ONERA Contribution to HiLiftPW-1

L. Wiart
Aerospace Engineer, Civil Aircraft Unit, Applied Aerodynamics Department

M. Meunier
Aerospace Engineer, Civil Aircraft Unit, Applied Aerodynamics Department

June 26th-27th 2010, Chicago, Illinois
Outline

• Grids overview
• The elsA solver
• Computation strategy
• Grid convergence study
• Flap deflection prediction study
• Turbulence modeling
• Flap/SOB separation bubble investigation
• Far-Field Drag analysis
• In-house overset grid results
Grids overview

- Str-OnetoOne-A-v1 (supplied by HiLiftPW-1 committee)
  - Coarse: 22,606,727 points
  - Medium: 52,061,907 points
  - Fine: 170,661,635 points

- Structured overset created in-house using Icem-CFD
  - Equivalent to CONF1 medium grid: 32,389,554 points
The elsA solver

RANS computations
- Cell-centered finite volume on structured multi-block meshes
- Time integration: Backward-Euler scheme with LU-SSOR relaxation
- Spatial discretization: Jameson’s second-order centered scheme
- V-cycle multigrid technique
- Low-speed preconditioning

CGNS input and output format

Parallel mode (SGI Altix ICE 8200 EX)
Computation strategy

- Polars obtained with increasing AoA
- Non-unique solutions
  - if no initialization from previous AoA
  - hysteresis indication

\[ M = 0.2 \]
\[ Re = 4.3 \]
Grid convergence study

- No asymptotic convergence reached as such
- But fairly small variations between different grid levels

Influence of grid refinement on aerodynamic coefficients

CONF1, SA, $\alpha = 13$ deg.
Flap deflection prediction study

CONF1: flap 25 deg.
CONF8: flap 20 deg.
Turbulence modeling (1/2)

- All KW-SST models over-predict flap TE separation
  → not suited for this configuration

- Rotation correction in SA changes stall behavior

CONFl, $\alpha = 13$ deg.

<table>
<thead>
<tr>
<th>CONF1</th>
<th>EXP $C_L$max</th>
<th>SA $C_L$max</th>
<th>SA_RC $C_L$max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.995</td>
<td>3.054</td>
<td>3.063</td>
</tr>
<tr>
<td>Error</td>
<td></td>
<td>1.9%</td>
<td>2.3%</td>
</tr>
<tr>
<td>$\alpha_{\text{max}}$</td>
<td>33 $^\circ$</td>
<td>$\sim 34^\circ$</td>
<td>$\sim 32^\circ$</td>
</tr>
</tbody>
</table>
Turbulence modeling (2/2)

- Major impact of slat-tip vortex resolution on stall

CONF1, SA, $\alpha = 32$ deg.

CONF1, SA_RC, $\alpha = 32$ deg.
Flap/SOB separation bubble investigation (SA)

- Grid refinement impact ($\alpha = 13$ deg.)
  - little influence on separation bubble topology
  $\rightarrow$ indication of good grid convergence

- Influence of AoA

- Flap deflection effect ($\alpha = 13$ deg.)
  - similar to an increase of AoA
Far-Field Drag analysis

- Spurious drag mainly created in high curvature areas
  - drops from 4.66 to 0.35 drag counts from coarse to medium grid
- Drag mostly dominated by induced component

\[ \eta = 50\% \]

CONF1, SA, \( \alpha = 13 \text{ deg.} \)

Spurious drag creation areas

Near-field drag breakdown

Far-field drag breakdown
Overset grid results (1/2)

- Excellent agreement with coincident grid results
- Lesser meshing effort !!
Overset grid results (2/2)

CONF1, SA

\[ \alpha = 13 \text{ deg.} \]
Conclusion

- **Grid convergence study**
  - no asymptotic convergence as such reached with Spalart-Allmaras but fairly small differences between different grid levels
  - major impact of slat-tip vortex resolution
  - grid refinement did not solve flap TE separation issue; the efforts should rather focus on turbulence models

- **Flap deflection prediction study**
  - good overall agreement with experimental data
  - complicated by the approximate prediction of flap TE flow separation

- **Good validation case for elsA overset technique on 3D high lift configurations**

- **Suggestions**: HiLiftPW-2 should focus on $C_{L_{\text{max}}}$ area (viscous dominated flow) with extended experimental measurements and visualization (oil flow, PIV/5-hole probe, model deformation, wake rakes…)}