Contribution to GMGW-2

• Pei Li and Todd Michal
• The Boeing Company
• PID: 14
Summary of grids generated

<table>
<thead>
<tr>
<th>Case 2</th>
<th>Code(s)</th>
<th>Starting Geometry Model</th>
<th>Grid Type</th>
<th>Number of Grid Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL-CRM full gap</td>
<td>AGPS, AFLR3</td>
<td>IGES</td>
<td>Unstructured Mixed Element</td>
<td>1</td>
</tr>
</tbody>
</table>

• Summary of grid generation algorithms
  • Medium grid created directly on the HL-CRM rev. 2 geometry model 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
    • Refined grid density compared to GMGW-1
  • Volume grid generated using AFLR3 (Advancing Front with Local Reconnection)
    • Modified AFLR3 with multiple BL normals

• Relevant technical references
Geometry Import and Preparation

- Based on the geometry connectivity from GMGW-1, replace the fuselage and side of body fairing by the new trimmed surfaces from HL-CRM rev. 2 geometry model
  - Wing LE cap geometry preserved on the inboard and outboard
    - modified to remove sharp corners for volume meshing in GMGW-1
- From GMGW-1, 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 LEs
  - Simplified edges on slat and wing caps
Surface Mesh Generation

- 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, quad grid at all TE bases and cove lips
  - Chordwise spacing at LE and TE, and the number of cells on the TEs specified according to the HLPW3 gridding guidelines for medium mesh
- Grid spacing refined from GMGW-1 on both edges and interior surfaces to provide a better resolution and spacing match between neighboring components
- Mesh exported in the AFLR UGRID format
Surface Mesh
Wing Upper Surface

GMGW-2

GMGW-1
Surface Mesh
Wing Slat LE at Root

GMGW-2

GMGW-1

GMGW-2, San Diego, CA, January 2019
Surface Mesh
Wing Flap TE at Root

GMGW-2, San Diego, CA, January 2019
Surface Mesh
Wing Tip LE

GMGW-1

GMGW-2
Surface Mesh
Wing Tip TE

GMGW-2

GMGW-1
Flap Gap Upper Surface

GMGW-2

GMGW-1

GMGW-2, San Diego, CA, January 2019
Surface Mesh- Wing LE Caps

GMGW-2, San Diego, CA, January 2019

GMGW-2

GMGW-1
Volume Mesh Generation

- Volume grid generated using AFLR3, with prismatic BL grid of mixed element types and tetrahedral mesh in the field
- Multiple BL normal capability implemented into the AFLR3 code, by modifying the boundary surface connectivity with the addition of duplicate nodes and degenerate boundary faces to the singular convex points
  - Four-face pyramid created from a convex ridge on the first boundary layer, which can be handled as polyhedron in CFD++
  - For HL-CRM, additional normal vectors applied to convex singular nodes along all trailing edges, the cove and cap ridges
  - Same initial wall spacing $\Delta y=0.00117''$ and same BL growth rate $GR=1.15$ as that for GMGW-1
  - Anisotropic wake grid from GMGW-1 utilized with the AFLR metric node capability

GMGW-2, San Diego, CA, January 2019
Volume Mesh Cut at y=277.5
Volume Mesh Cut at y=638

Flap TE

GMGW-2

GMGW-1

GMGW-2, San Diego, CA, January 2019
Volume Mesh Cut at y=1050

Slat Cove

GMGW-2

GMGW-1
### Mesh Statistics

<table>
<thead>
<tr>
<th>Geometry Model Grid Type</th>
<th>Grid Level</th>
<th>Nodes (M)</th>
<th>BFaces (M)</th>
<th>Volume Cells (M)</th>
<th>Cell Volume min</th>
<th>Min Dihedral</th>
<th>Volume Ratio min</th>
<th>Area Ratio min</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLCRM Medium Unstr. Mixed Element</td>
<td>GMGW-1</td>
<td>41.84</td>
<td>1.44</td>
<td>106.74</td>
<td>7.740e-09</td>
<td>6.125e-04</td>
<td>109.5</td>
<td>4.924e-05</td>
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<tr>
<td>HLCRM Medium Unstr. Mixed Element</td>
<td>GMGW-2</td>
<td>53.30</td>
<td>1.79</td>
<td>133.50*</td>
<td>1.496e-11</td>
<td>2.963e-02</td>
<td>109.5</td>
<td>3.353e-04</td>
</tr>
</tbody>
</table>

*133.5 million of mixed elements corresponds approximately to 316 million tetrahedra, an order 8.5 resolution mesh.*
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, area ratio, etc.

• CFD++ solution at 8 degree angle of attack generated to assess flow solver convergence on the mesh and as a solution verification
  • Residual convergence and force/moment compared to those from GMGW-1

• Adherence to meshing guidelines
  • Most guidelines adhered except for discrepancies below
    • 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
Surface Skin Friction from CFD++
SA-QCR Model, Mach = 0.2, Re = 3.26x10^6, AOA = 8°

GMGW-2
CL=1.74047, CD=0.170429
Conv_ratio=5.2686 (1500 cycles)

GMGW-1
CL=1.73947, CD=0.170477
Conv_ratio=5.2158 (2500 cycles)
Summary

- HL-CRM mesh in the order 8.5 generated for GMGW-2
  - Geometry connectivity rebuilt based on that from GMGW-1 for the modified fuselage and side of body fairing
  - Surface mesh refined on most edges and interior surfaces
  - Volume grid generated using the updated AFLR3 version with the multiple BL normal capability
  - CFD++ solution produced as additional mesh evaluation and solver verification
- Lessons learned through the geometry modification, mesh refinement, and re-generation for GMGW-2 will be useful for further improving the in-house automatic process for low-speed unstructured grid generation
  - More improvements needed to provide better mesh quality and higher flow solution accuracy
  - Increased robustness and efficiency