2nd AIAA CFD Drag Prediction Workshop

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DLR-F6 Wing-Body-Nacelle Simulations

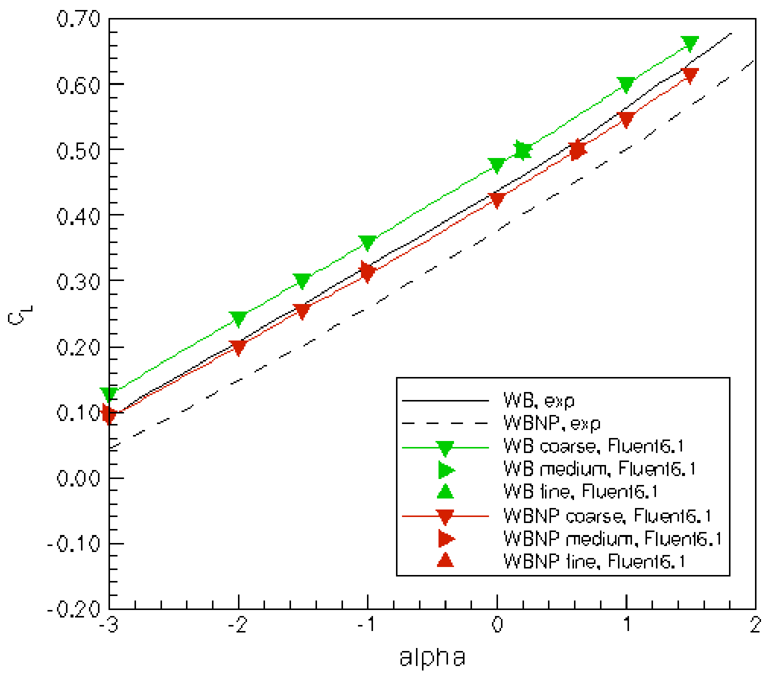
- Fluent 6 - Unstructured solver
- Single point grid sensitivity study for M=0.75, C_L=0.5 on provided point-matched ICEM grid
- Drag polar for M=0.75, Re=$3.0x10^6$ on provided point-matched coarse ICEM grid, fully turbulent
- Point-matched structured grid family
- Flow visualization

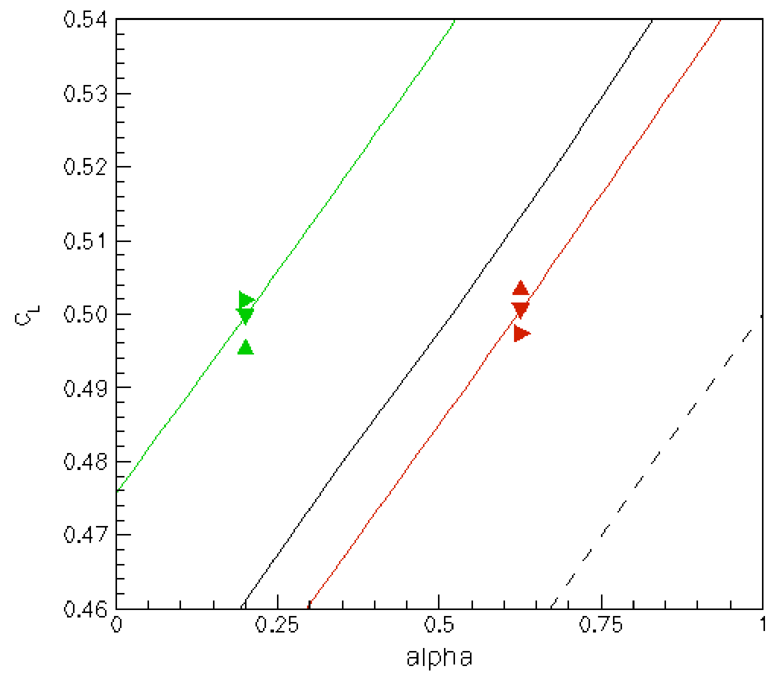
Fluent 6 – Solver

- Cell-centered unstructured on hybrid meshes
- Segregated implicit (pressure based, SIMPLE) and coupled implicit (density based) solver
  - Segregated solver requires 11GB for 13.5M cell fine WBNP case, fits on 8 node Linux cluster with 16GB of RAM
  - Coupled solver doubles the memory requirements, requires more resources
- Second-order upwind reconstruction
- Cell- or node-based gradient calculation
- Algebraic Multigrid
- Realizable k-ϵ turbulence model
- Two-layer zonal model for wall treatment

Single Point Grid Sensitivity: $C_L(\alpha)$

M=0.75, Re=3.0x10^6, segregated node-based solver





- WB coarse: C_L=0.500 at α=0.2007°

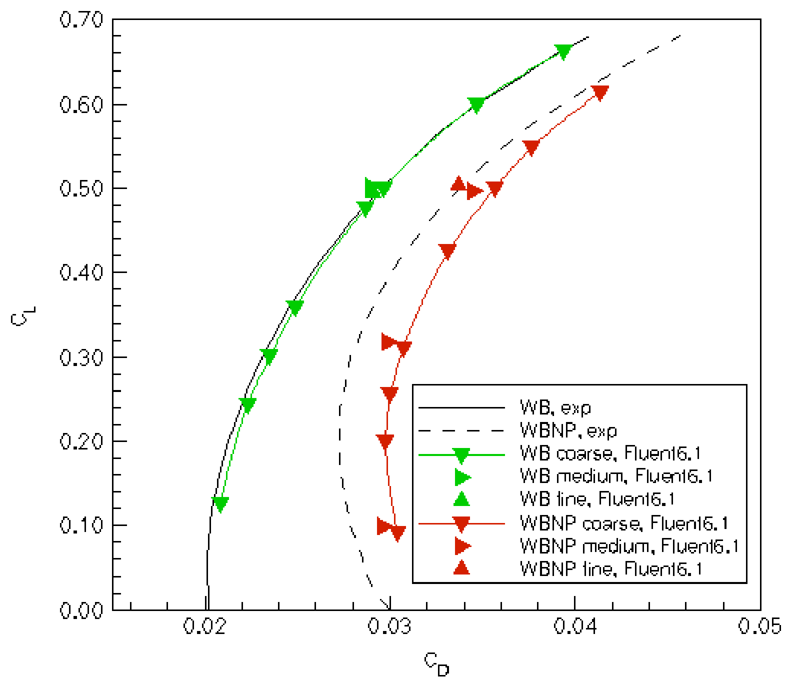
- WBNP coarse: C_L=0.500 at α=0.6263°

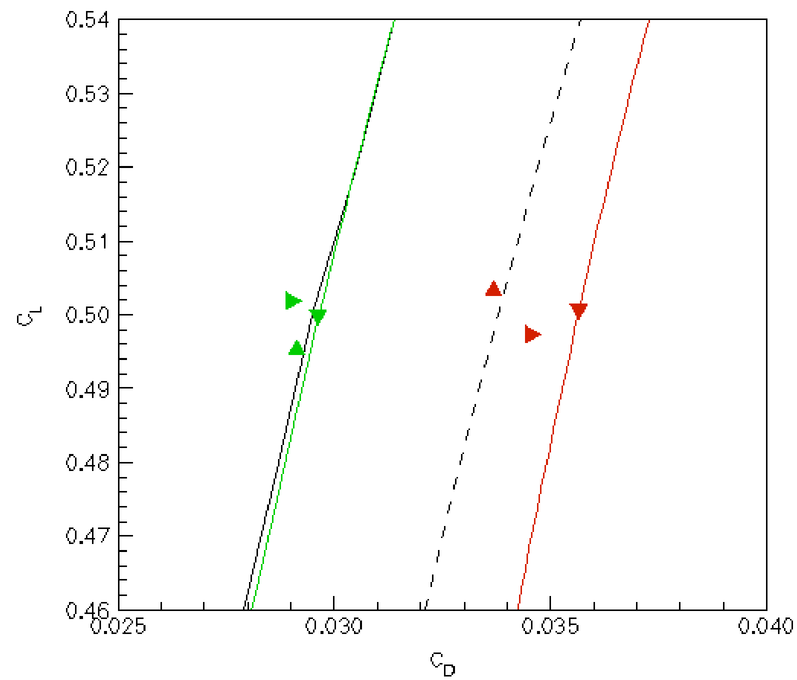
- Medium and fine grid runs at fixed angles of attack obtained from coarse grids

- $C_L(\alpha)$ not monotonically increasing or decreasing as grid is refined

Single Point Grid Sensitivity: $C_L(C_D)$

M=0.75, Re=3.0x10^6, segregated node-based solver





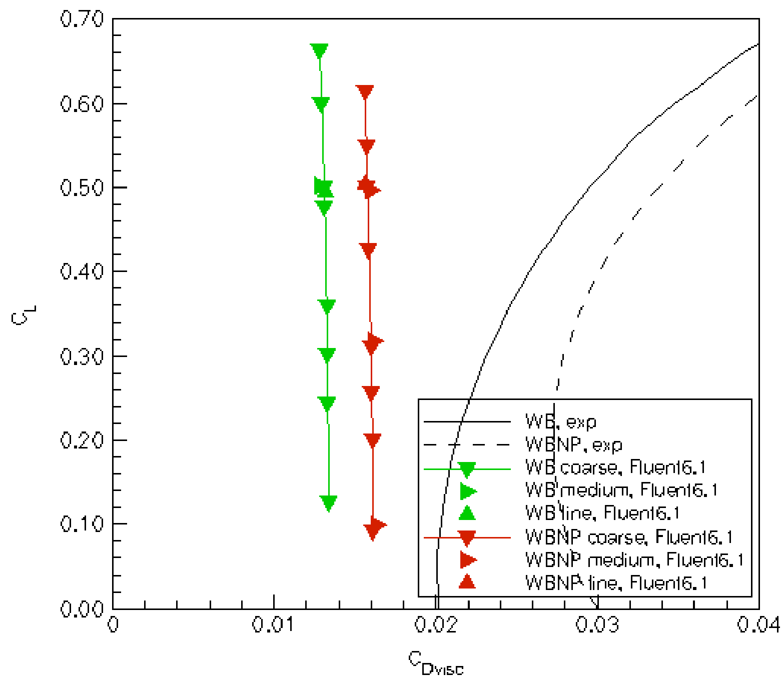
- Deviation in C_L of 0.001 due to fixed angle of attack corresponds at C_L=0.5 to deviation in C_D of less than 0.5 drag counts

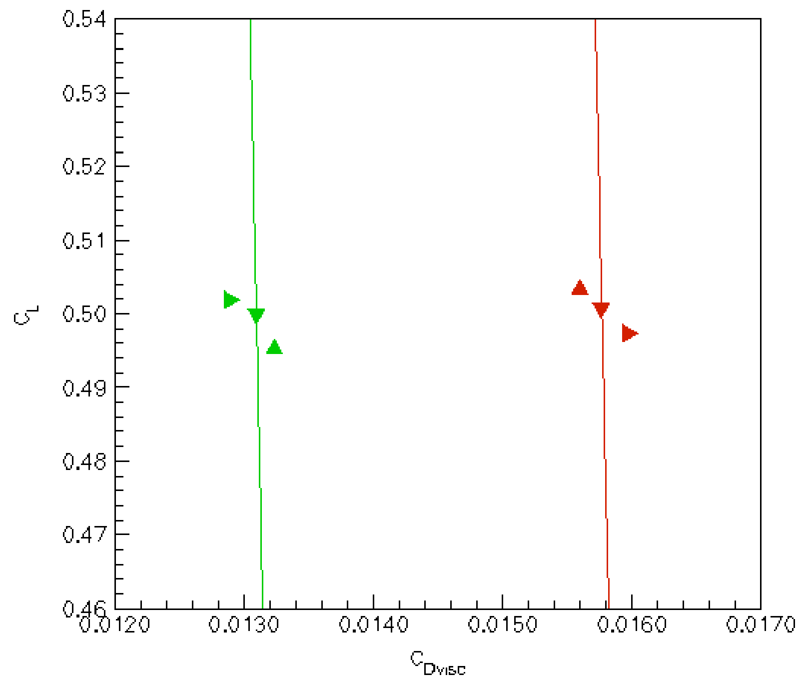
- Monotonic C_D reduction for WBNP with mesh refinement

- Non-monotonic C_D for WB as mesh is refined

Single Point Grid Sensitivity: $C_L(C_{Dvisc})$

M=0.75, Re=3.0x10^6, segregated node-based solver

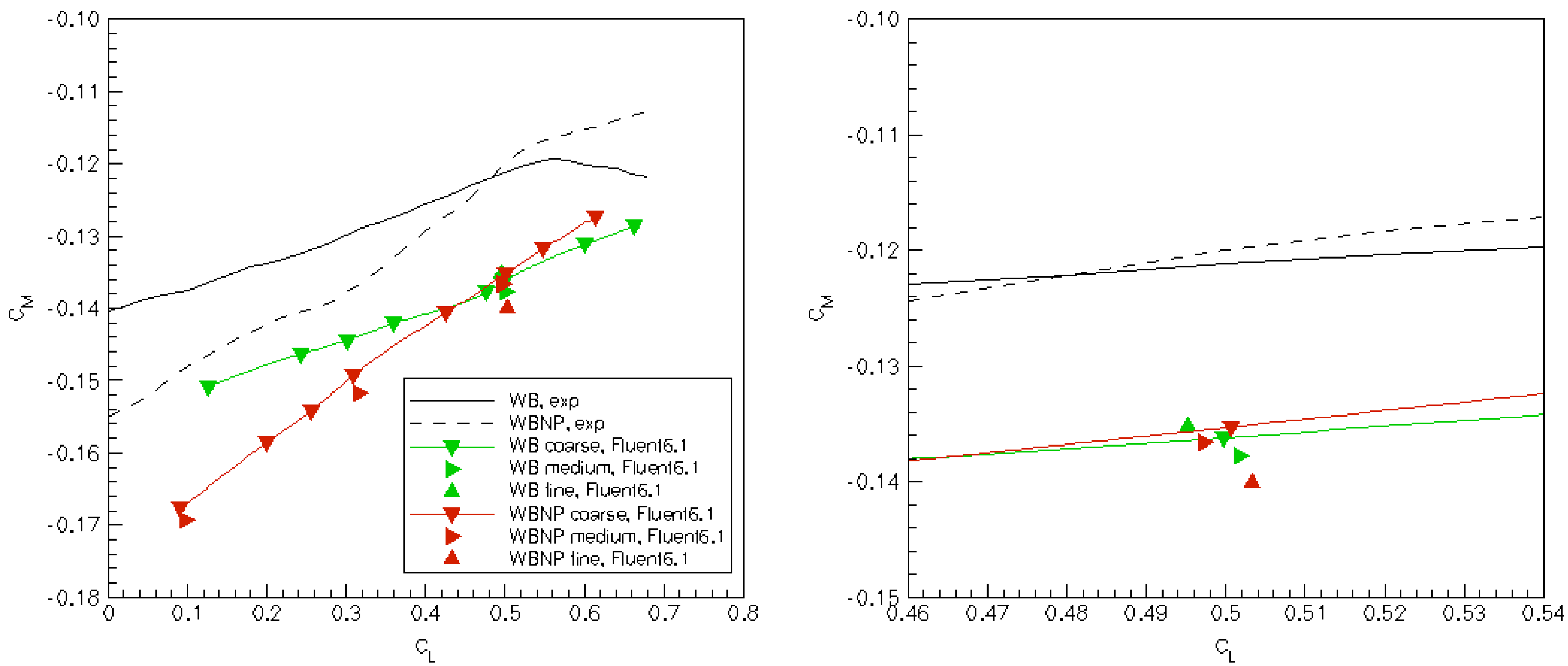




- Viscous drag component C_{Dvisc} not monotonic with grid refinement

Single Point Grid Sensitivity: $C_M(C_L)$

M=0.75, Re=3.0×10^6, segregated node-based solver



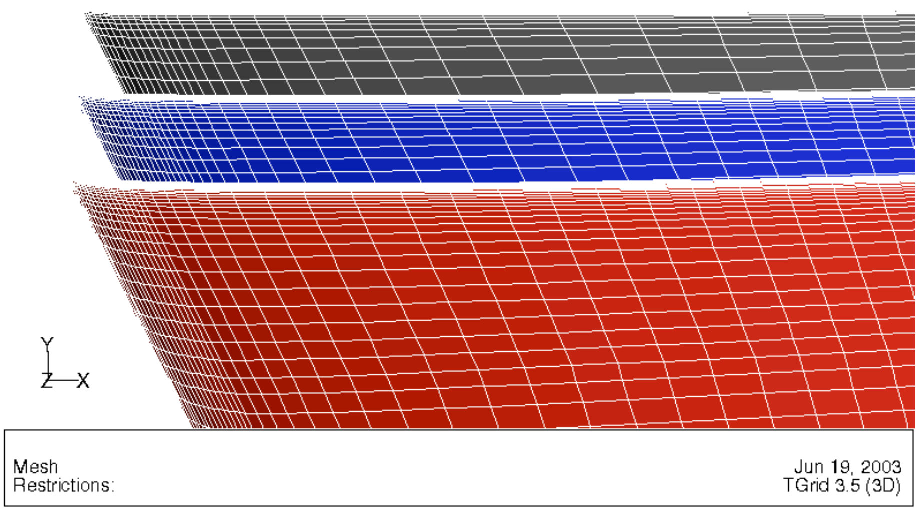
-Too large downward pitching moment for both WB and WBNP

-C_M not monotonic with mesh refinement for WB

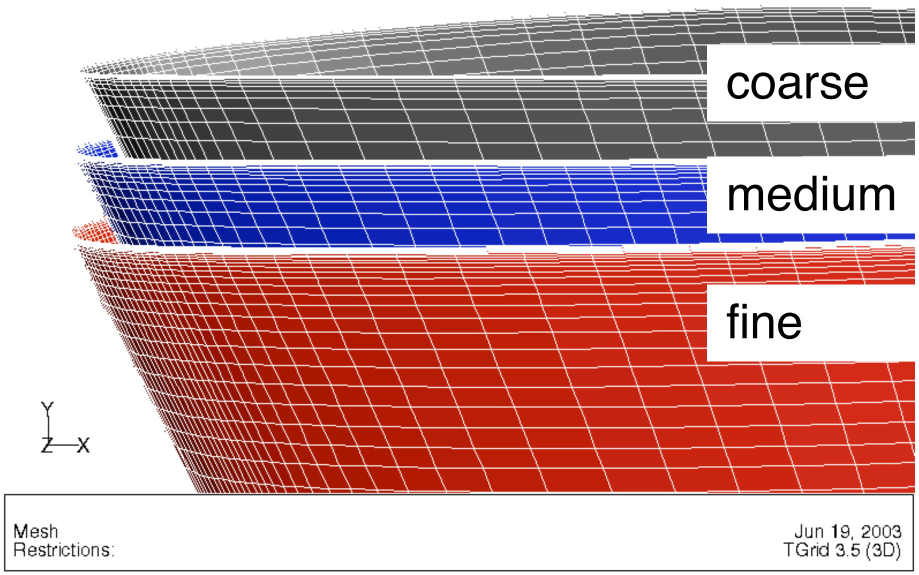
Single Point Grid Sensitivity

ICEM grids at wing root: coarse, medium, fine

WB



WBNP

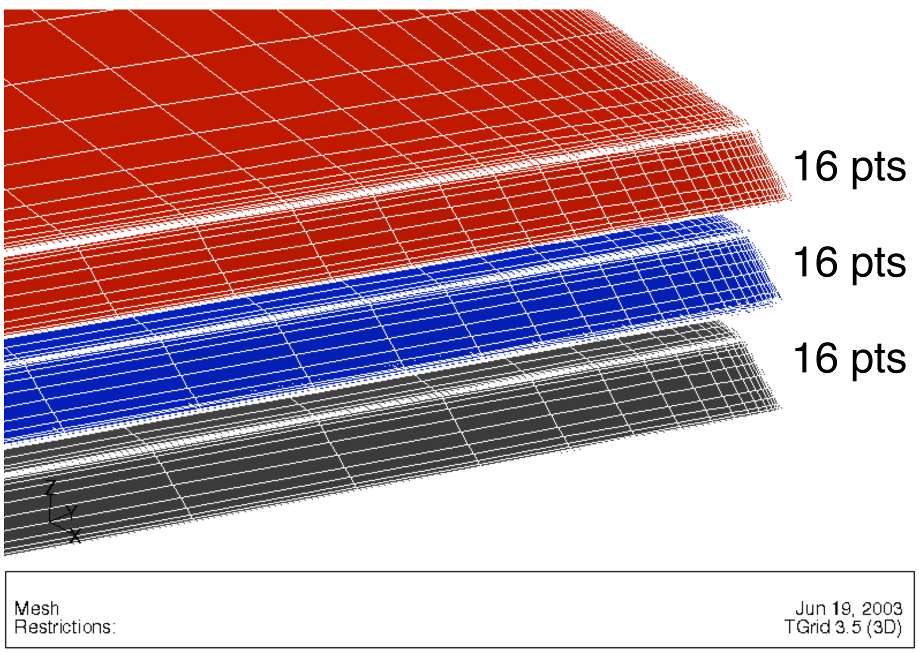


- Nonuniform streamwise refinement
- Medium surface grid locally often finer than fine grid

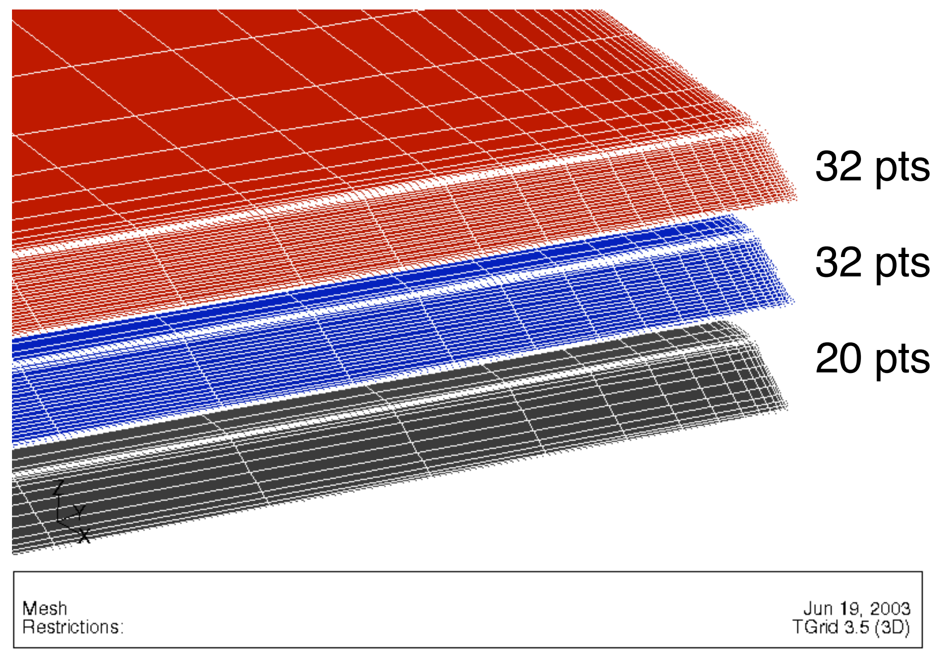
Single Point Grid Sensitivity

ICEM grids at trailing edge: coarse, medium, fine

WB



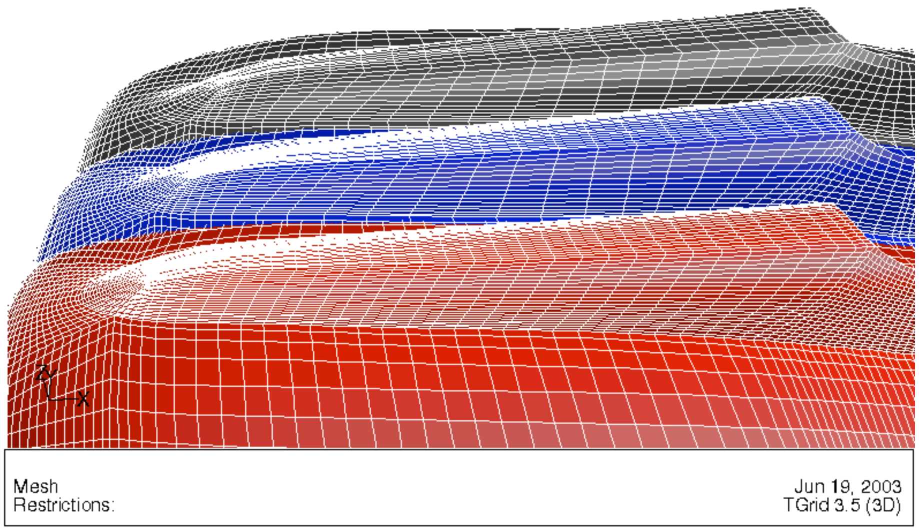
WBNP

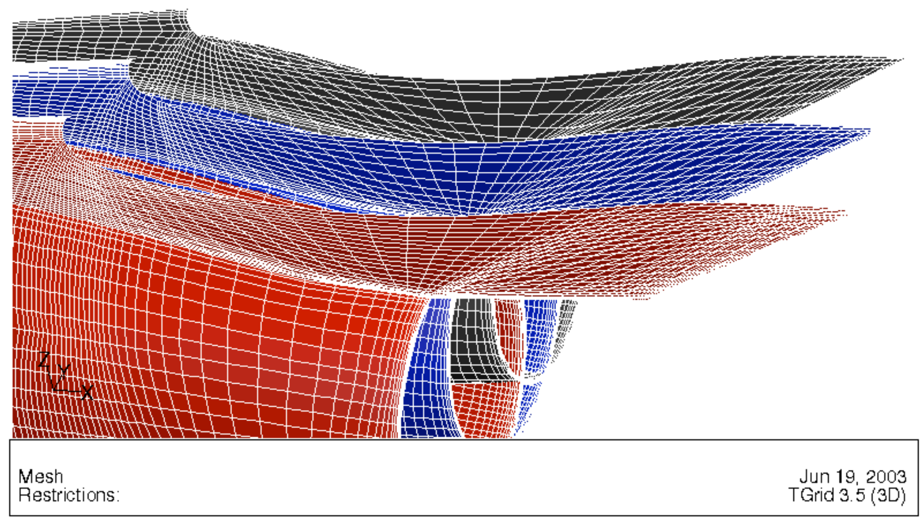


- Irregular trailing edge refinement

Single Point Grid Sensitivity

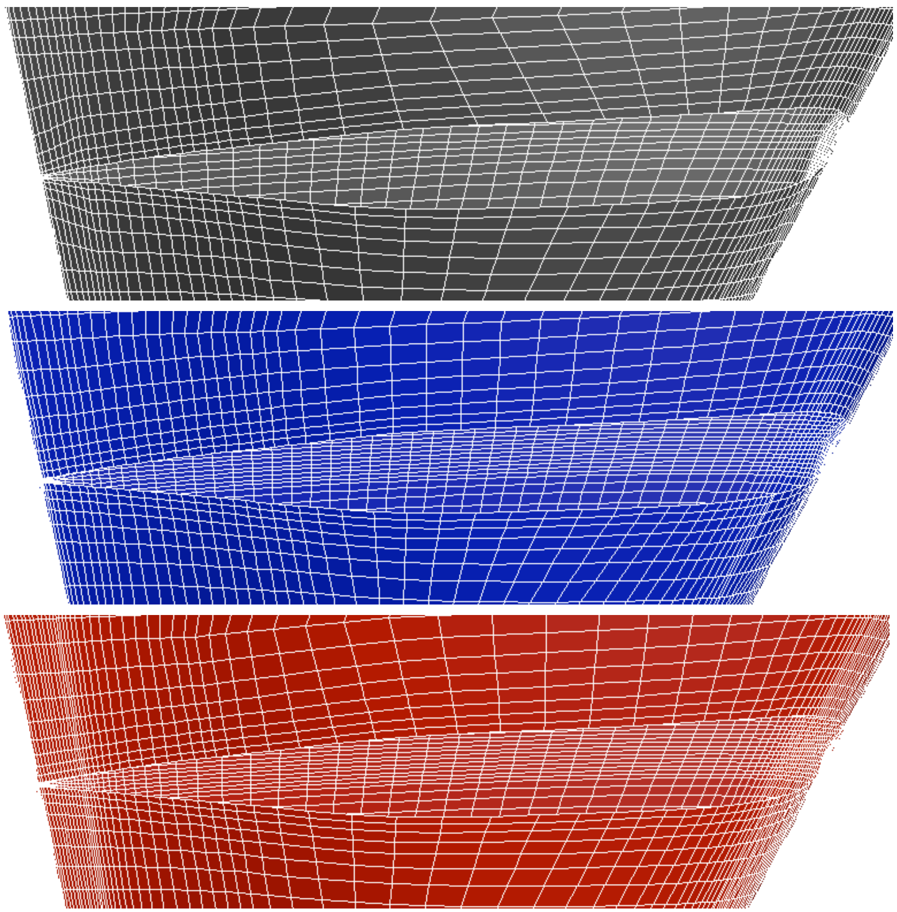
ICEM grids (WBNP) at nacelle, pylon: coarse, medium, fine





Single Point Grid Sensitivity

ICEM grids (WBNP) at bottom wing: coarse, medium, fine



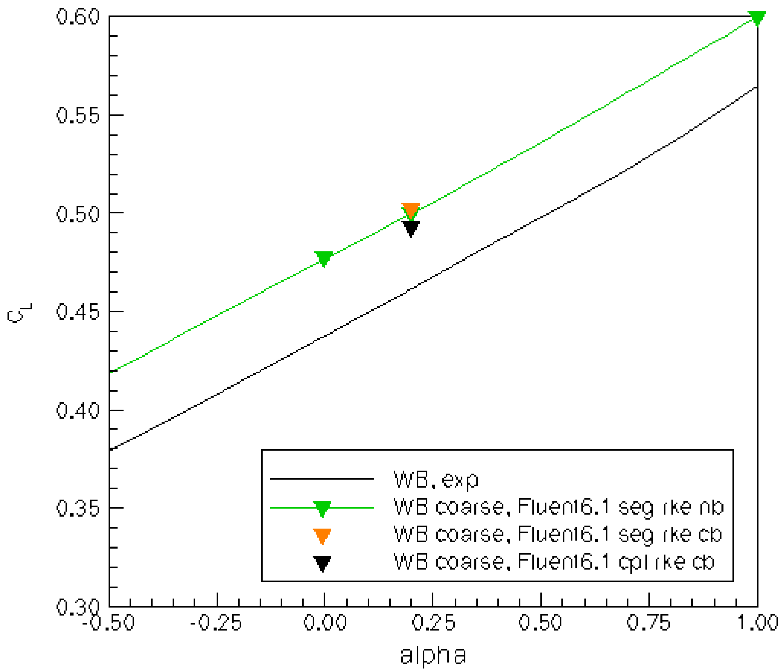
- Medium surface grid is locally often finer than fine grid

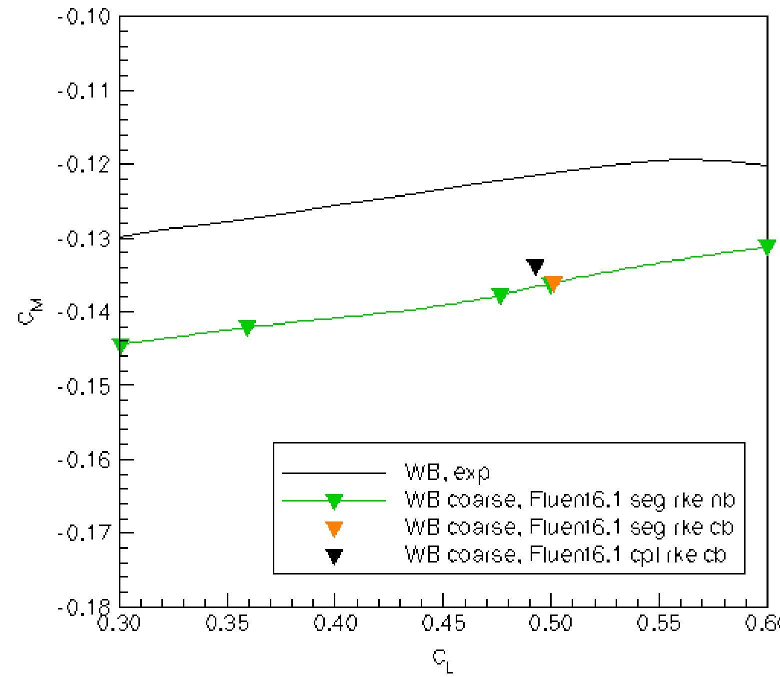
- Refinement levels considerably lower than gridding guidelines (e.g. fine WB wing surface mesh has only 17% more elements than medium WB wing)

- Are results still expected to be monotonic with grid refinement?

WB coarse grid: $C_L(\alpha)$ and $C_M(C_L)$

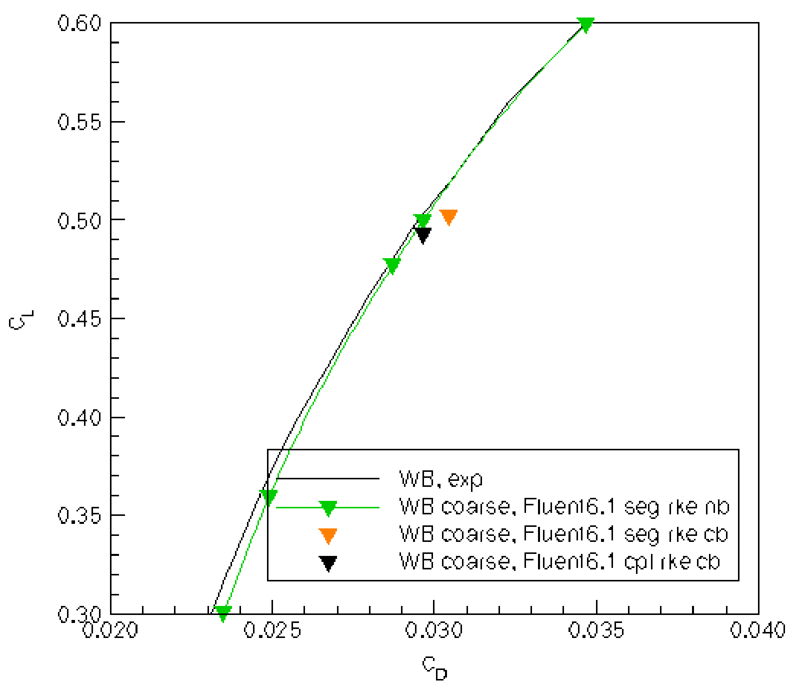
M=0.75, Re=3.0×10^6
Solver: Segregated (seg) vs. Coupled (cpl)
Discretization: node-based (nb) vs. cell-based (cb)

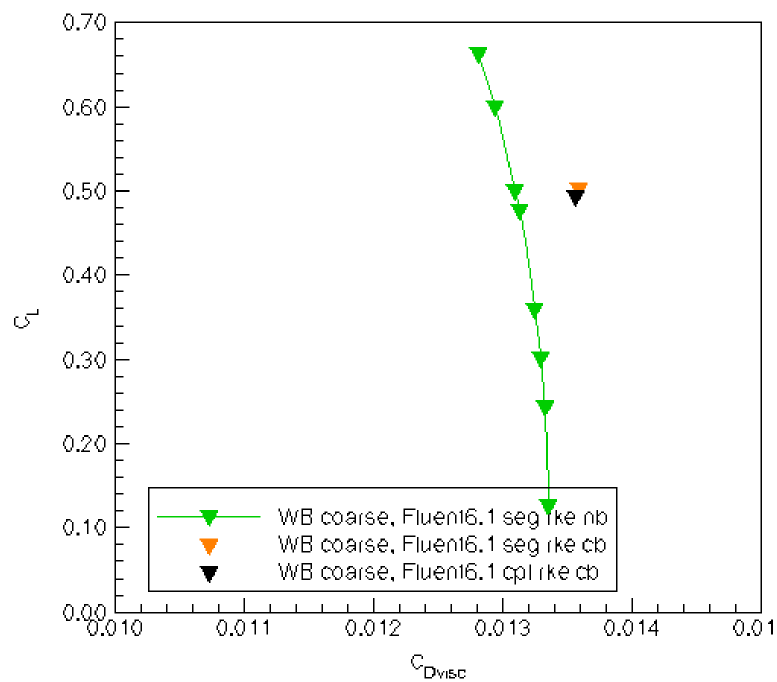




WB coarse grid: $C_L(C_D)$ and $C_L(C_{Dvisc})$

M=0.75, Re=3.0×10^6
Solver: Segregated (seg) vs. Coupled (cpl)
Discretization: node-based (nb) vs. cell-based (cb)

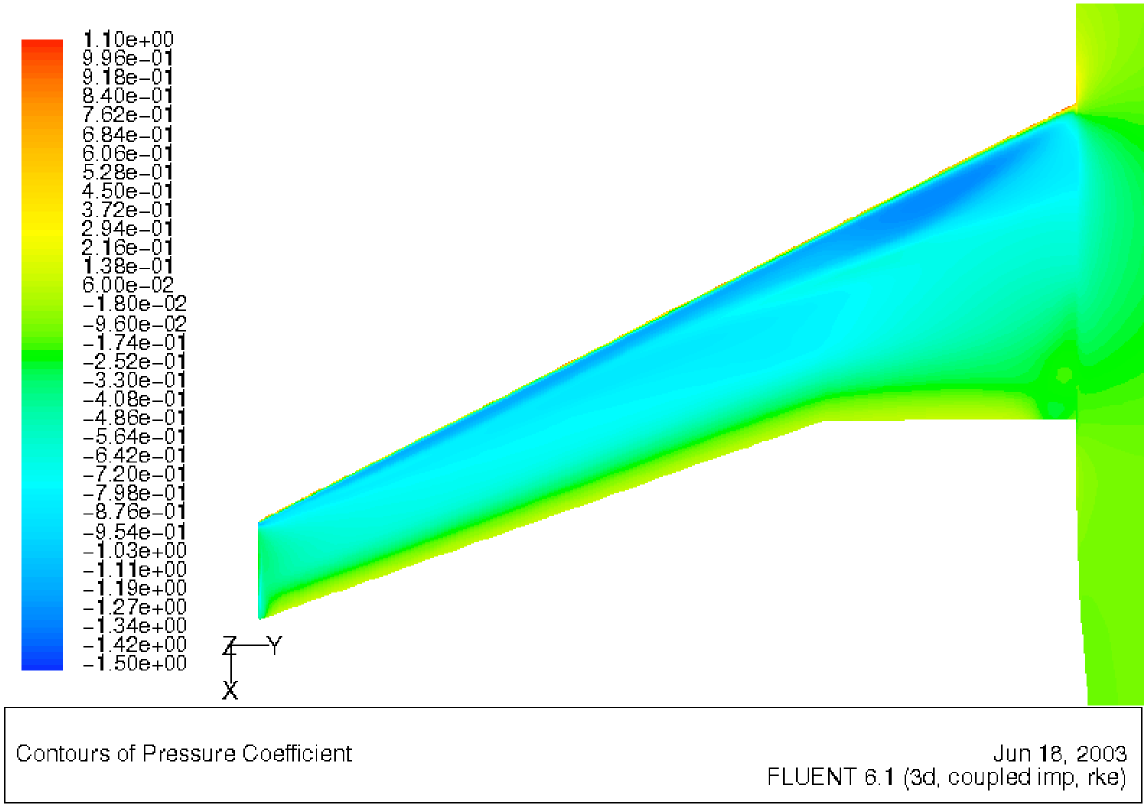




- C_{Dvisc} increased by 5 counts for cell-based solver

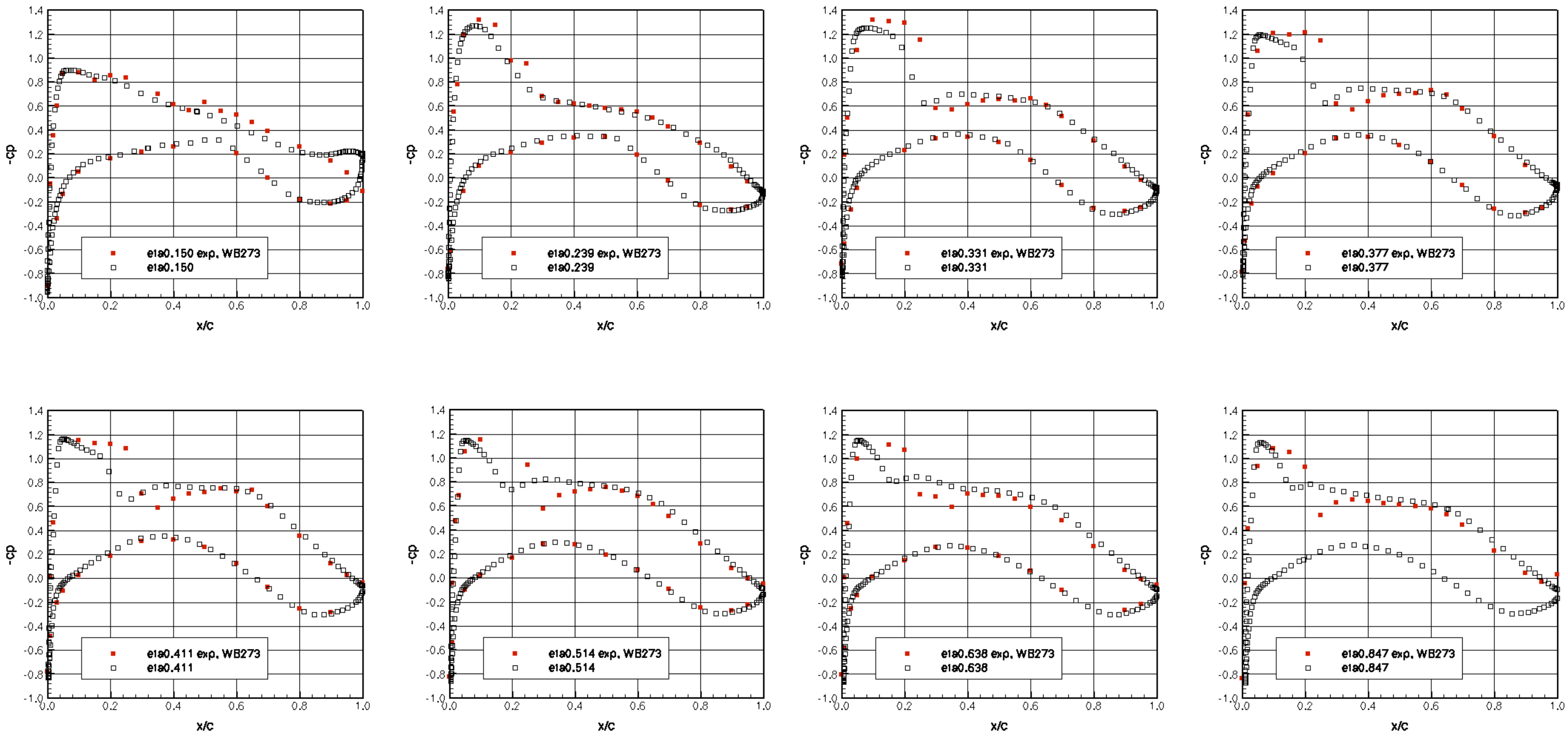
WB coarse grid: C_p

M=0.75, Re=$3.0x10^6$, []=0.2007°, C_L=0.493
Coupled cell-based solver



WB coarse grid: C_p

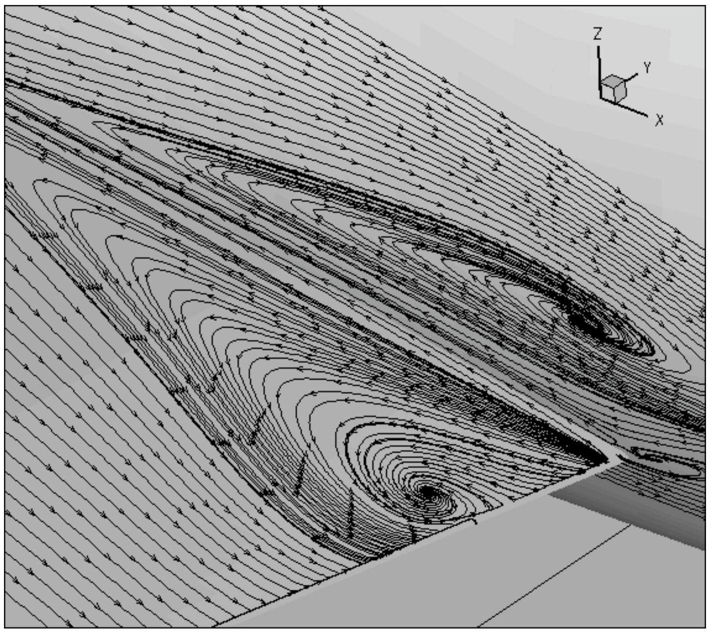
M=0.75, Re=3.0x10^6, α=0.2007^o, C_L=0.493
Experiments at α=0.490^o, C_L=0.4984
Coupled cell-based solver



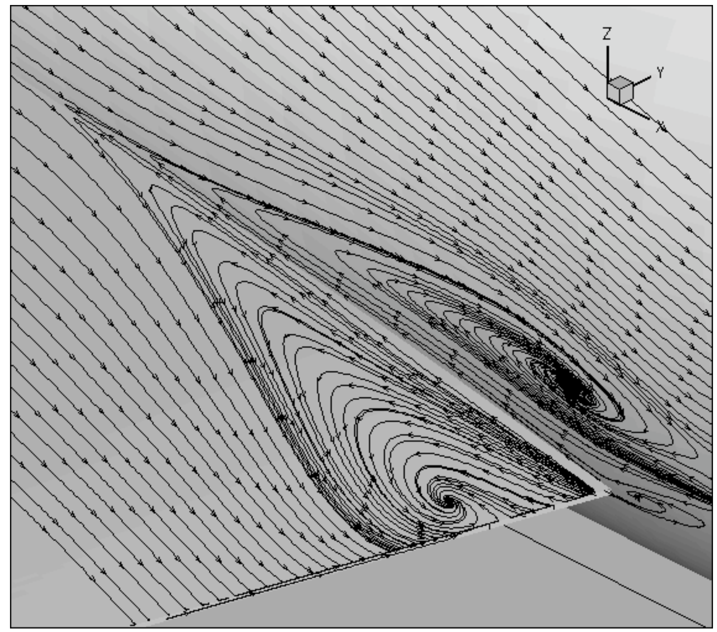
Flow separation at wing root

M=0.75, Re=3.0×10^6, $\alpha=0.2007^o$
Segregated node-based solver

WB fine grid



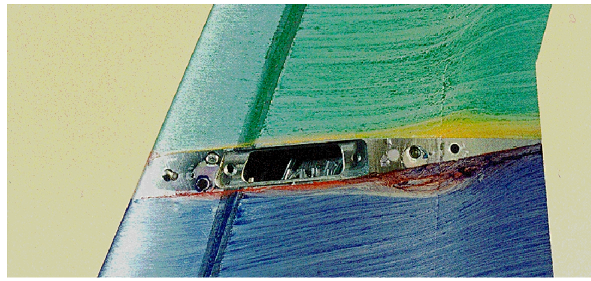
WBNP fine grid



- BL_{BUB} not available due to missing saddle point near trailing edge
- FS_{BUB} difficult to measure

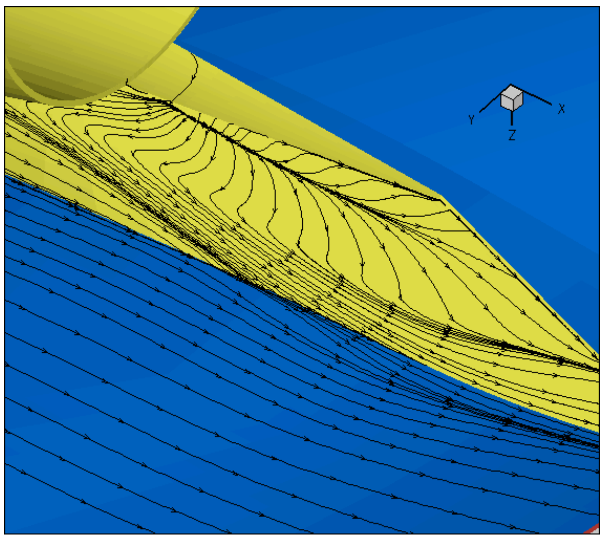
Streamlines at pylon-wing junction

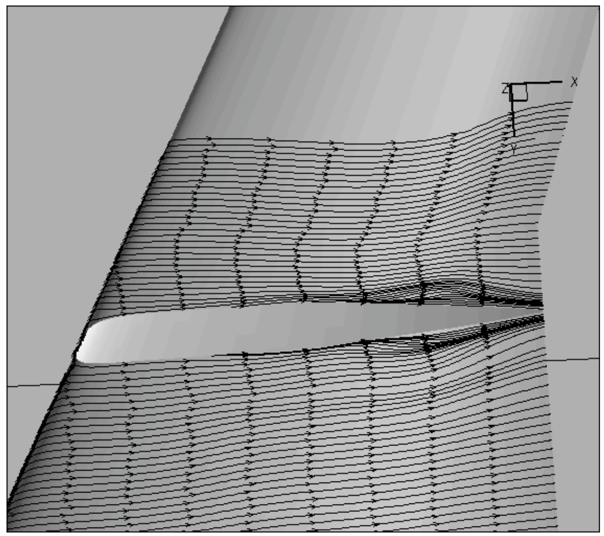
M=0.75, Re=3.0×10^6, α=0.6263°
Segregated node-based solver, WBNP fine grid

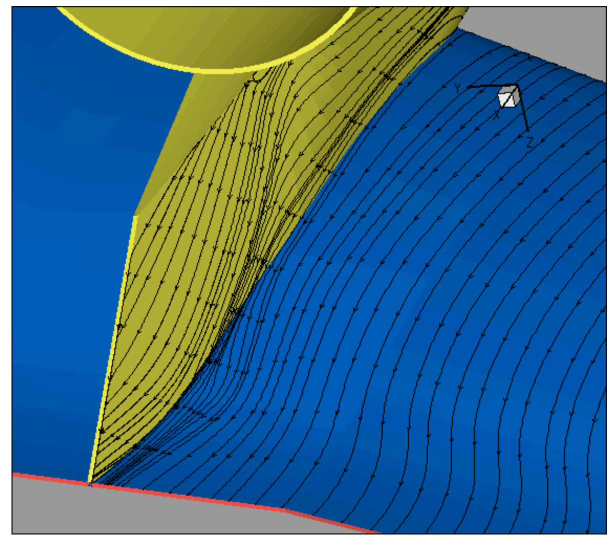


Inboard pylon

Outboard pylon



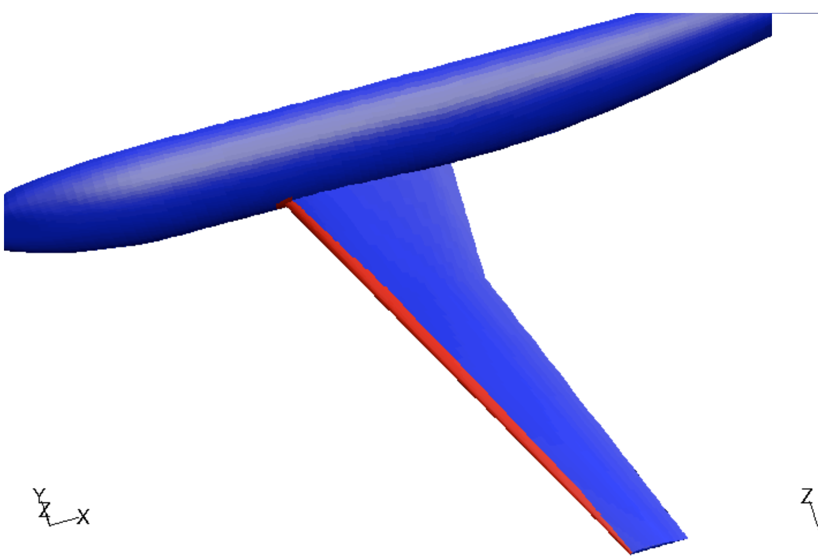


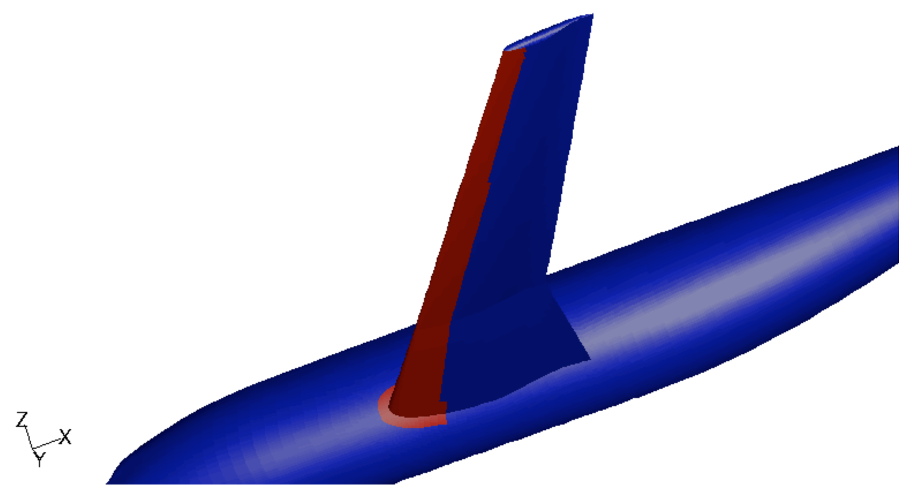


- No separation on lower wing surface near pylon

Transition location specification

- Laminar zone option in Fluent to model transition
- Not used for DPW2 calculations





Summary

- Overprediction of lift very similar to DLR-F4 case of DPW1
- Good match of drag polar, despite unsatisfactory match of c_p distribution in vicinity of shock
- Poor match of pitching moments
- Good quality grids are essential
  - Distributed point-matched structured grid family has poor and inconsistent refinement
  - Even the fine mesh doesn't capture the shock locations properly
  - A proper grid refinement study requires a parametrically refined family of grids
  - Efficient use of grid points is critical for economics
  - Grid generation of multi-block structured grids is still a bottleneck
- Coupled (density based) solver in Fluent 6 recommended for transonic drag predictions on marginally resolved grids