Contribution to GMGW-1

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- PID: 07
Summary of grids generated:

<table>
<thead>
<tr>
<th>Case</th>
<th>Code(s)</th>
<th>Starting Geometry Model</th>
<th>Grid Type</th>
<th>Number Grid Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL-CRM full gap</td>
<td>SLUGG</td>
<td>IGES</td>
<td>Unstruct, Tetrahedra or Mixed Element</td>
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<tr>
<td>HL-CRM full gap</td>
<td>AGPS, AFLR3</td>
<td>IGES</td>
<td>Unstruct, Tetrahedra or Mixed Element</td>
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<tr>
<td>HL-CRM partially sealed</td>
<td>AGPS, AFLR3</td>
<td>IGES</td>
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<tr>
<td>Other</td>
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</table>

- Fixed grids of the gapped HL-CRM generated with the Boeing SLUGG process (System for Low-speed Unstructured Grid Generation)
- HL-CRM grids created directly on the original geometry by building a watertight connectivity from the trimmed surfaces
- Surface grid generation using the in-house AGPS-based (Aero Grid and Paneling System) unstructured meshing tool
- Volume grids generated using AFLR3 (Advancing Front with Local Reconnection)
- A few relevant technical references
Geometry Preparation and Repair in SLUGG

- Designed for processing the AGPS lofts, trimming and positioning of airplane components
- For HL-CRM, de-featureing and simplification of the CAD model required to arrive at a mesh-able representation
- Surface fitting performed in some areas to create parametrically smooth surfaces
- Watertight connectivity of a set of proper feature-based geometric surfaces
Geometry Import and Preparation

• Collect and import all trimmed surfaces into AGPS-based unstructured meshing tool
• Modifications performed on the geometry to build a watertight connectivity
  • Repair needed on the inboard flap trimmed surfaces
  • Leading edge split applied to the slat and flaps so that hybrid grid is assigned along all the LE’s
  • Wing LE cap geometry modified to remove sharp corners for volume meshing
  • Simplified edges on slat and wing caps
Surface Mesh Generation

• Grids generated using surface-based advancing front technique that allows for curvature-sensitive, stretching-ratio controlled surface meshing, and quadrilateral-triangular hybrid grid
  • Hybrid grid along all the LE, TE and wing-body junction, with the same growth distance for all three grid levels based on the geometry features
  • Quad grid at all TE bases and cove lips, with the number of cells on the TE’s specified according to the HLPW gridding guidelines, and two layers of quads on the cove lips
• Grid spacing assigned based on the knowledge from the SLUGG-type meshes, in which the meshing properties specified depending on the planform functions and geometry features
• Chordwise spacing at LE and TE proportionally reduced when refining the grids, edge and surface meshing properties adjusted accordingly
• Wakesheets created from SLUGG with structured grids for all the wing-type components
• Mesh exported in the AFLR UGRID format
Surface Mesh
Wing Upper Surface
Surface Mesh
Wing Lower Surface
Surface Mesh - Wing Slat LE at Root
Surface Mesh - Wing Flap TE at Root

Gapped Inboard Flap

Partially Sealed IB Flap
Surface Mesh - Wing Tip LE
Surface Mesh - Wing Tip TE
Flap Gap Upper Surface

Gapped Flaps

Partially Sealed Flaps
Volume Mesh Generation

- Volume grids generated using AFLR3, with prismatic BL grid of mixed element type and tetrahedral mesh in the field or pure tetrahedral grid
- Anisotropic tetrahedral blending between the BL prisms and isotropic tetrahedra to allow a smooth transition
- Anisotropic wake grids created utilizing the AFLR metric node capability
Volume Mesh Cut at $y=277.5$
Volume Mesh Cut at y=638
Volume Mesh Cut at y=1050
## Mesh Statistics

<table>
<thead>
<tr>
<th>Geometry Model</th>
<th>Grid Type</th>
<th>Grid Level</th>
<th>Nodes</th>
<th>BFaces</th>
<th>Volume Cells</th>
<th>Criteria 1</th>
<th>Criteria 2</th>
<th>Criteria 3</th>
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<td>min</td>
<td>max</td>
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<tr>
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<td>Unstruct, Mixed Element</td>
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<td>HLCRM-Full Gap</td>
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Mesh Evaluation

• A series of unstructured grid quality metrics utilized to evaluate the grid quality/suitability, including min/max dihedral angle, cell volume, volume ratio, skewness, face alignment, prism column count, etc.
• CFD++ and GGNS solutions at 8 and 16 degrees angle of attack generated to assess flow solver convergence on the meshes, and as a solution verification
  • All the GGNS solutions converged to machine zero
  • Most CFD++ solutions converged to five or more orders of magnitude
  • Very good comparison obtained between the CFD++ and GGNS results
• Adherence to meshing guidelines
  • Most guidelines adhered in our meshes, except from discrepancies below
    • TE chordwise spacing relaxed to be twice of the LE spacing
    • Spanwise spacing calculated from quad grid aspect ratio, instead of semispan
    • Cell size near body nose and tail based on the body maximum diameter, instead of Cref
    • Total grid size growing about 2.5X between each grid level
Streamtraces of the HL-CRM from Medium Mesh
CFD++, SA Model, Mach = 0.2, Re = 3.26x10^6, AOA = 8°

Gapped Flap

Partially Sealed Flap
Streamtraces of the HL-CRM from Medium Mesh
**CFD++, SA Model, Mach = 0.2, Re = 3.26x10^6, AOA = 16°**

Gapped Flap

Partially Sealed Flap
Effect of Grid Refinement on Sectional Cp-distributions

CFD++, SA Model

Mach = 0.2
Re = 3.26x10^6
AOA = 8°

AOA = 16°
Effect of Geometry Refit and Simplification
SARC Model, Mach = 0.2, Re = 3.26x10^6

- Impact of geometry refit and de-featuring on the overall vehicle lift of HL-CRM
- To what extent a geometry simplification/modification could be acceptable for practical applications?
Sectional Cp-comparison of the Gapped HL-CRM from Medium Mesh

CFD++, SARC Model, Mach = 0.2, Re = 3.26x10^6, AOA = 8°
Sectional Cp-comparison of the Gapped HL-CRM from Medium Mesh

CFD++, SARC Model, Mach = 0.2, Re = 3.26x10^6, AOA = 16°
Summary

• Geometric fidelity on wing-type components is necessary for high-lift CFD simulations, while other components like fuselage may be able to be simplified to some extent.

• Geometry tool development like GEODUCK (General Environment for Optimization and Development Using a Common Kernel), which handles both CAD model and AGPS objects consistently, is crucial.

• Capability to generate anisotropic triangle faces needs to be implemented.

• Automatic meshing process is mandatory for aerospace engineers to carry out practical high-lift CFD applications.

• Fixed grid generation of a sequence of three meshes involved several weeks of manual interaction, based on the best practice built over the years. The solution adaptive approach provides great advantage and benefits compared to the fixed grid approach.