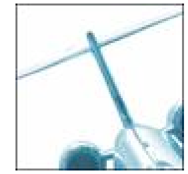
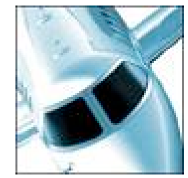


DPW2 results using Bombardier Full-Aircraft Navier-Stokes Code FANSC



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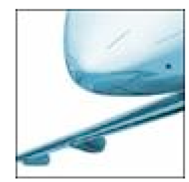
Advanced Aerodynamics Department

Bombardier Aerospace



D. Parks

NEC Solution America

Outline

- FANSC Basic Solver
- DPW1
- DPW2
- Conclusions

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FANSC Basic Solver

- **Multi-Block Structured grids**
- **Finite Volume, Cell-Centered, Explicit Runge-Kutta**
- **Local-Time stepping, FAS, Residual Smoothing (CFL=5)**
  - JST and CUSP scheme
  - Full NS terms
  - Spalart-Allmaras and Menter's Turbulence Model

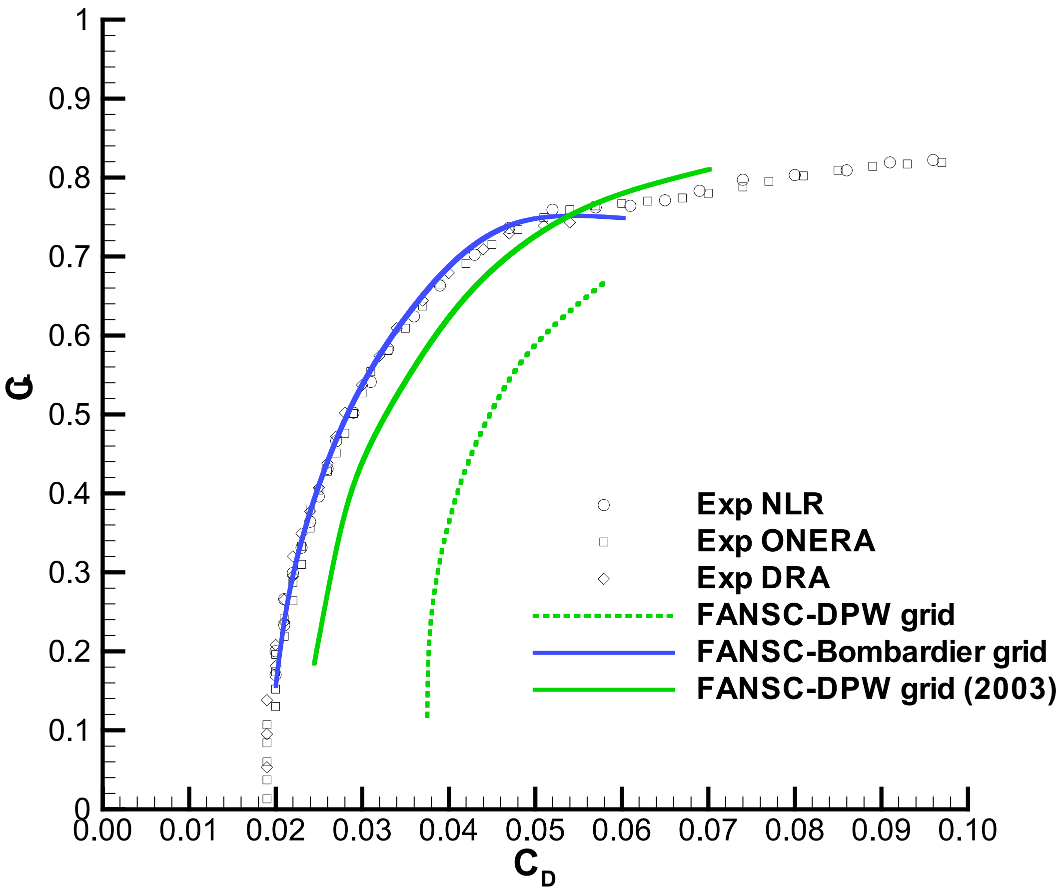
  - FANSC references
  - CASI papers (2001, 2003)
  - Canadian CFD society (CFD 2000)

Outline

- FANSC Basic Solver
- DPW1
- DPW2
- Conclusions

DPW1 (provided grid)

- **Distance computation to account for mesh non-orthogonality implemented in FANSC**



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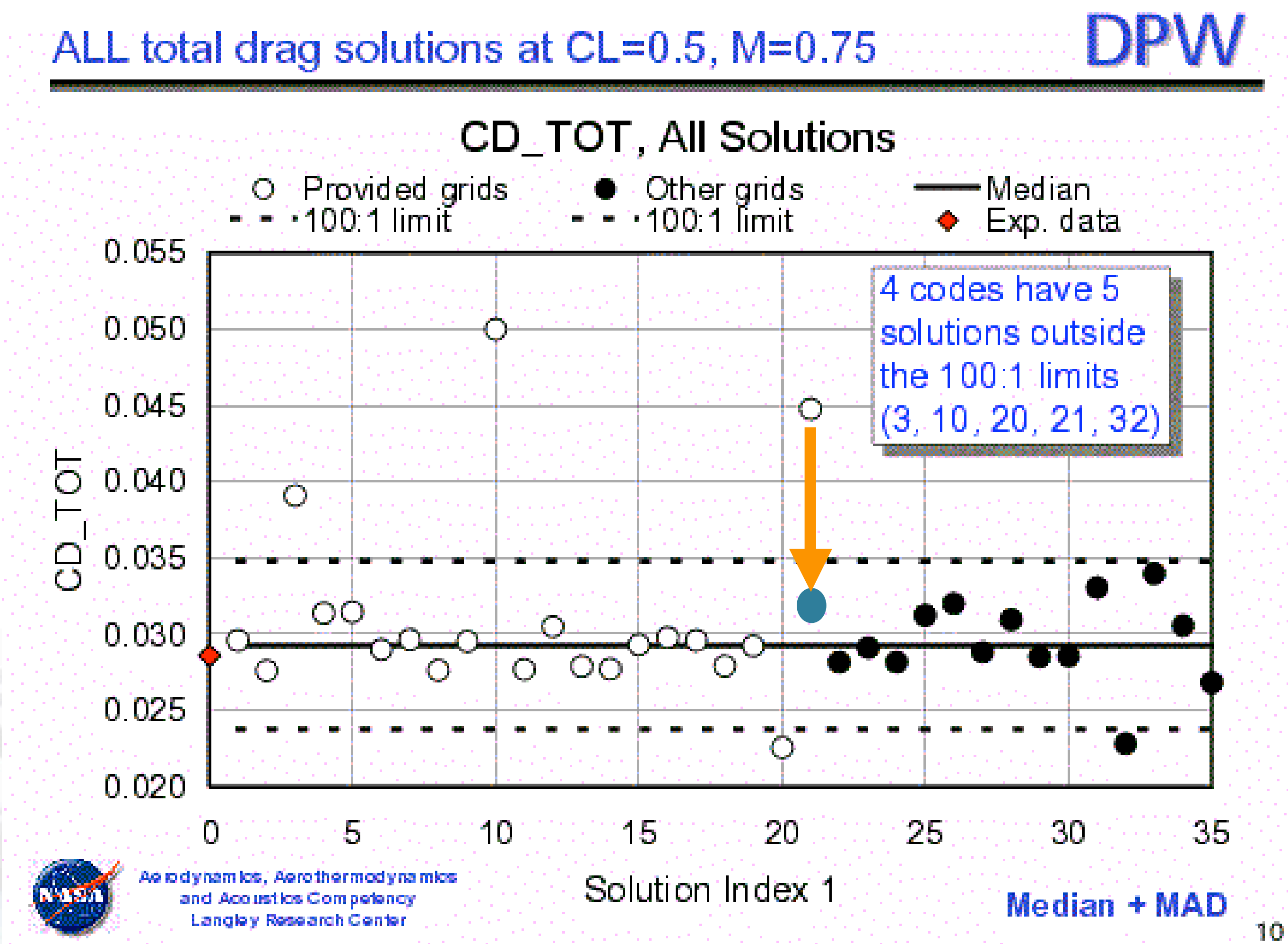
DPW1 (provided grid)



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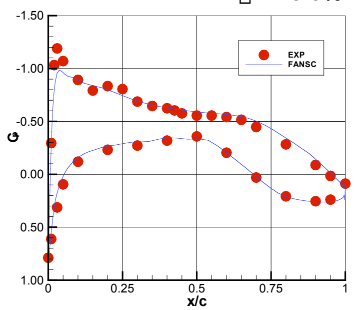
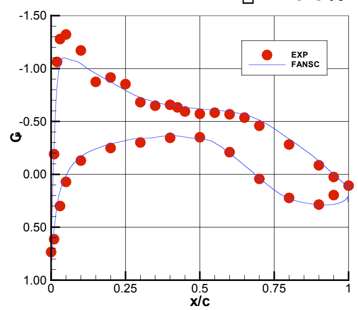
DPW1 (provided grid)

- **Pressures unchanged from previous version; similar to those published by DLR**

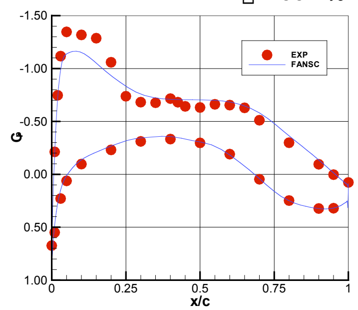
□ = 18.5%



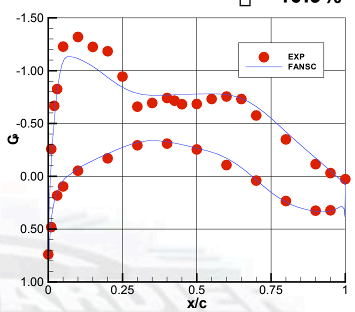
□ = 23.8%



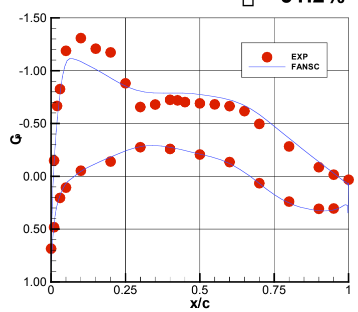
□ = 33.1%



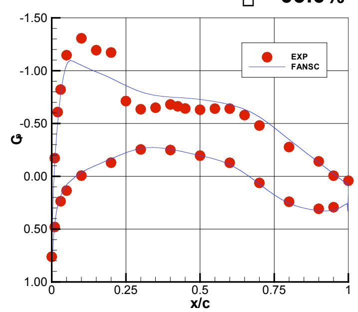
□ = 40.9%



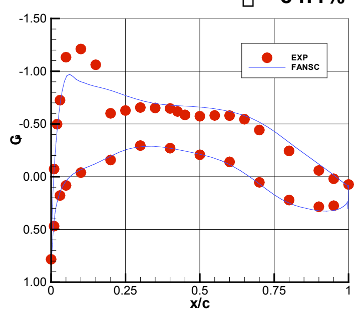
□ = 51.2%



□ = 63.6%



□ = 84.4%



Outline

- **FANSC Basic Solver**
- **DPW1**
- **DPW2**
- **Conclusions**

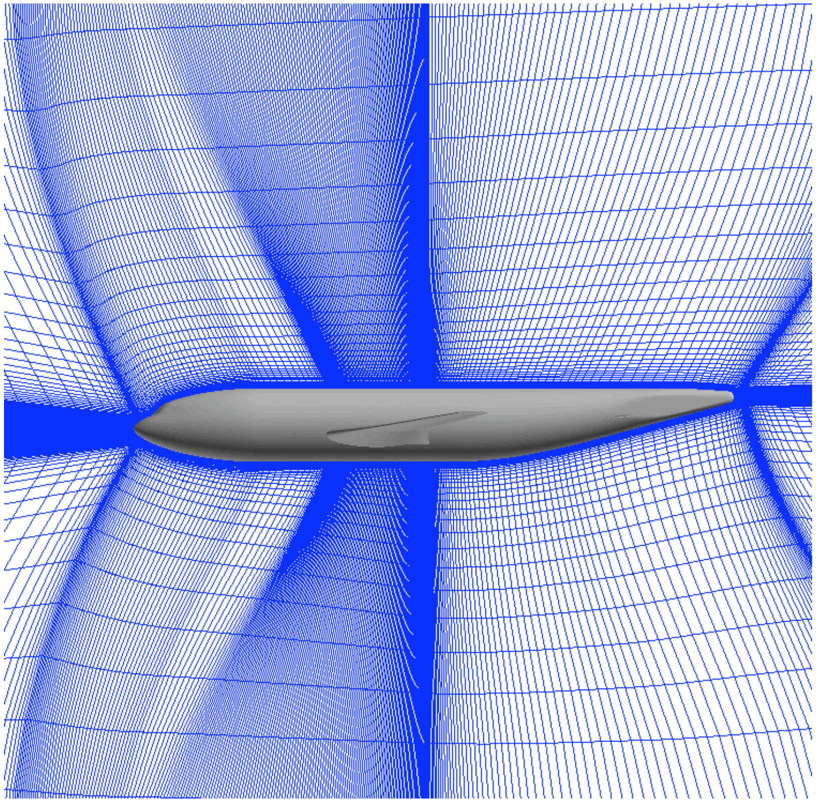
DPW2 Run Schedule

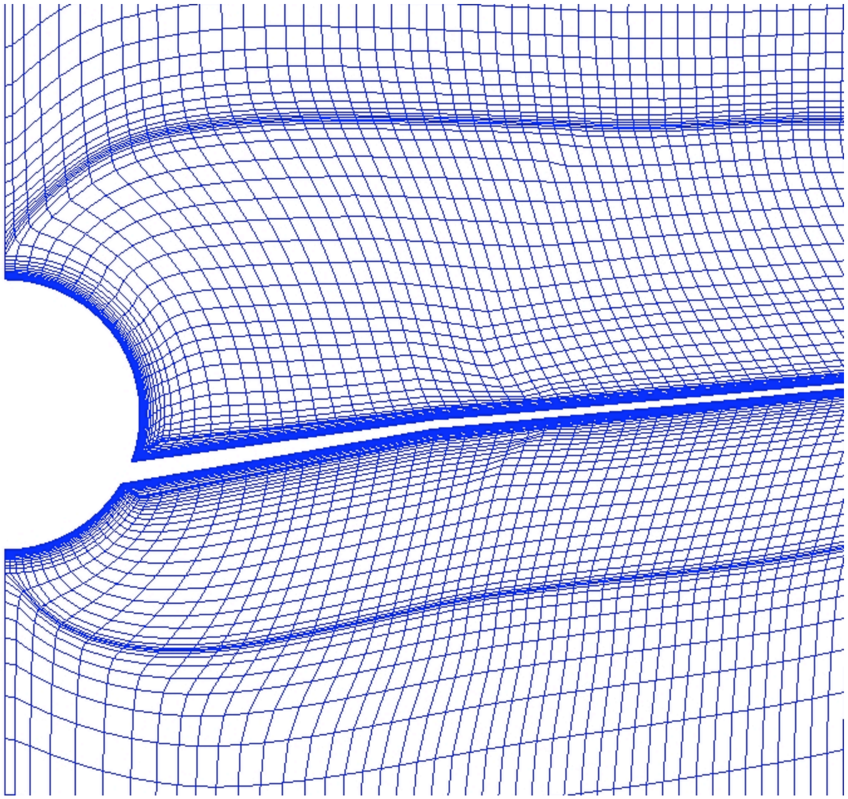
	Wing-Body			Wing-Body-Engine		
	C	M	F	C	M	F
▪ ICEM-CFD	x	x	x	x	x	x
▪ BOEING	x			NC		
▪ MBGRID	x	x		x		

- Drag polars (7 alpha runs) for the 6 ICEM-CFD meshes were run on the 32 CPU NEC SX7 Supercomputer in Japan in collaboration with NEC/CRAY
- All other runs ran on the 8-CPU NEC SX6 Supercomputer of Bombardier Aerospace

WB& WBE MBGRID Meshes

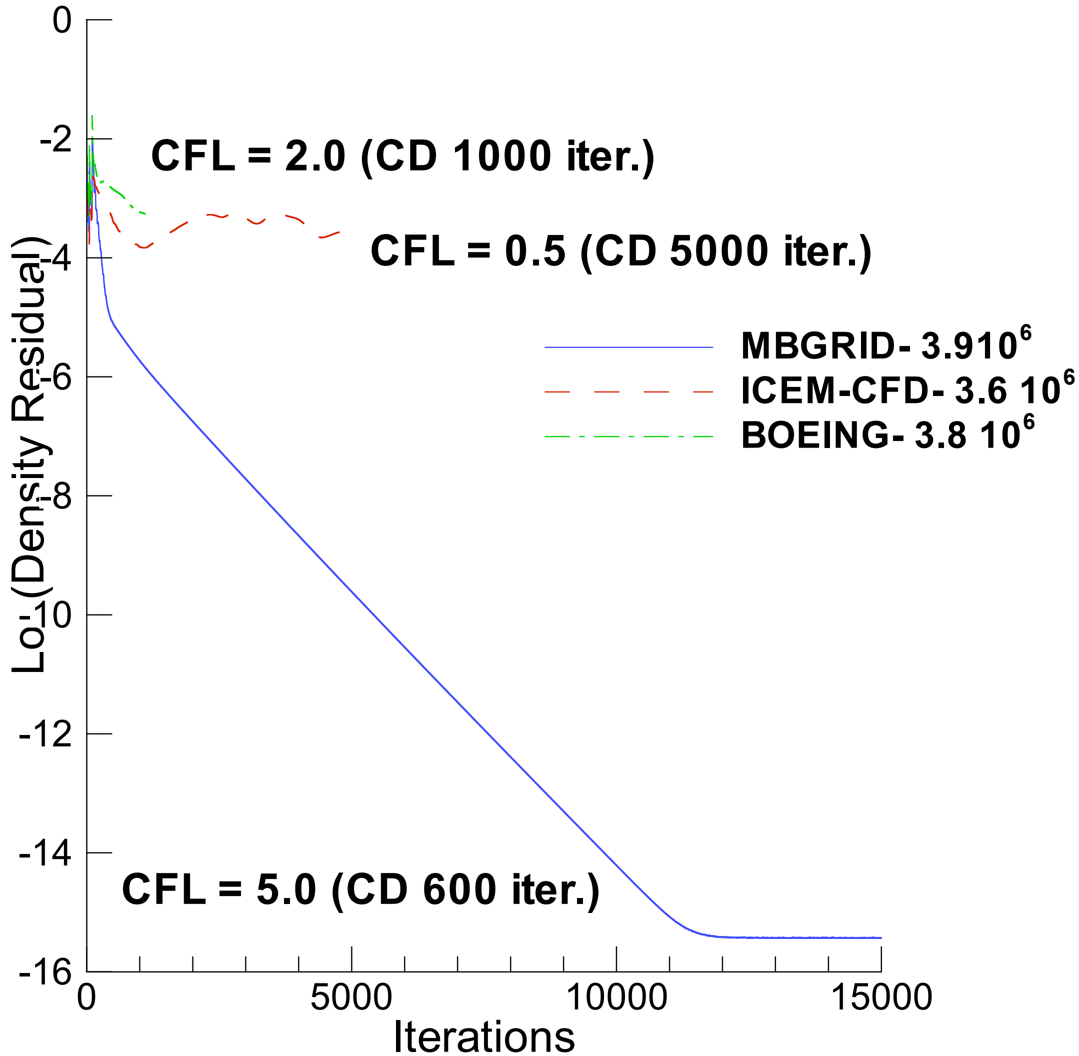
- **MBGRID mesh with “skin-growth” approach**
  - Mixed O-H topology with inner skin (thickness ~4% chord)
  - No geometric modification to CAD surface
- **EGRID Elliptic Smoothing to Ensure Orthogonality**
- **First cell height y+<1, far-field ~ 50 chords**





WB-C Effect of Different Grids on Convergence

M=0.75
□=0.5°
Re=3M



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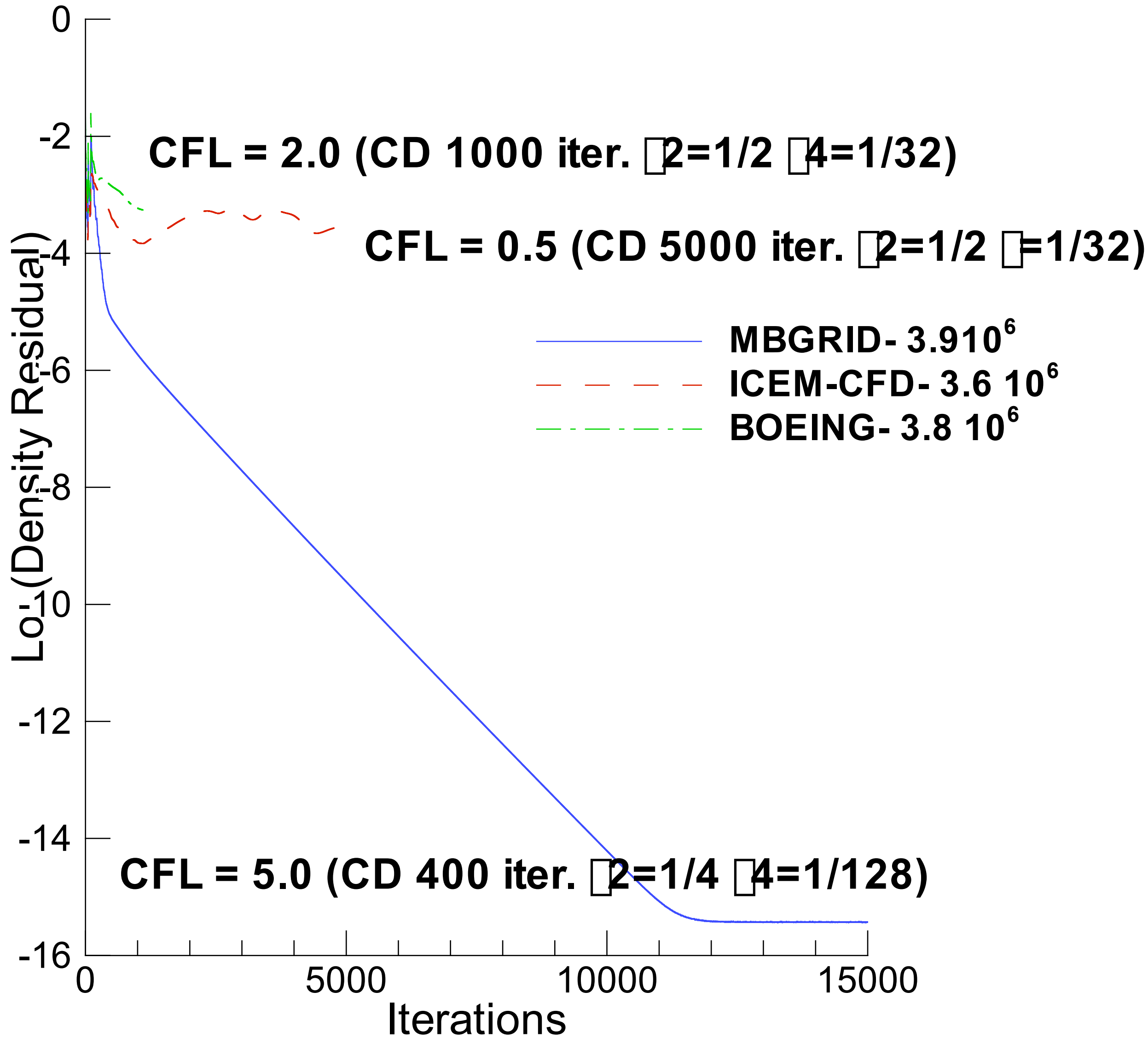
WB-C Effect of Different Grids on Convergence

M=0.75
□=0.5°
Re=3M



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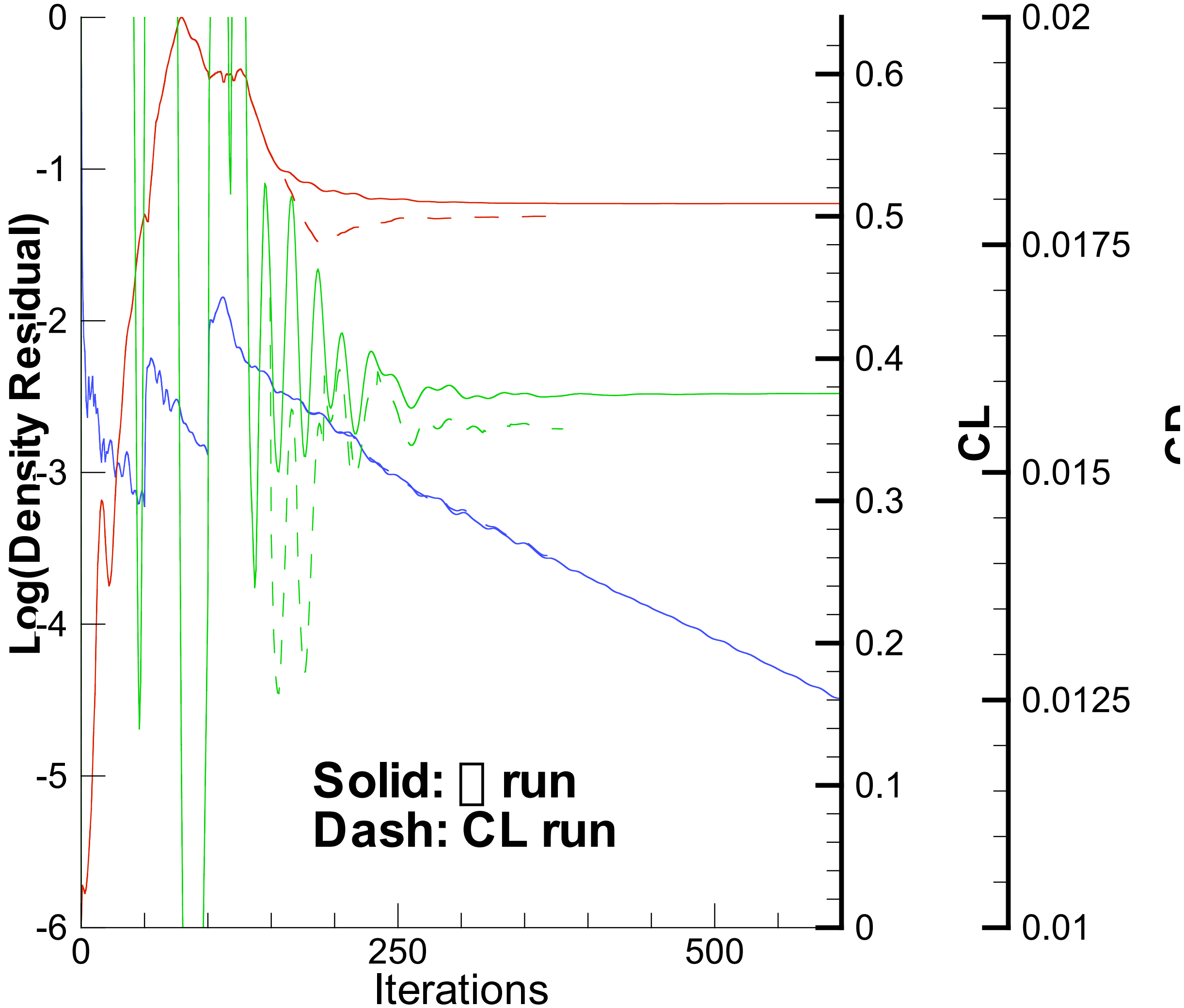
WB-C Alpha Run and CL Runs on MBGRID Mesh

M=0.75
□=0.5°
Re=3M

M=0.75
CL=0.5
Re=3M



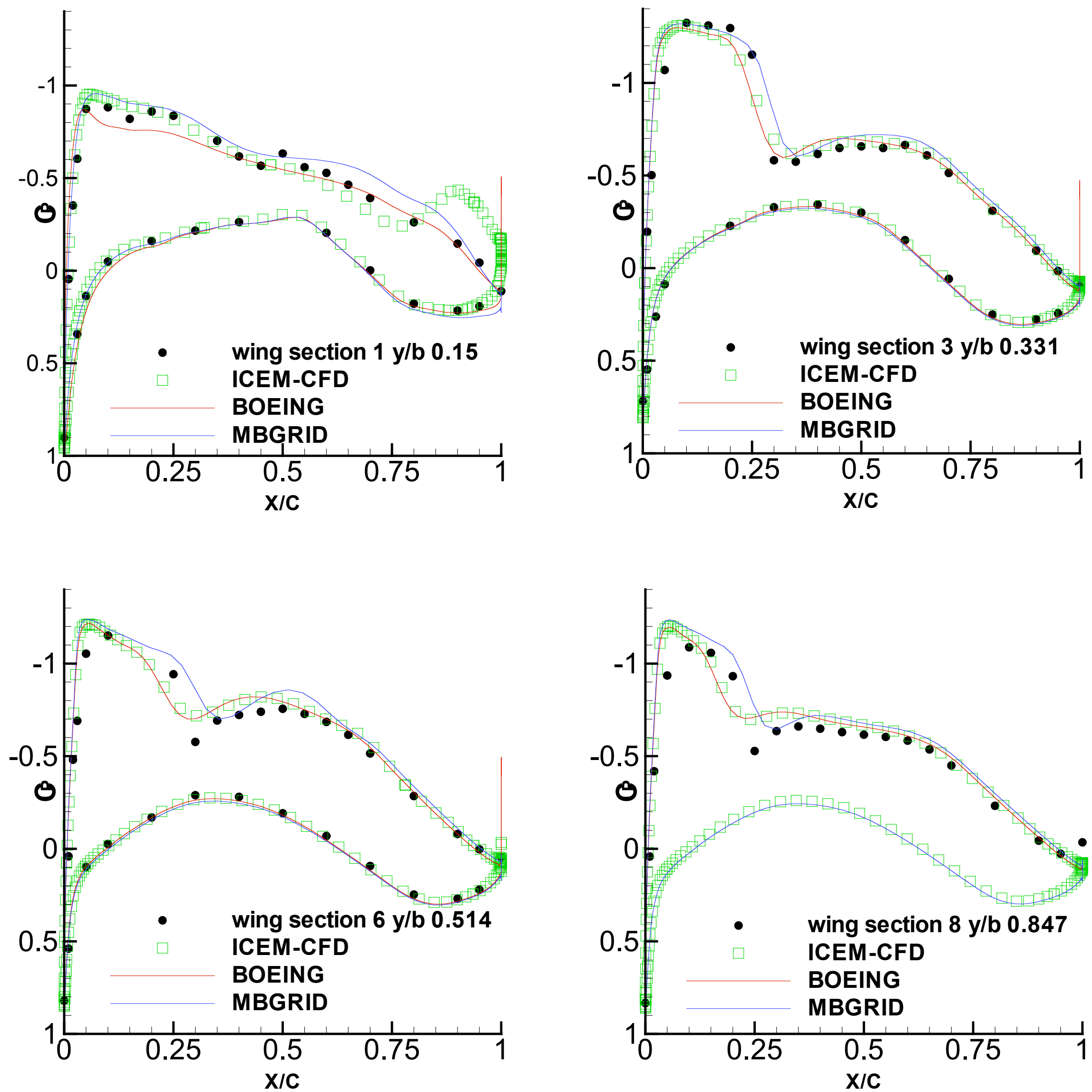
Run Time 1:30 on 4 CPU NEC SX6

WB-C Effect of Different Grids on CPs

M=0.75

□=0.5°

Re=3M



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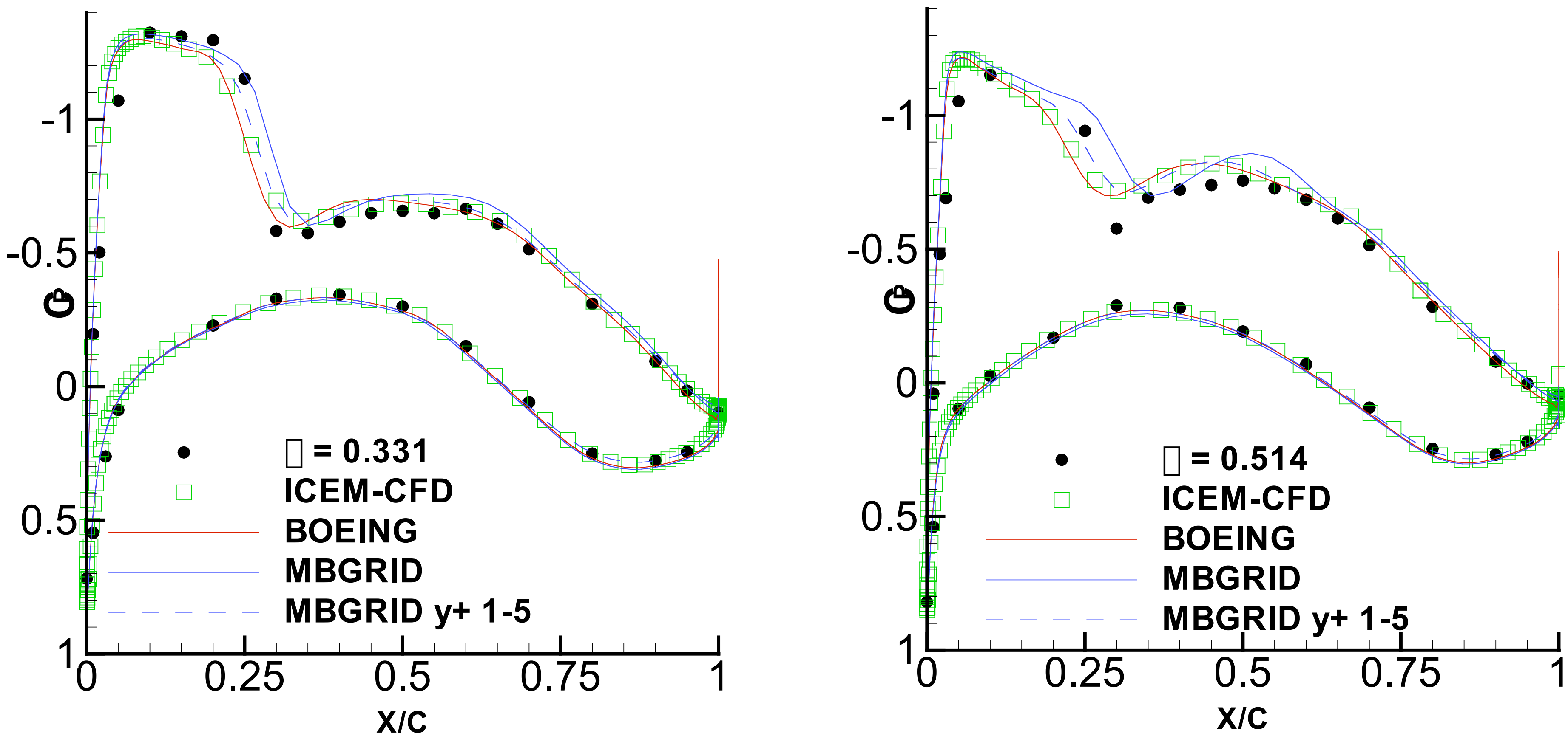
WB-C Effect of y+ on CPs

M=0.75
=0.5°
Re=3M



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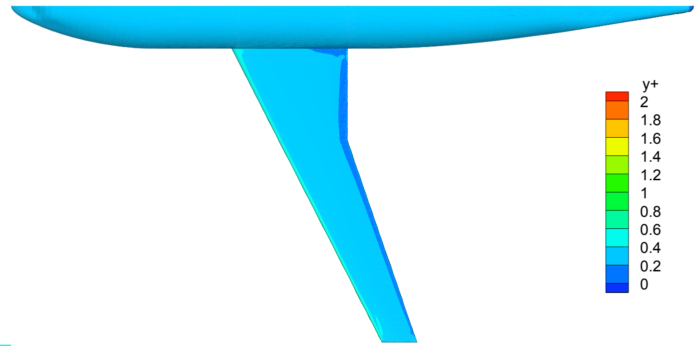
WB-C Y+ on Different Grids

M=0.75

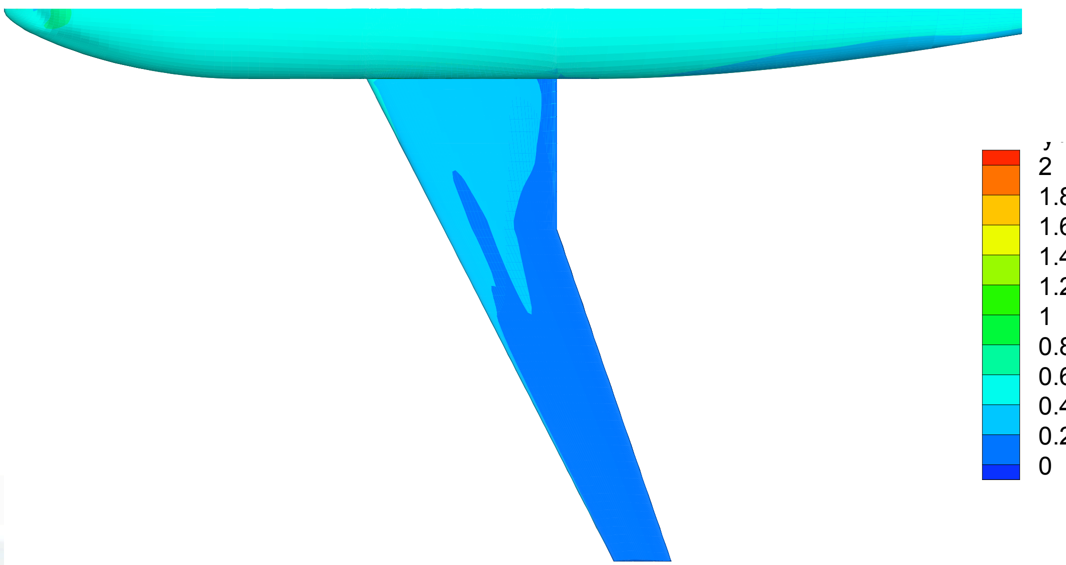
□=0.5^{o}

Re=3M

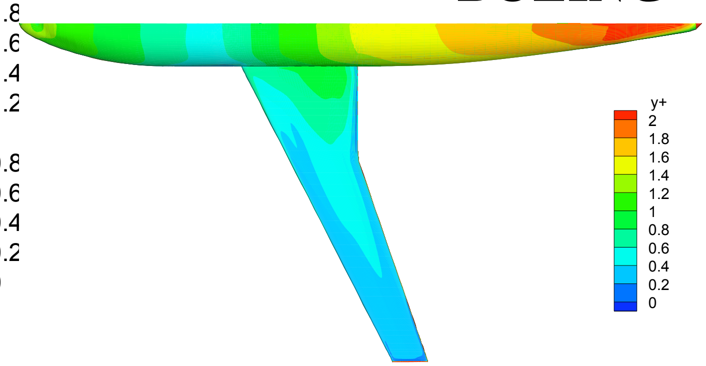
ICEM-CFD



MBGRID



BOEING



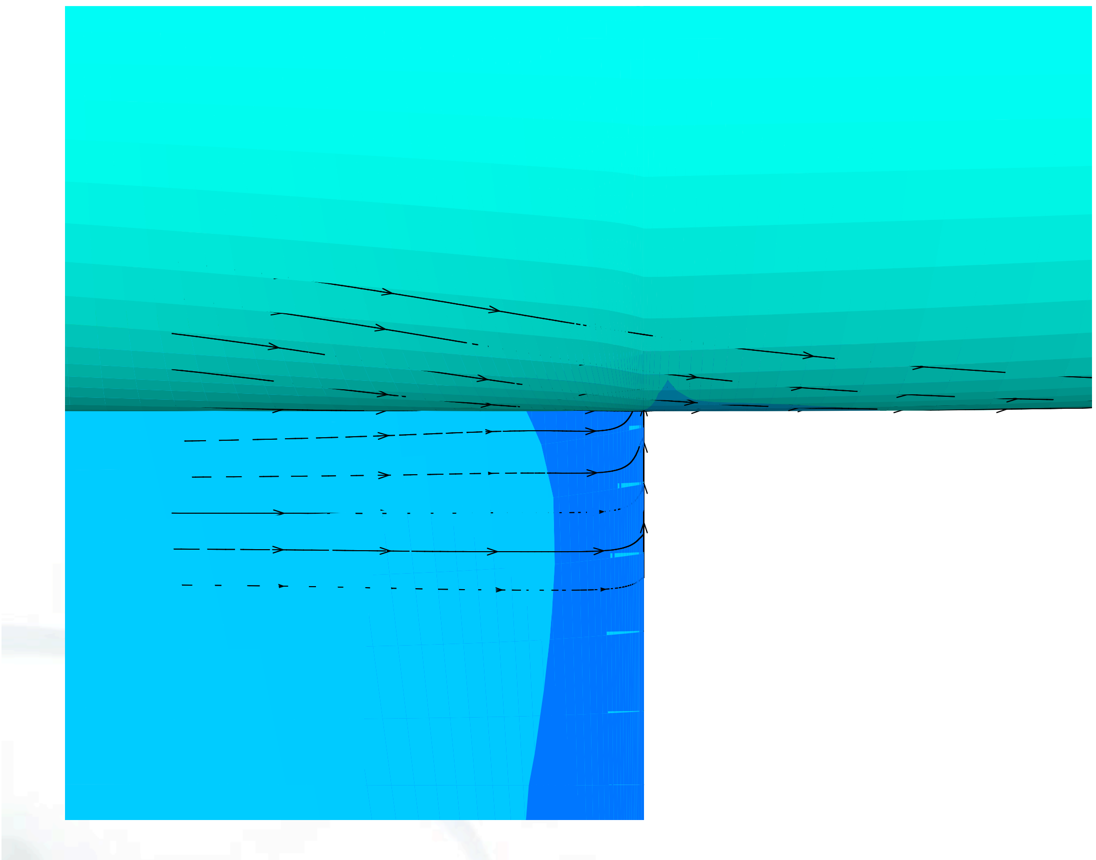
WB-C Separation on different grids

M=0.75

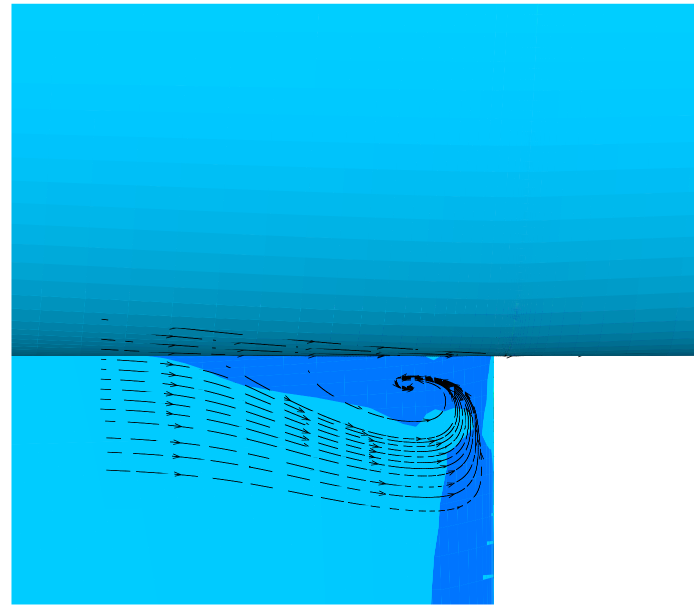
□=0.5°

Re=3M

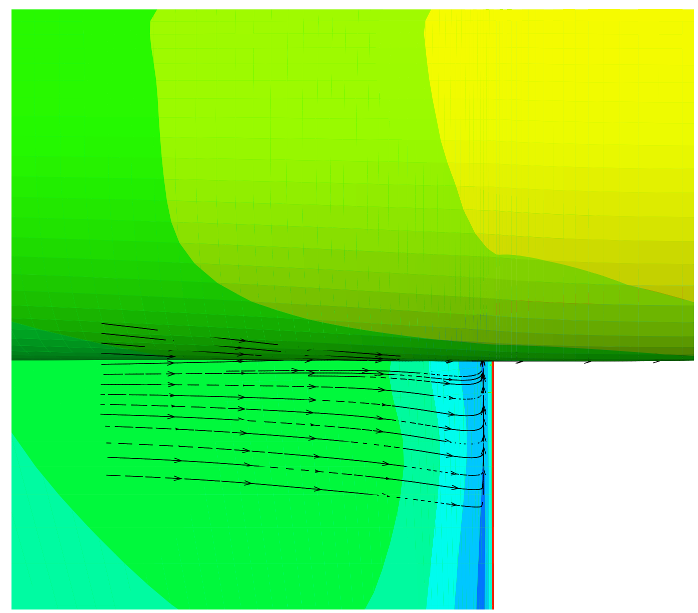
MBGRID



ICEM-CFD



BOEING



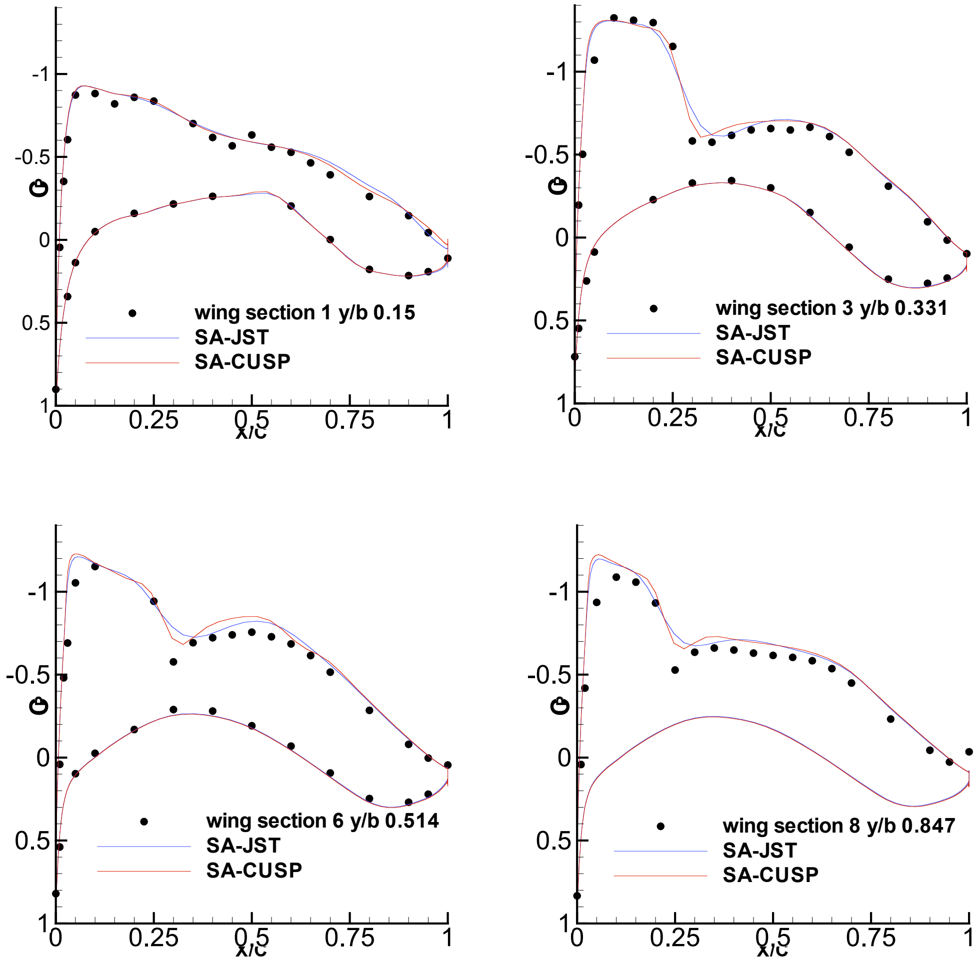
WB-C Effect of Artificial Dissipation

- **Pressure distributions obtained with CUSP scheme sharper than those obtained with the JST scheme, as expected**

M=0.75

□=0.5^{o}

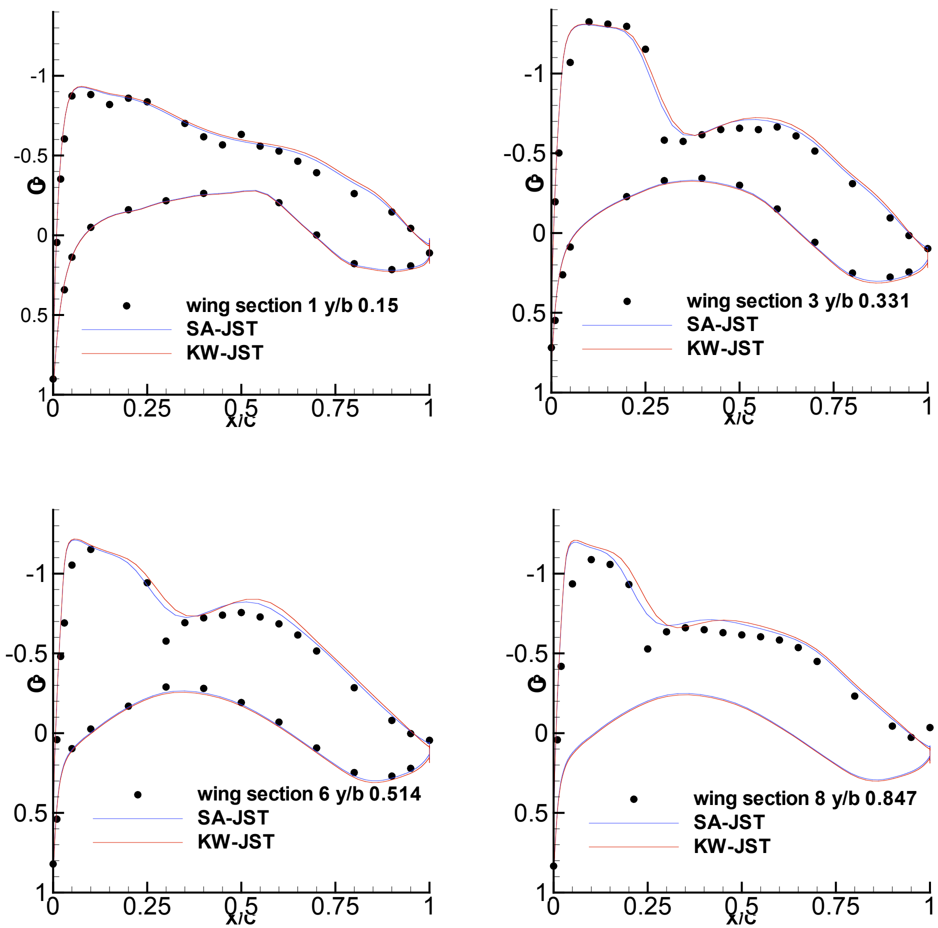
Re=3M



WB-C Effect of Turbulence Model

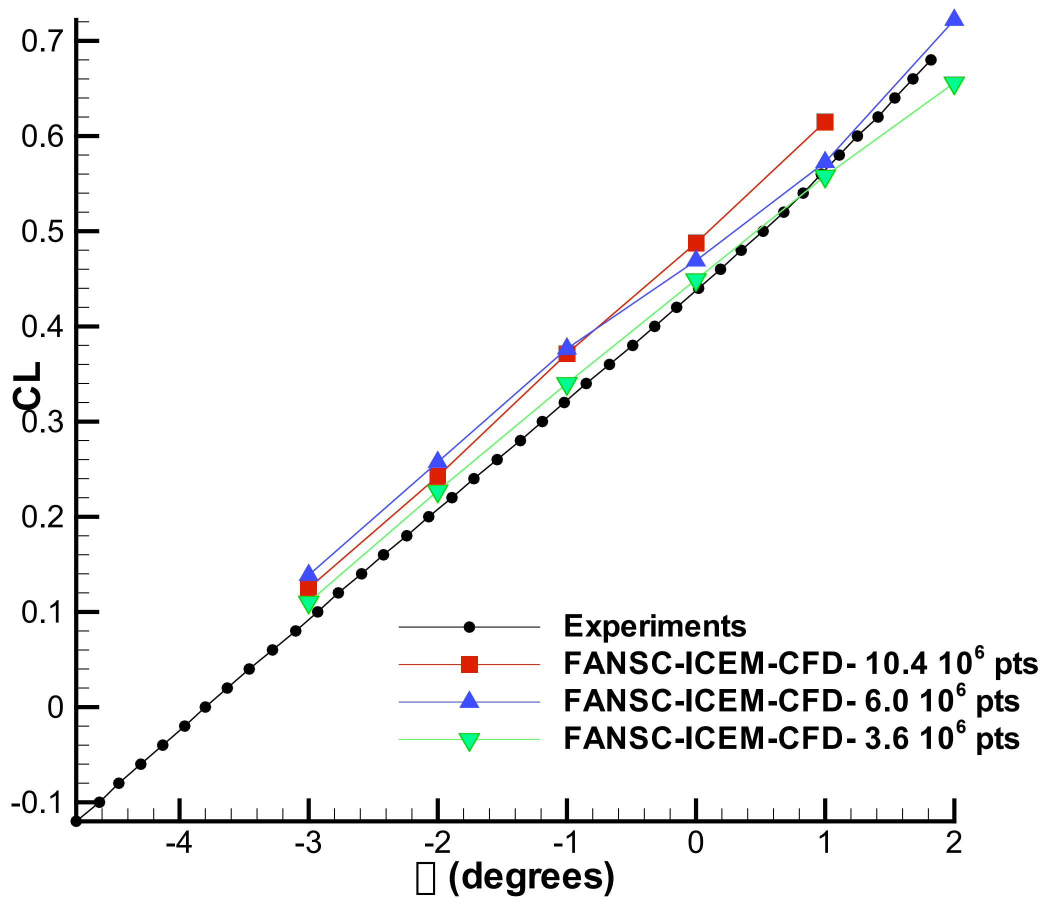
- **Pressure distributions obtained with Spalart-Allmaras turbulence model are as good as those obtained with the k-ω model, as expected for this "attached" flow condition**

M=0.75
α=0.5°
Re=3M



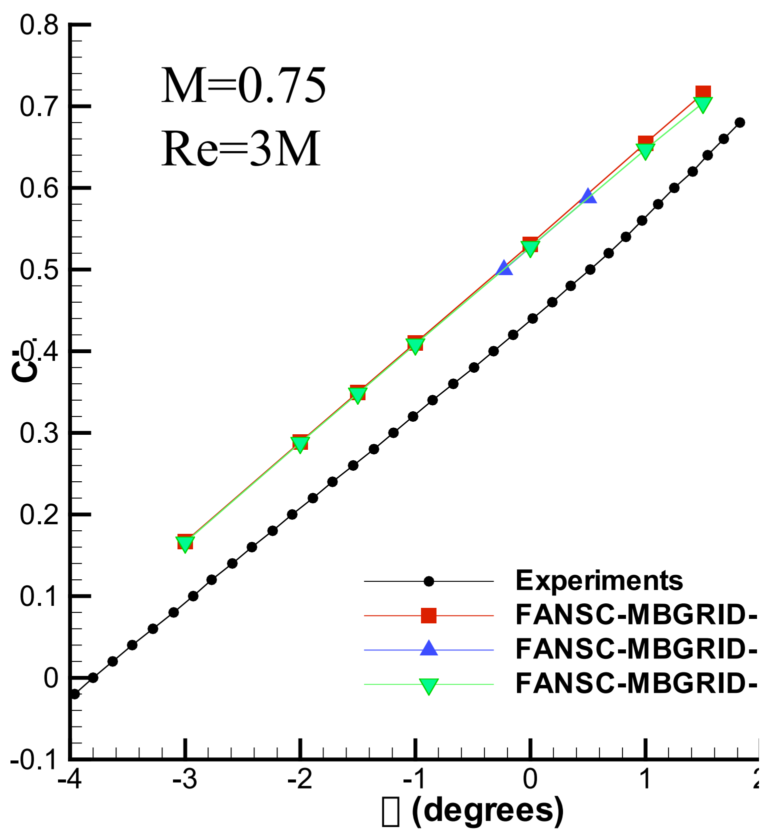
Wing-Body ICEM-CFD- grid convergence

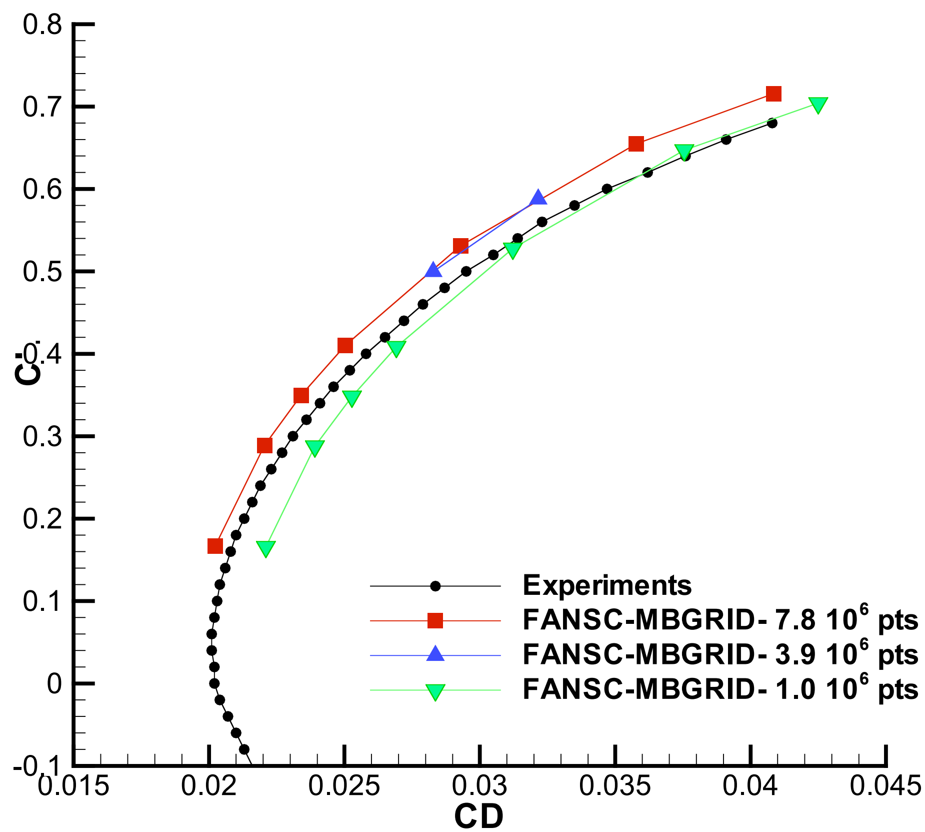
- **Convergence issues results in inconsistent data**



WB MBGRID- grid convergence

Lift less sensitive to mesh density than drag



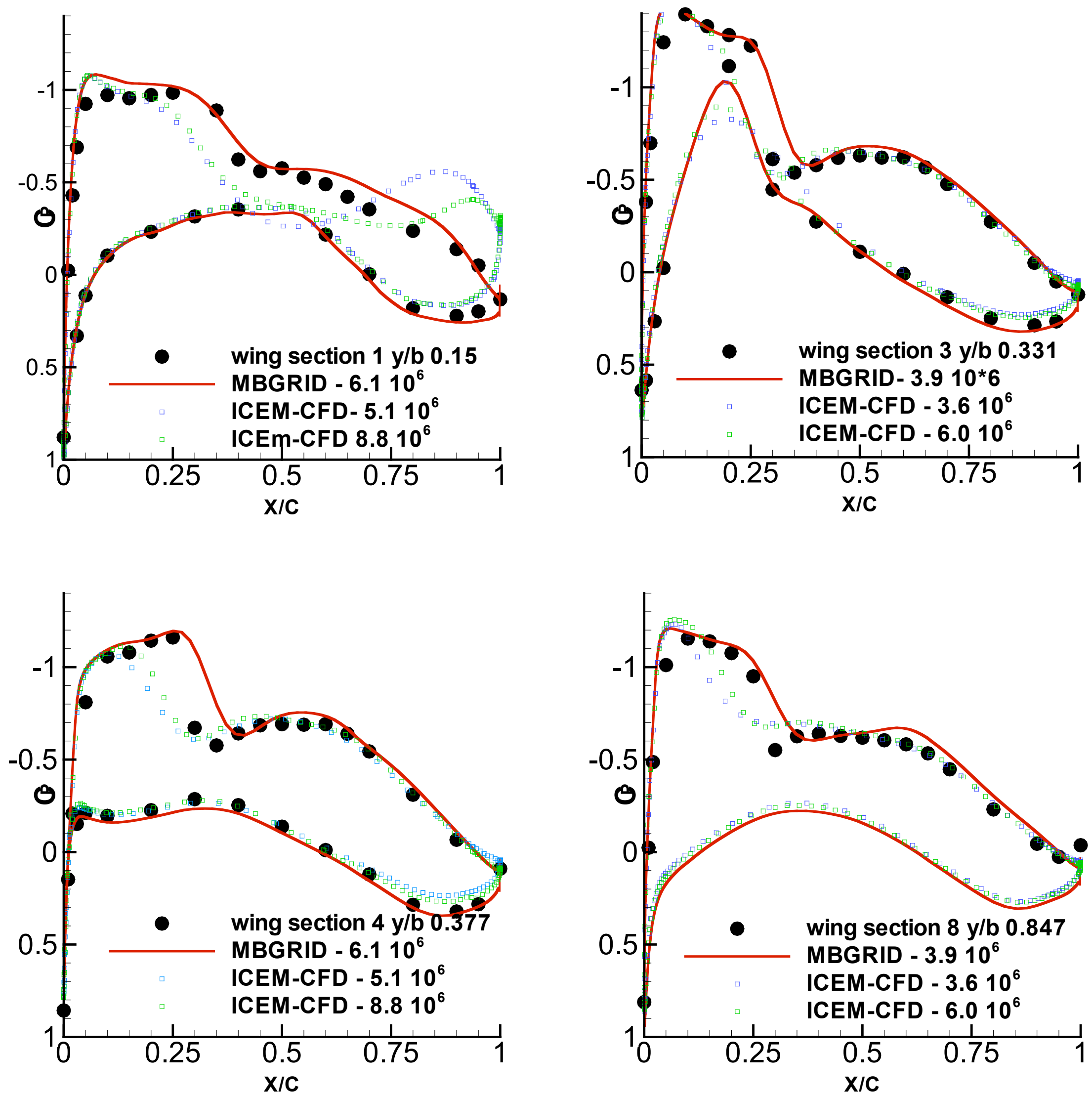


WBN Effect of Different Grids

M=0.75

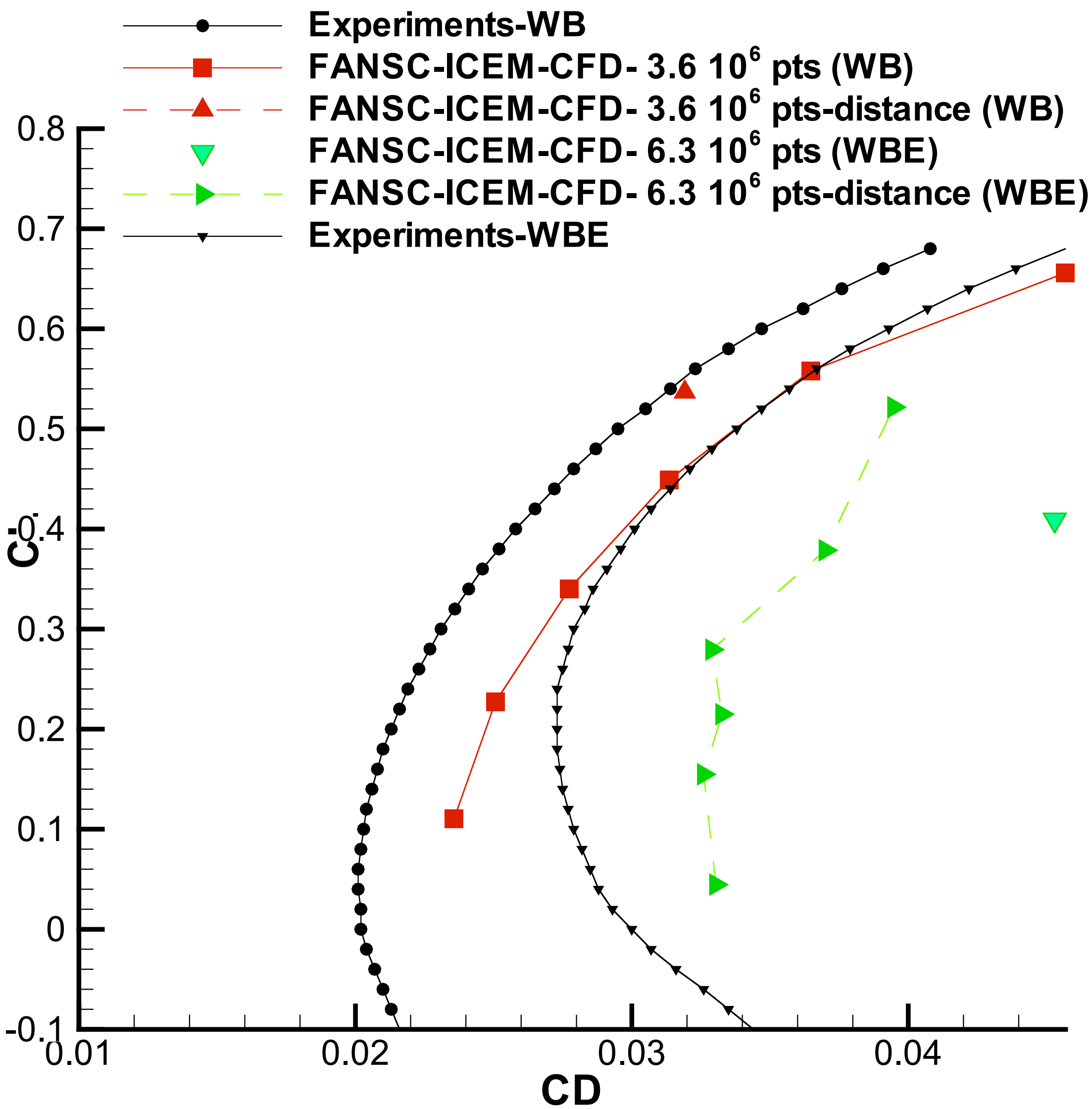
□=1.0°

Re=3M



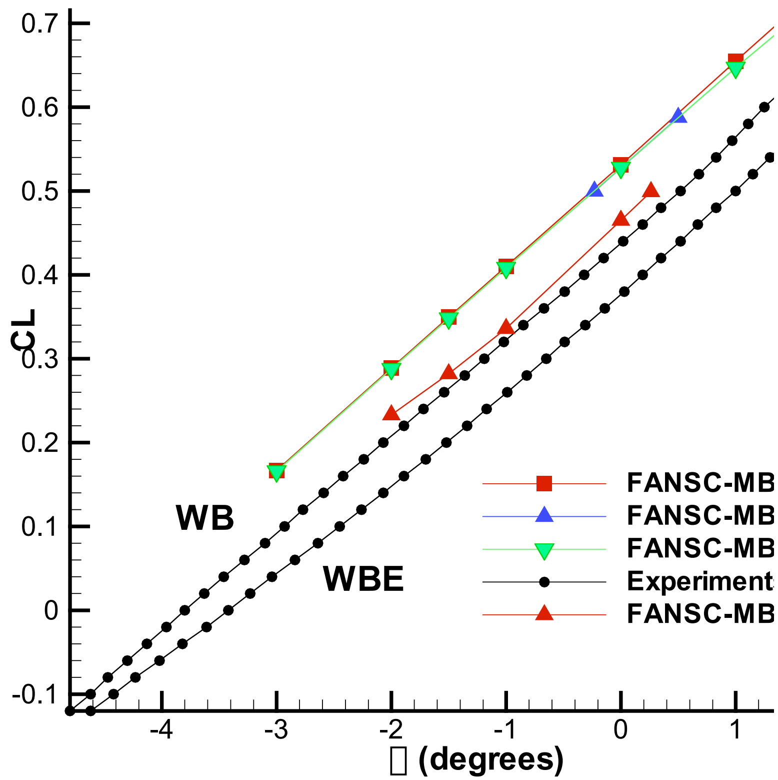
WBN-C Effect of Normal Wall Distance Calculation on ICEM-CFD Meshes

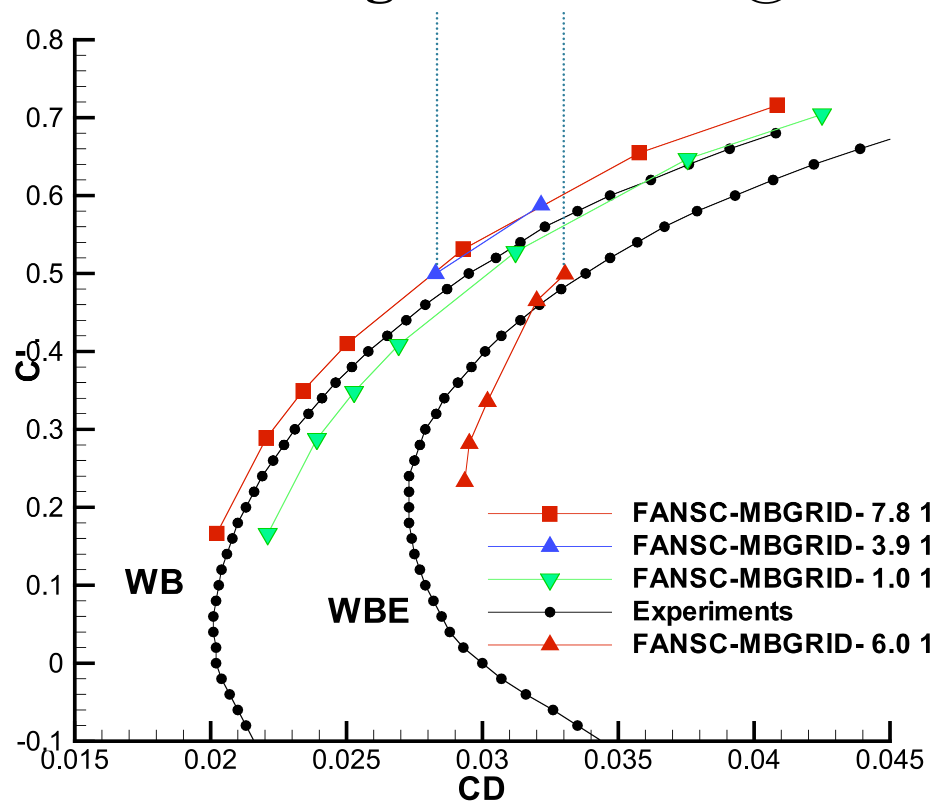
M=0.75
Re=3M



WBN-C Drag Polar with MBGRID

Installation drag = 41Counts @ CL=0.5





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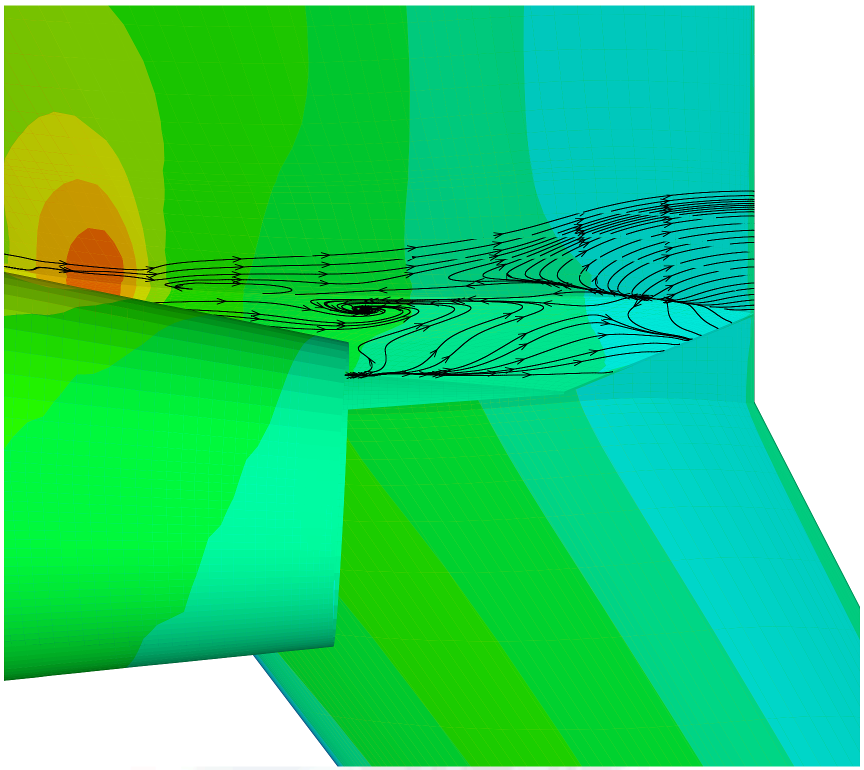
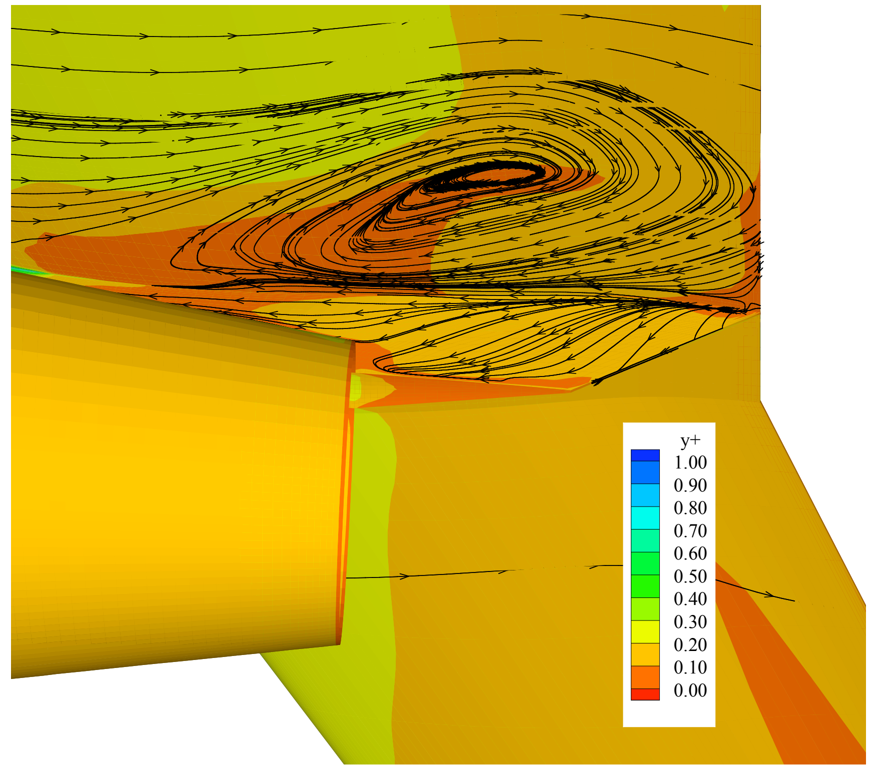
WBN-C Flow Details on FANSC/MBGRID Results

M=0.75
CL=0.5
Re=3M

M=0.75
□ = -2°
Re=3M





Conclusions

- **Several issues remains, even for wing-body test cases**
  - Grid attributes influences the results even more so than mesh density on the same grid template
  - y+< 1 is a necessary but not sufficient condition
  - CL at constant overpredicted by most codes in DPW1 and our results of DPW2
  - Drag polar difficult to obtain with absolute accuracy

- **WBE test cases issues**
  - Convergence deterioration, especially since large areas of flow separation are almost always presents near the pylon
  - Stiffness of the mesh generation process in wing-pylon-engine area