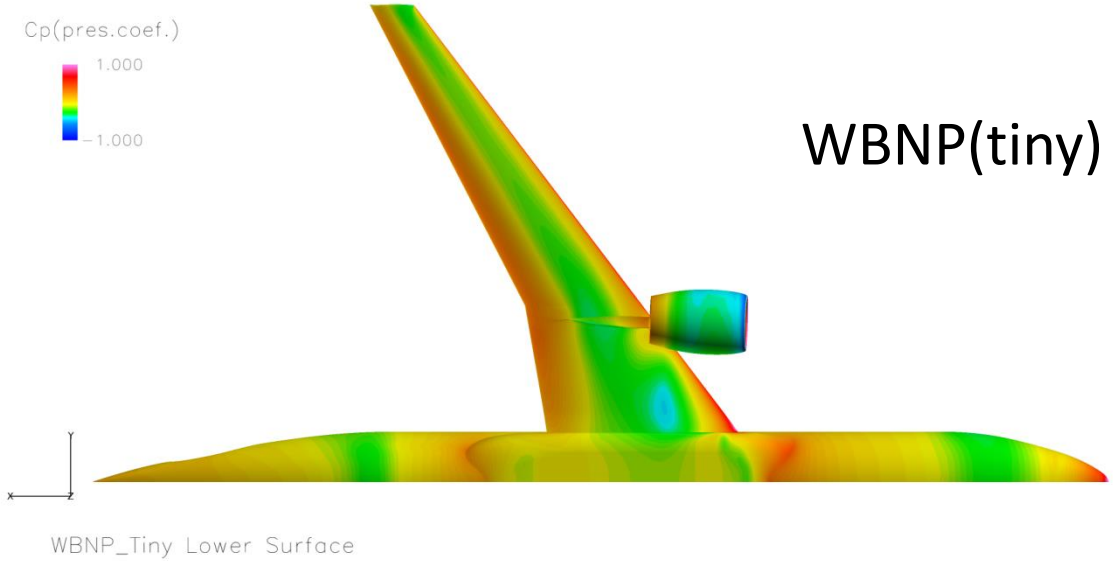


WB (tiny)

# Cp contours (case2)

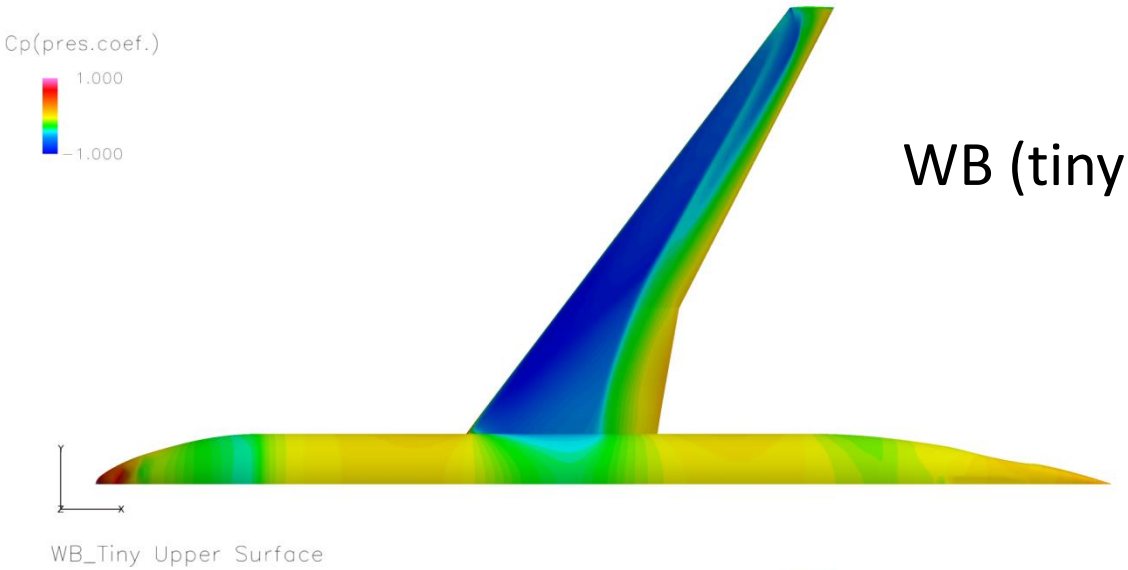



WB (tiny)

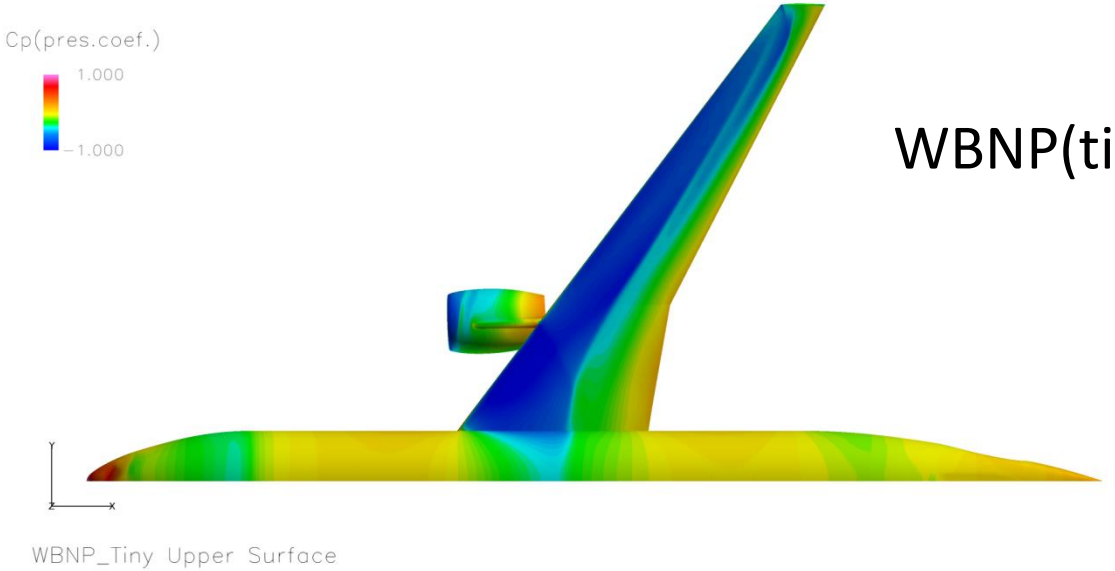



WBNP(tiny)

# Cp contours (case2)

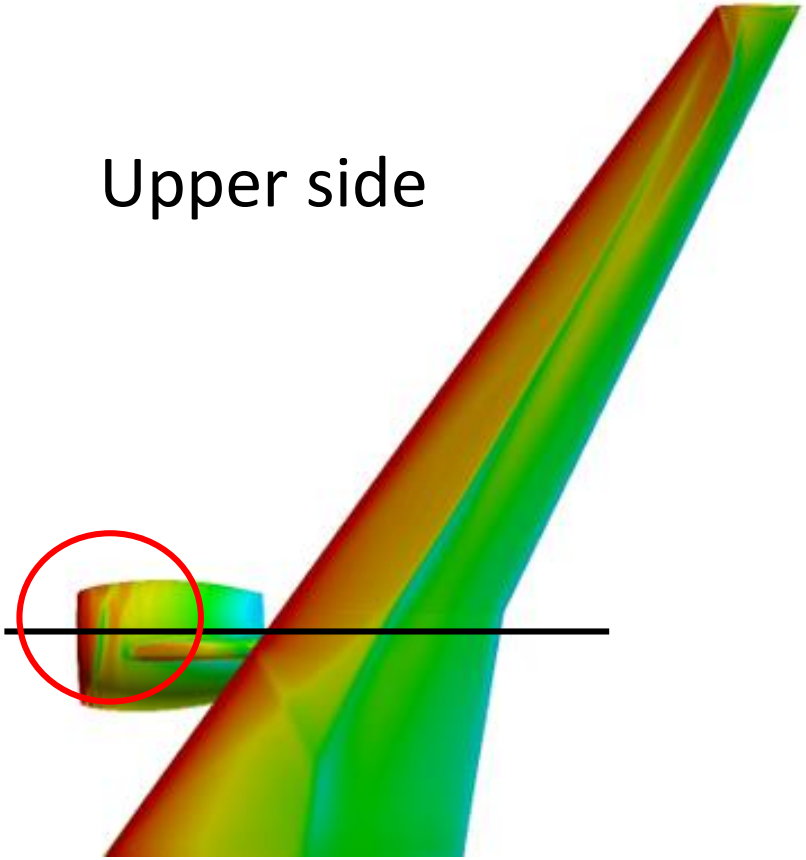


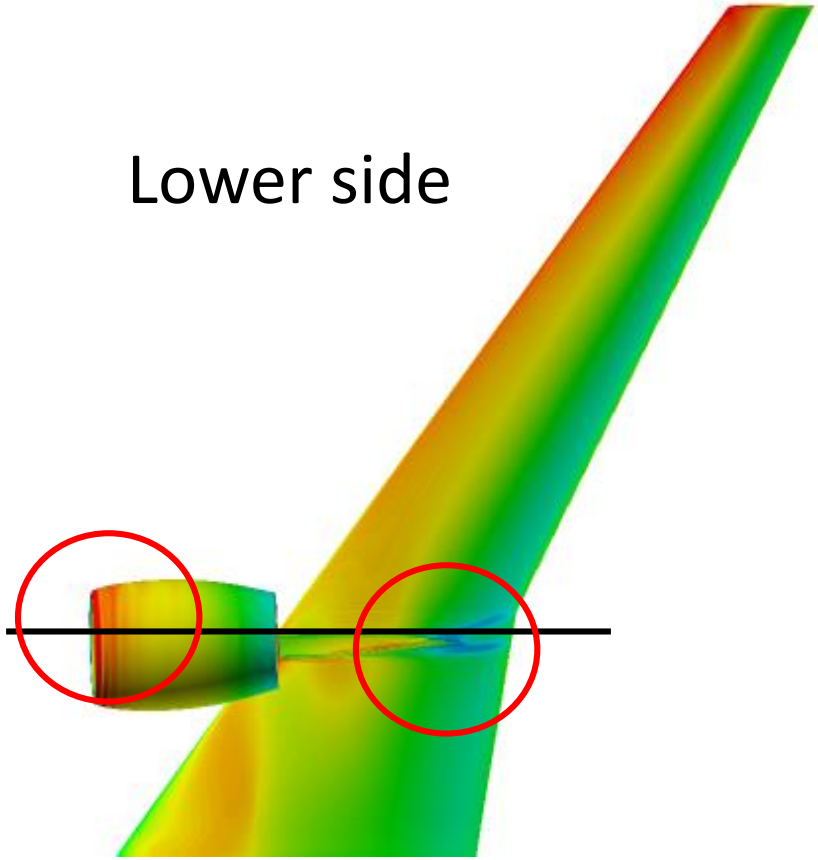

WB (tiny)




WBNP(tiny)

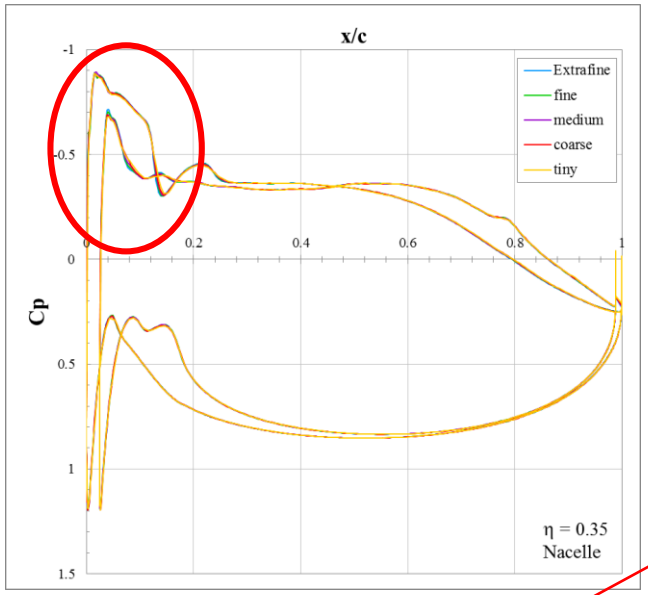
# Cfx contours



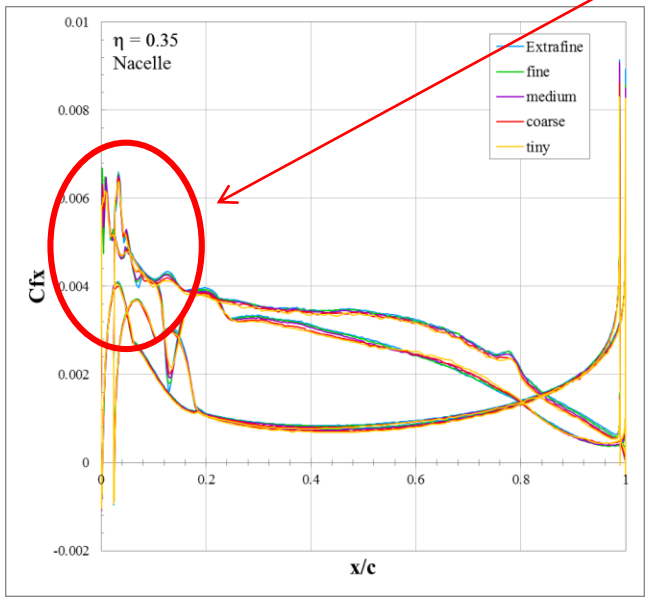



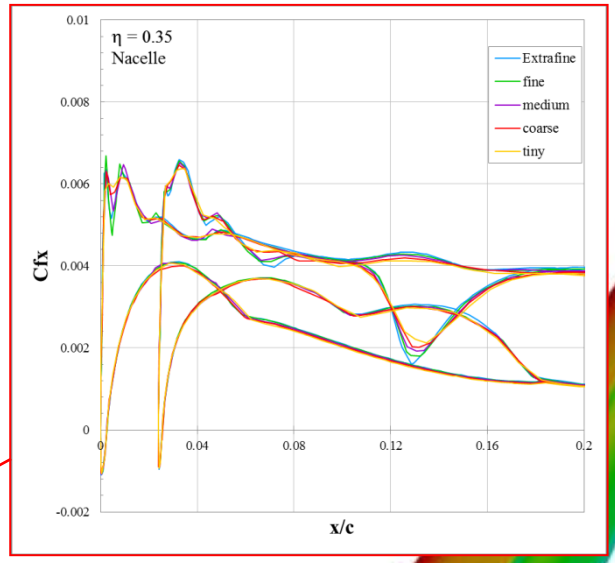
# Nacelle

Cp



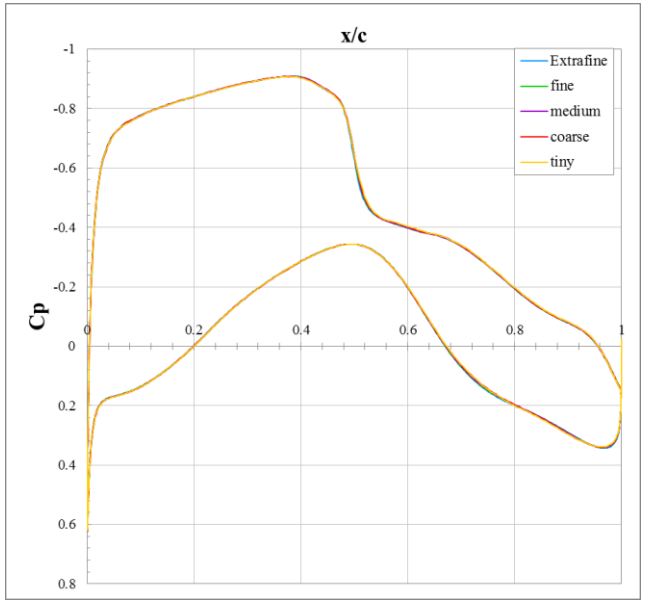

Cf



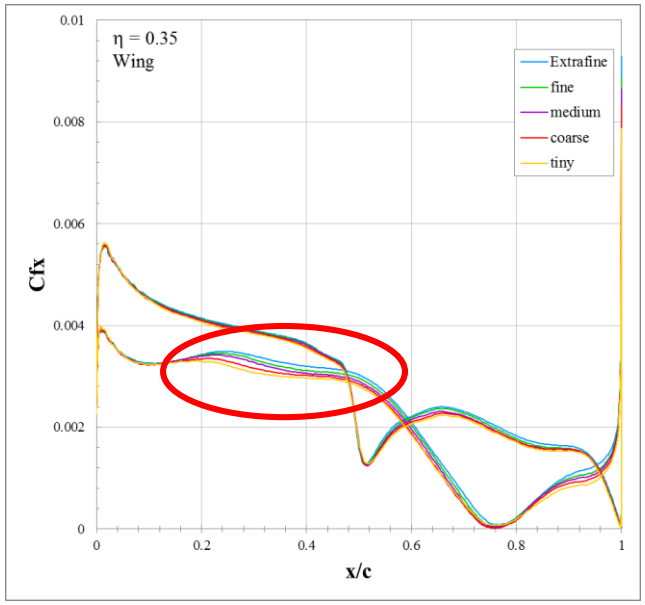



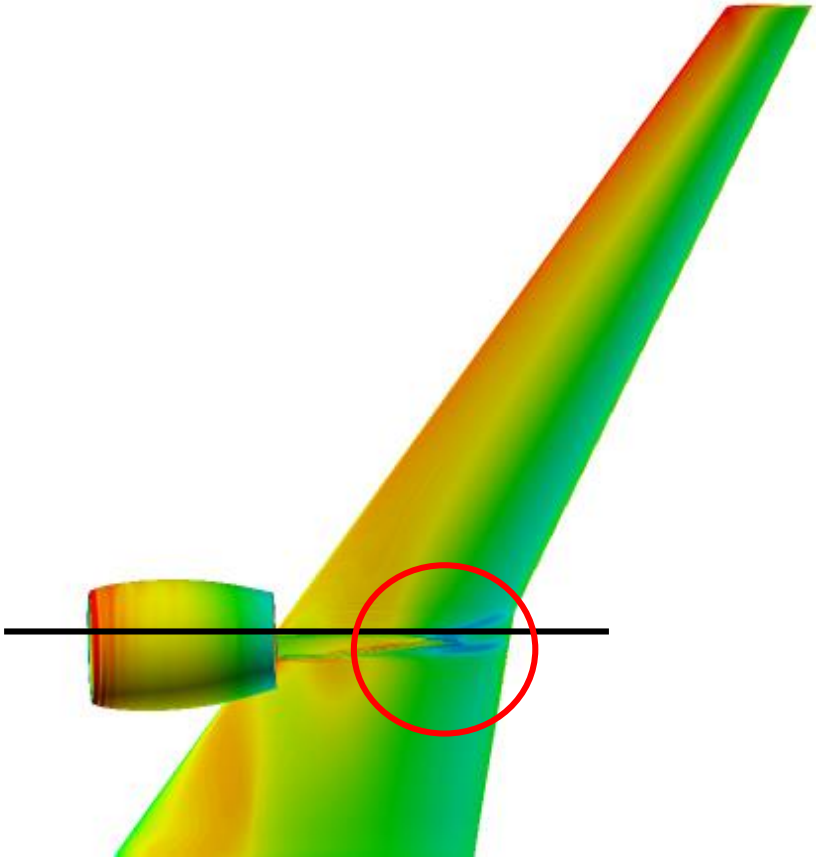
# Wing-pylon interference

Cp

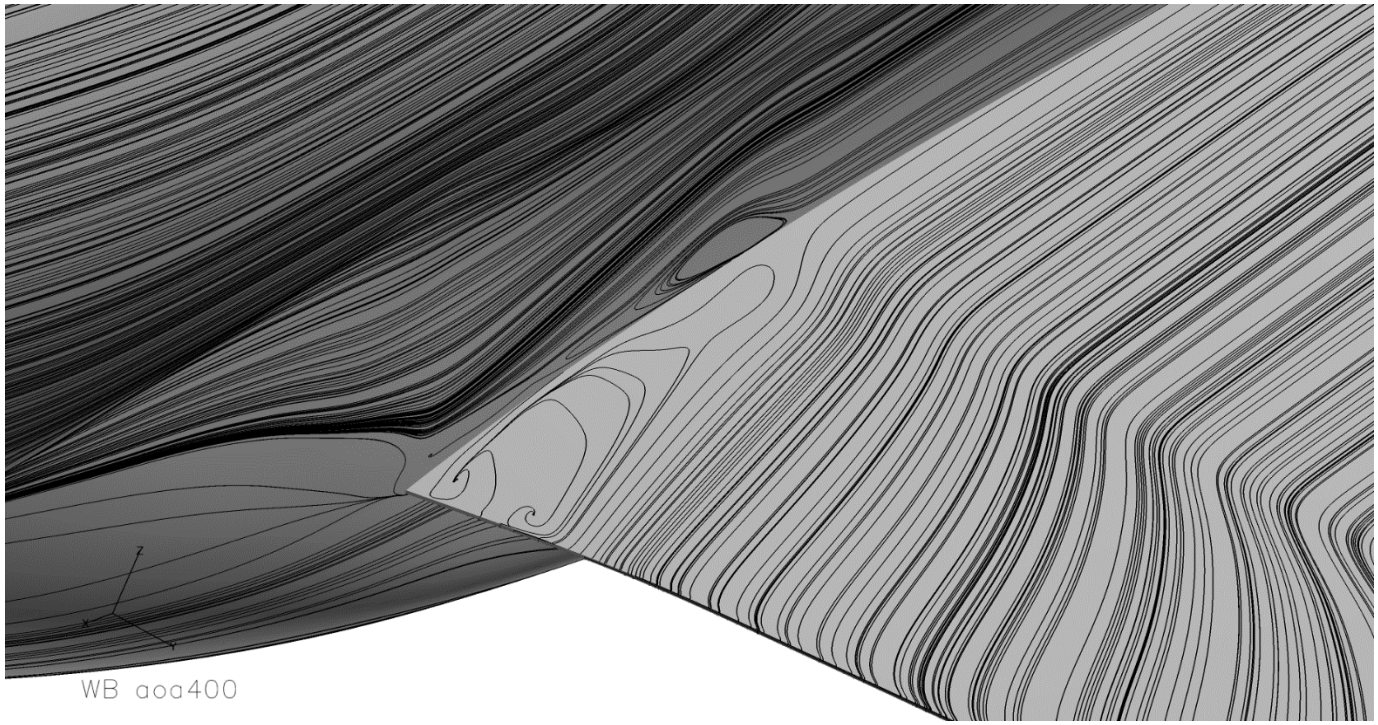



Cf



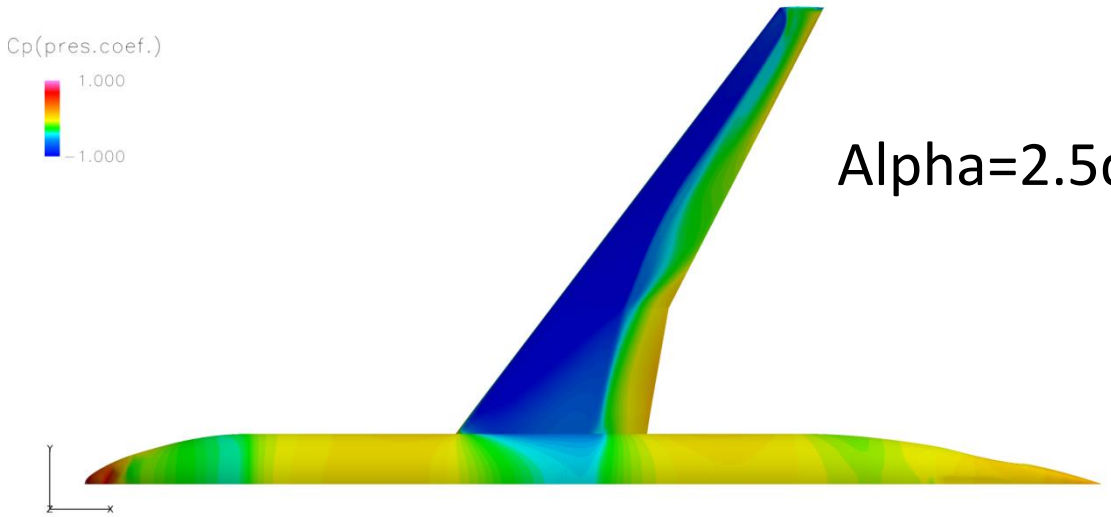



# SOB (case3)



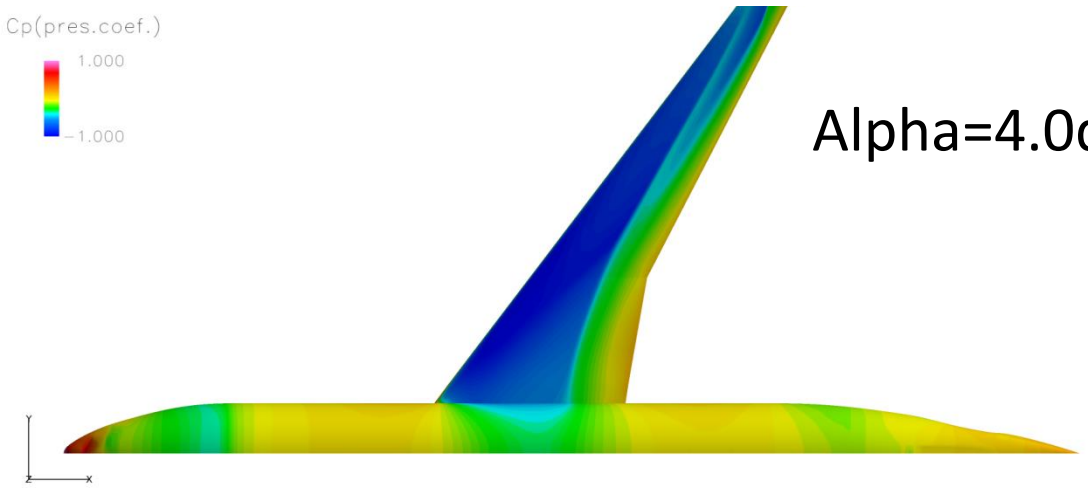

Alpha=4.0deg

# Cp contours (case3)




Alpha=2.5deg

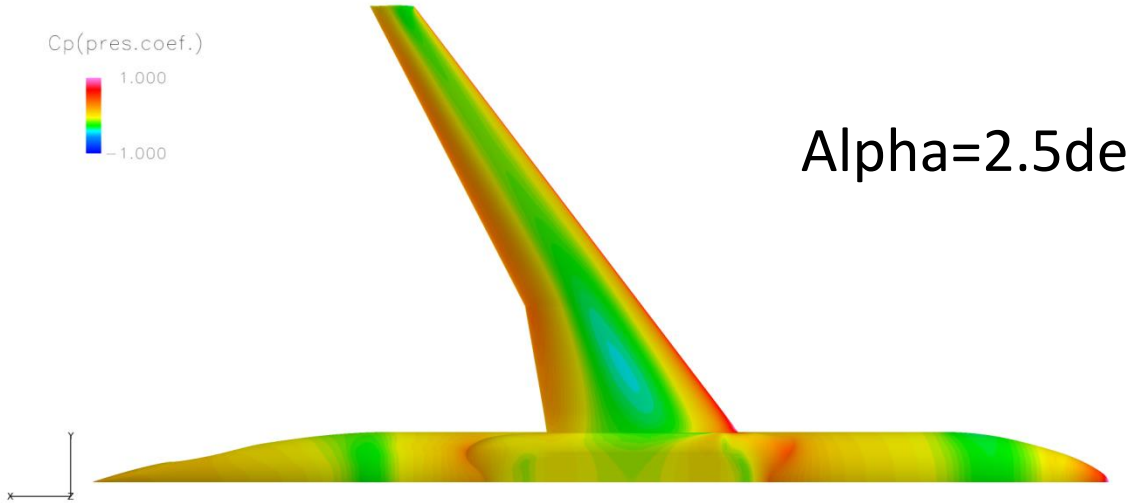
WB aoa400 Upper Surface



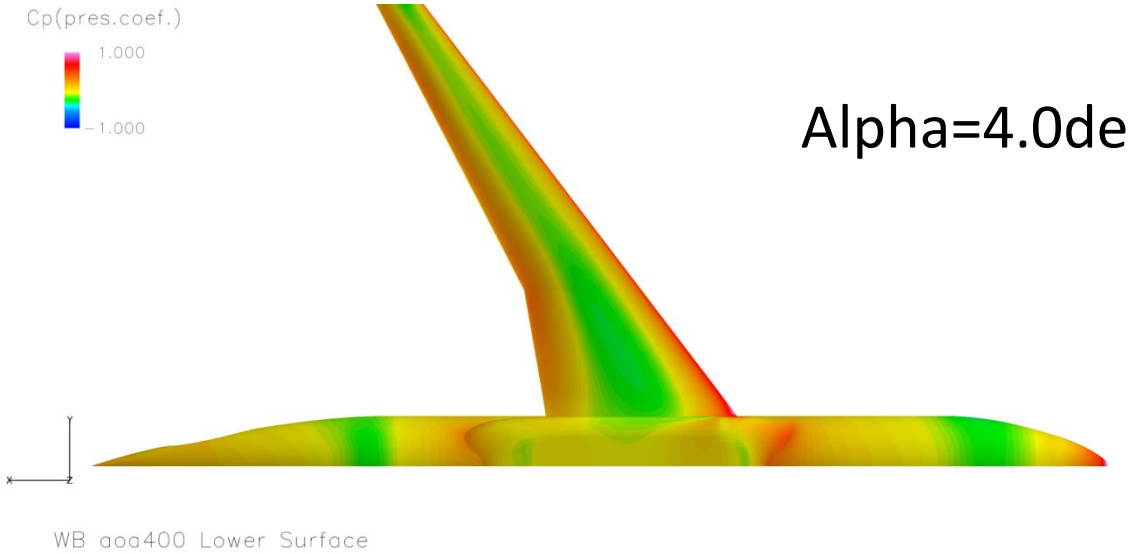

Alpha=4.0deg

WB aoa250 Upper Surface

# Cp contours (case3)

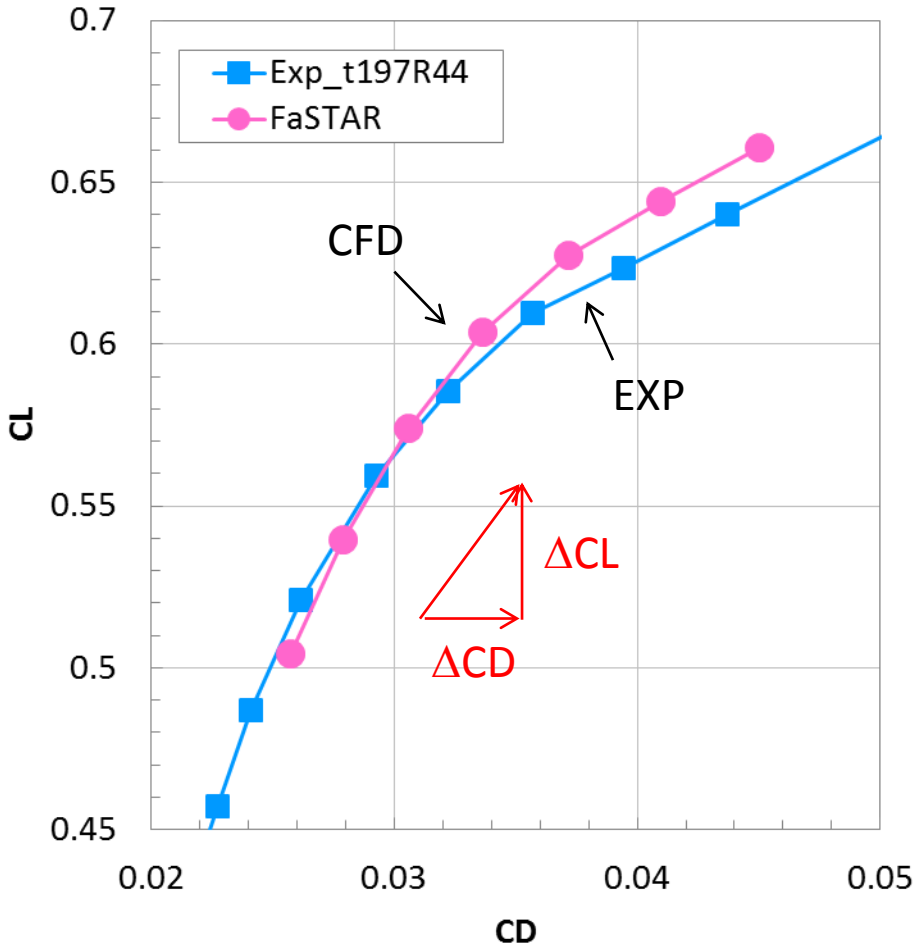



Alpha=2.5deg




Alpha=4.0deg

# Polar curve


Exp_t197R44
FaSTAR
CFD
EXP
ΔCL
ΔCD
CL
CD
0.7
0.65
0.6
0.55
0.5
0.45
0.02
0.03
0.04
0.05