Drag Prediction Workshop Study Using Falcon

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Outline

- Falcon code description
- Lift, Drag and Moment coefficient comparisons
- Grid generation issues
- Convergence issues
- Conclusions
Falcon Flow Solver

Capabilities

Multiple block structured grids for accurate viscous flow analysis.
Point-to-point or overset.

Euler/Navier-Stokes with turbulence modeling, wall functions and LES.
Very low subsonic to high supersonic Mach numbers.

Highly implicit solvers for fast solution convergence.
Unsteady capability using dual time-stepping, with time varying boundary conditions.
Falcon Flow Solver cont’d

- Cell-centered, finite-volume
- Roe’s Flux Difference Split scheme for inviscid fluxes, central differenced viscous fluxes
- Second order or third order MUSCL extrapolation with limiters
- Limiter varies between MINMOD and Superbee
- Two equation k-kl turbulence model with wall functions
- Large Eddy Simulation capability
- Optional local time-stepping for convergence acceleration, otherwise use a block global time-step
- MPI communications between processors
- Several implicit solver options:
  - LU-SSOR
  - SIP
  - Modified SIP (Jacobian storage)
Comparison of Falcon Lift Curve With Experiment
Comparison of Falcon Moment Curve With Experiment
Grid Generation Issues

- Supplied grid used for Case 1.
- Gridgen, a commercial package marketed by Pointwise Inc., was used to make two additional grids (LM1 & LM2).
  - LM1 contained 1,393,485 points (same number of surface points as supplied grid)
  - LM2 contained 1,913,373 points (increased number of points on wing)
  - LM2 has better surface resolution and was selected for Case 2 solutions.
- Grid spacing in the supplied grid (DLRF4V2) may have affected solution accuracy.
Disparate Grid Spacings at Block Boundaries in DLRF4V2 Grid

3,389,945 points

Average $Y^+ < 1$. 

$Y \approx 225 \text{ mm}$
Smoother Grid Spacings at Block Boundaries in LM2 Grid

- 1,913,373 points
- 1,798,464 cells
- 24 Blocks
- 31,392 boundary nodes
- 29,402 boundary faces
- BL 1st-cell = 0.1 mm
- BL Max-Growth = 1.25
- BL cells = ~15
- Average Y+ ~61.

Y ~ = 225 mm
Convergence Issues

- The usual solution strategy is to incorporate local time-stepping to accelerate convergence.
- Disparate grid spacing results in disparate time-steps, especially at block boundaries.
- Residual and force history plots for supplied grid seemed to show solution convergence.
- When solution computed using global time step, a more accurate result was obtained.
Solution Information

<table>
<thead>
<tr>
<th>Case 2 - LM2 Grid Stats</th>
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<tbody>
<tr>
<td>4 HP-V2500 400 MHz processors</td>
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<tr>
<td>HPUX 11.0</td>
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<tr>
<td>HP Fortran 90</td>
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<tr>
<td>Average CPU Time = 216 Hrs.</td>
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<tr>
<td>Average Wall Time = 62 Hrs.</td>
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<td>Memory = 727 Mb</td>
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Conclusions

- Solution accuracy is highly dependent on grid quality. No surprises here!
- Solution convergence is dependent on grid spacing and the use of local time-stepping.
- The use of wall functions greatly enhances robustness and efficiency.
- Bottom Line -- Falcon can produce good results using our established procedures.
- This workshop is not so much a comparison of flow solver accuracy as it is a comparison of grid generation expertise and analysis process. (A Validated User!)