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 $M=0.75$, $Re=3.0\times10^6$ 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: $C_L(\alpha)$

$M=0.75$, $Re=3.0 \times 10^6$, segregated node-based solver

- WB coarse: $C_L=0.500$ at $\alpha=0.2007^\circ$
- WBNP coarse: $C_L=0.500$ at $\alpha=0.6263^\circ$
- 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: $C_L(C_{D\text{visc}})$

$M=0.75$, $Re=3.0 \times 10^6$, segregated node-based solver

- Viscous drag component $C_{D\text{visc}}$ not monotonic with grid refinement
Single Point Grid Sensitivity: $C_M(C_L)$

$M=0.75$, $Re=3.0\times10^6$, 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

- Nonuniform streamwise refinement
- Medium surface grid locally often finer than fine grid
Single Point Grid Sensitivity
ICEM grids at trailing edge: coarse, medium, fine

- 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: $C_L(\square)$ and $C_M(C_L)$

$M=0.75$, $Re=3.0 \times 10^6$
Solver: Segregated (seg) vs. Coupled (cpl)
Discretization: node-based (nb) vs. cell-based (cb)
WB coarse grid: $C_L(C_D)$ and $C_L(C_{D\text{visc}})$

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

- $C_{D\text{visc}}$ increased by 5 counts for cell-based solver
WB coarse grid: $C_p$

$M=0.75$, $Re=3.0 \times 10^6$, $\alpha=0.2007^\circ$, $C_L=0.493$

Coupled cell-based solver
WB coarse grid: $C_p$

$M=0.75$, $Re=3.0 \times 10^6$, $\alpha=0.2007^\circ$, $C_L=0.493$

Experiments at $\alpha=0.490^\circ$, $C_L=0.4984$

Coupled cell-based solver
Flow separation at wing root

M=0.75, Re=3.0x10^6, \alpha=0.2007^\circ

Segregated node-based solver

- 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\times10^6, \alpha=0.6263^\circ
Segregated node-based solver, WBNP fine grid

- 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