Contribution to HiLiftPW-3

Stephen Nichols
Nirajan Adhikari
Auburn University, Auburn, AL

PID: 020

3rd High Lift Prediction Workshop
Denver, CO June 3-4, 2017
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## Summary of cases completed: Auburn Grid, Wilcox k-omega

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**HiLiftPW-3, Denver CO, June 2017**
Summary of cases completed: Auburn Grid, SAS

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HiLiftPW-3, Denver CO, June 2017
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Summary of Tenasi

**Tenasi Unstructured Flow Solver**
- General multi-element, node centered, finite volume scheme
- Multiple flow regimes
- Fully implicit with multiple techniques to solve the system of equations
- Up to 4th order temporal accuracy
- At least 2nd order spatial variable reconstruction
- Roe Approximate Riemann or HLLC flux evaluation
- Highly scalable parallel algorithm
- Characteristic Variable Boundary Conditions (CVBC)

**Turbulence models**
- Loosely coupled with mean flow equations
- 3 one equation models with SGS modeling
- 4 two equation models (3 with SGS modeling)
- 2 Reynolds stress models
- Langtry-Menter transition model implemented
- Hybrid RANS-LES model under development
Verification study results

- The Incompressible and the non-preconditioned Arbitrary Mach Number flow regimes produced similar results with two turbulence models (SAS and SST)
  - Incompressible regime converged quicker and further
- When limiting is used, the Venkatakrishnan limiter offered better convergence than the Barth limiter
- Non-limited solutions were slightly more accurate than the limited solutions.
Brief overview of grid systems

- The provided committee grid systems were compatible with the solver
  - In most cases, the committee grids did not have any issues
- The created grid systems are multi-element grids with hexahedrals, prisms, pyramids and tetrahedrals elements generated using Pointwise
- The only problem encountered with the CAD model was in one of the surfaces on the wing-fuselage fairings of the HL-CRM
  - The faulty surface had overlapping boundaries
  - The mesh generation problem was fixed by creating mesh using boundaries of neighboring surfaces

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<tr>
<th>Grid System</th>
<th>Case(s)</th>
<th>If committee grid, report any problems/issues If user grid, reason for generating grid system</th>
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<tbody>
<tr>
<td>Committee (Case1a: B3-HLCRM_UnstrHexPrismPyrTet_PW, Case2: E-JSM_UnstrMixed_ANSA)</td>
<td>1a, 2a, 2c</td>
<td>No problems with the committee grids with appropriate choice of turbulence model</td>
</tr>
<tr>
<td>User (Unstructured multi-elements grid generated using Pointwise)</td>
<td>1a, 2a, 2c</td>
<td>Generated grid system to investigate the difficulties in creating grids for the high lift configurations and to have better control on the mesh compatibility with the solver</td>
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Brief overview of grid systems

- Some deviations from the gridding guidelines are present in the created grids in order to maintain the quality of the grids
  - Trailing edge spacings across the high lift elements are adjusted based on the number of points on the trailing edges
  - Spanwise spacings are also adjusted

Figure: Preview of the generated multi-element grid of the HL-CRM at constant Y cuts in two different locations
Brief overview of HL-CRM results

- Grid refinement increased the prediction of CL for a given angle of attack
- For a given CL, coarser grid over-predicts the CD and CM compared to finer grid
- Turbulence models show less effect on the force and moment prediction
- CP Convergence: Grid Refinement
  - Grid refinement shows significant effect on the CP at midspan of the wing
  - Grid refinement shows significant effect on the CP at higher angle of attack
Brief overview of HL-CRM results

• CP comparison: Auburn Grid VS Committee Grid
  • The results are comparable at coarse grid level
  • Significant differences in CP prediction at midspan of the wing-chord due to differences in the mesh element size

• CP comparison: Turbulence Model comparison
  • Menter SST, Wilcox k-omega, and SAS model results on CP are comparable to each other at all angles of attack

• Velocity profile
  • Effects of grid refinement is more pronounced at higher angle of attack
  • The Y-component (v) and Z-component (w) of the velocity are more sensitive to grid refinement than the X-component (u) of the velocity
  • Resolution of wake by different turbulence models are almost identical
Brief overview of HL-CRM results

Lift Convergence

(a) Committee Grid

(b) Auburn Grid
Brief overview of HL-CRM results

Force and Moments Comparison

Turbulence Model Comparison (Auburn Grid)

Coarse Grid

Medium Grid
Brief overview of HL-CRM results

Y = 638.0

CP Convergence

Y = 792.5

Auburn Grid

AOA 8°

Y = 947.0

Y = 1050.0
Brief overview of HL-CRM results

Grid Comparison (Auburn VS Committee)

Y = 174.5

Medium Grid
AOA 8°

Y = 380.5

Y = 483.5

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Brief overview of HL-CRM results

Grid Comparison (Auburn VS Committee)

Y = 638.0

Medium Grid
AOA 8°

Y = 947.0

Y = 792.5

Y = 1050.0
Brief overview of HL-CRM results

Turbulence Model Comparison (Auburn Grid)

Coarse Grid

AOA 8°
Brief overview of HL-CRM results

Turbulence Model Comparison (Auburn Grid)

Coarse Grid

AOA 8°
Brief overview of HL-CRM results

Auburn Grid
AOA 8°

Velocity Convergence

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Brief overview of HL-CRM results

Velocity Convergence

Auburn Grid
AOA 16°
Brief overview of HL-CRM results

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Grid Comparison (Auburn VS Committee)

X = 1475, Y = 277.5

Medium Grid
AOA 8°
Brief overview of HL-CRM results

Grid Comparison (Auburn VS Committee)

Coarse Grid
AOA 16°
Brief overview of HL-CRM results
Brief overview of JSM results

- Force and Moment Comparison
  - CFD under-predicts the CL at linear region of the lift curve
  - CFD over-predicts the $\text{CL}_{\text{max}}$ and stall occurs at much higher angle of attack than experiments
  - For a given CL, CFD over-predicts CL and CM than experiments
- JSM Nacelle/Pylon OFF Configuration (CP comparison)
  - For most part, CP comparison with experiments are satisfactory
  - It takes longer distance to recover pressure towards the root of the wing compared to experiments
  - Auburn grid results are relatively closer to experiments than Committee grid
  - The prediction of CP at low pressure side is poorer compared to high pressure side of the wing
- JSM Nacelle/Pylon ON Configuration (CP comparison)
  - Wilcox k-omega results are relatively better at predicting CP than Mentor SST model
  - More investigation is required on the effect of turbulence models on the Nacelle/Pylon ON configuration (comparing results of two different models with Auburn Grid)
Brief overview of JSM results

**Force and Moment Comparison**
(JSM Nacelle/Pylon OFF)

**Medium Grid**

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Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)

Medium Grid
4.36°

Flap A-A

Slat A-A

Wing A-A

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Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)

Slat B-B

Wing B-B

Flap B-B

Medium Grid
4.36°
Brief overview of JSM results

### CP Comparison

**Wing C-C**

- **CP Comparison (JSM Nacelle/Pylon OFF)**

**Flap C-C**

- **Medium Grid 4.36°**

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Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)

Medium Grid
4.36°

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Brief overview of JSM results

**HiLiftPW-3, Denver CO, June 2017**

Medium Grid
4.36°

**CP Comparison**
(JSM Nacelle/Pylon OFF)
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)

Medium Grid
10.47°
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)

Medium Grid 14.54°
Brief overview of JSM results

Slat B-B

CP Comparison (JSM Nacelle/Pylon OFF)

Wing B-B

Medium Grid 14.5°

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Brief overview of JSM results

GRID Comparison
(Auburn VS ANSA)

Medium Grid
JSM
Nacelle/Pylon
OFF

Auburn Grid

ANSA Grid
Brief overview of JSM results

Force and Moment Comparison
(JSM Nacelle/Pylon ON)

Medium Grid
Brief overview of JSM results

Force and Moment Comparison
(JSM Nacelle/Pylon ON)

Medium Grid

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Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon ON)

Medium Grid
4.36°

HiLiftPW-3, Denver CO, June 2017
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon ON)

Medium Grid
4.36°
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon ON)

Medium Grid
10.47°
Brief overview of JSM results

CP Comparison (JSM Nacelle/Pylon ON)

Medium Grid 18.58°
Brief overview of JSM results

CP Comparison (JSM Nacelle/Pylon ON)

Medium Grid 18.58°
Summary

• Mesh generation for high lift configurations is challenging
• Turbulence model plays significant influence on the force and moment prediction
• CFD predicts CP with acceptable accuracy for most of the wing elements
• Provided committee grids are compatible with the solver and did not show any convergence issue
• Flow field associated with Nacelle/Pylon ON configuration is difficult to resolve with SST model (based on TENASI results...work in progress)
• Since half-span test data is consistent with the CFD results, half-span tests are valid for high lift experiments
• Prediction of CLmax and stall might improve with the transition modeling in the CFD solutions (work in progress)
• Hybrid RANS-LES modeling might improve the overall CFD predictability of high-lift flow field (work in progress)