Contribution of BETA CAE to GMGW-2
Case 2: Remeshing of the HL-CRM

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GMGW-2, 5-6 January 2018, San Diego, California
ANSA meshing approach

Unstructured meshing with standard:
- surface mesh generation
- layers inflation
- volume meshing process
aiming at:

- High quality surface mesh, capturing all geometrical details
- Efficient lean meshing
- Powerful layers algorithm inflating up to 100 times the local element length and with aspect ratios of over 1000
- Robust volume meshing to fill up remaining volume and extreme proximities
- Automation via Batch Mesh tool
- Use of multi-core shared memory hardware for speed
- Efficient handling of large CFD meshes in v19
Issues in creating a 316 (or higher) million cell mesh for CRM

- Model does not contain a lot of details that require refinement
- Refining the surface mesh does not help in the creation of a large total layer height extrusion for the given growth ratio of 1.16 as the outer elements tend to become stretched in the normal direction
Software and Hardware used for Case 2

- ANSA v19.0.1
- Linux Centos 6.8
- 2x20 core Intel Xeon ES-2660 v3 @ 2.6GHz
- 256 Gb RAM
- NVIDIA Quadro K4000
GMGW-2 – Case 2 – Remeshing the HL-CRM model

hl-crm-gapped-flaps5.stp file was read in ANSA
GMGW-2 – Case 2 – Remeshing the HL-CRM model

Comparison of original and updated CRM geometries
CRM model geometry preparation

- 1 farfield
- 2 fuselage
- 3 fuselage_proximity_with_IBFLAP
- 4 IBFLAP
- 5 IBFLAP_proximity_with_fuselage
- 6 IBFLAP_proximity_with_OBFLAP
- 7 IBSLAT
- 8 IBSLAT_proximity_with_main...
- 9 main_wing_flap_cave
- 10 main_wing_flap_cave_proximity
- 11 main_wing_lower
- 12 main_wing_proximity_with_IBS...
- 13 main_wing_trailing_edge
- 14 main_wing_upper
- 15 OBFLAP
- 16 OBFLAP_proximity_with_IBFLAP
- 17 OBFLAP_proximity_with_main...
- 18 symmetry
- 19 wingtip
Batch Meshing in ANSA

- Mesh type
- Target curvature refinement
- Growth rate of mesh on flat areas
- Minimum and maximum length
- Sharp edges length
- Proximity refinement
- Size Box refinement
- Target quality criteria threshold values

- Automation
- Consistency
- Meshing specs traceability
Anisotropic meshing benefits

Isotropic mesh

Anisotropic mesh
Anisotropic meshing process
Medium with 8 rows of elements across the trailing edge
Surface mesh of the CRM model

Medium mesh 3.4 million shell elements (15min batch mesh time + 45 min manual time)
Surface mesh of the CRM model
Medium mesh 3.4 million shell elements
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Medium mesh 3.4 million shell elements
Surface mesh of the CRM model
Medium mesh 3.4 million shell elements
### Summary of medium gapped flaps CRM meshes created

<table>
<thead>
<tr>
<th></th>
<th>GMGW-1 Medium CRM</th>
<th>GMGW-2 Medium CRM v1 (uploaded to committee)</th>
<th>GMGW-2 Medium CRM v2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface mesh size (millions)</strong></td>
<td>2.3</td>
<td>3.4 (+48%)</td>
<td>3.7 (+61%)</td>
</tr>
<tr>
<td><strong>Volume mesh size (millions)</strong></td>
<td>144</td>
<td>287 (+99%)</td>
<td>326 (+126%)</td>
</tr>
<tr>
<td><strong>Trailing edge rows of elements</strong></td>
<td>6</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><strong>Number of layers</strong></td>
<td>Wing: 45, Fuselage: 57</td>
<td>Wing: 55, Fuselage: 62</td>
<td>72</td>
</tr>
<tr>
<td><strong>Layers growth</strong></td>
<td>2 layers: 1.0, remaining: 1.16</td>
<td>3 layers: 1.0, remaining: 1.16</td>
<td>3 layers: 1.0, 49 layers: 1.16 wing, 1.13 fuselage, 20 layers: 1.0</td>
</tr>
<tr>
<td><strong>Layers first height (inches)</strong></td>
<td>0.000787”</td>
<td>0.000787”</td>
<td>0.000787”</td>
</tr>
<tr>
<td><strong>Total layers height (inches)</strong></td>
<td>Wing: 4”, Fuselage: 23”</td>
<td>Wing: 13” (+225%), Fuselage: 36” (+57%)</td>
<td>43” (+975%)</td>
</tr>
</tbody>
</table>
Layers generation

- Generation of penta or hexa layers
- Variable growth rate per layer
- Different first height, growth rate and number
- Initial layers with no vector smoothing
- Advanced smoothing algorithm
- Local layer squeezing at proximities
- Local layer collapsing at problematic areas
- Controlled skew and warp of top cap
Layer inflation

Medium size 182 million cells (prisms, hexas, pyramids, tetras)
3 hours and 40 minutes run time
Layers in CRM model

GMGW-1
45 layers
Total layer height: 4”

GMGW-2
55 layers
Total layer height: 13”
Layers near flaps

GMGW-1
45 layers
Total layer height: 4”

GMGW-2
55 layers
Total layer height: 13”
Layers around flaps

GMGW-1
45 layers
Total layer height: 4”

GMGW-2
55 layers
Total layer height: 13”
Layers – orthogonality near the wall

Layer smoothing around the trailing edge and close up of imposed orthogonality in the near wall region
CRM Medium GMGW-1 mesh
144 million cells
CRM Medium GMGW-2 (v1) mesh

287 million cells
(103 million prisms, 95 million hexas, 67 million tetras, 2 million pyramids)
Total run time 4 hours and 20 minutes
CRM Medium GMGW-2 (v1) mesh

287 million cells
(103 million prisms, 95 million hexas, 67 million tetras, 2 million pyramids)
Total run time 4 hours and 20 minutes
CRM Medium GMGW-2 (v1) mesh
287 million cells
CRM Medium GMGW-2 (v1) mesh

287 million cells
GMGW-2 Medium v2 mesh

GMGW-2 v1
55 layers
Total layer height on wing: 13”
on fuselage: 36”
287 million cells

GMGW-2 v2
72 layers
Total layer height: 43”
326 million cells
GMGW-2 Medium v2 mesh

GMGW-2 v1
55 layers
Total layer height on wing: 13”
on fuselage: 36”
287 million cells

GMGW-2 v2
72 layers
Total layer height: 43”
326 million cells
Mesh quality considerations
- Negative volume
- Left handed elements
- OpenFOAM non-orthogonality
- OpenFOAM skewness
Mesh quality statistics for the CRM gapped medium size model

\[
\text{skewness} = \max \frac{d_i}{c_i}
\]

\[
\text{non-orthogonality}
\]

<table>
<thead>
<tr>
<th>OpenFOAM Skewness</th>
<th>Number of elements (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.96E+01</td>
<td>Worst 7.3</td>
</tr>
<tr>
<td>2.35E-01</td>
<td></td>
</tr>
<tr>
<td>1.17E-01</td>
<td></td>
</tr>
<tr>
<td>9.84E-03</td>
<td></td>
</tr>
<tr>
<td>4.25E-04</td>
<td></td>
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<tr>
<td>1.08E-04</td>
<td></td>
</tr>
<tr>
<td>1.50E-05</td>
<td></td>
</tr>
<tr>
<td>8.02E-06</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OpenFOAM Non-Orthogonality</th>
<th>Number of elements (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.4</td>
<td>Worst 89.5</td>
</tr>
<tr>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>25.3</td>
<td></td>
</tr>
<tr>
<td>11.6</td>
<td></td>
</tr>
<tr>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>
Mesh quality statistics for the CRM gapped medium size model

- **Aspect Ratio**
  - **Worst**: 3900
  - **Number of elements (%)**: 99.52%

- **Volume growth ratio**
  - **Number of elements (%)**: 97.96%
Layers quality violations – Aspect ratio > 1000
Layers quality violations – Non-Orthogonality > 70
Layers quality violations – Skewness > 4
Mesh quality statistics for the CRM medium v1 model

Layers area

Quad_He-He

Tri_Prism-Prism

Fraction of Faces

Size Ratio

% of quadrilateral faces

$log_{10}(D)$
Mesh quality statistics for the CRM medium v1 model

Tetra volume

![Histogram of Tri_edge-angle](image1)

![Graph of Tri_Tet-Tet volume ratio](image2)
Contour plot of surface mesh size
As calculated by Unstructured Mesh Analyzer
Contour plot of first layer height
As calculated by Unstructured Mesh Analyzer
Wide I/O selection

- FLUENT and CFX
- StarCD and StarCCM+
- OpenFOAM
- CFD++
- TAU
- SC/TETRA
- CGNS
- CMSSoft AeroF

Structured
  - Unstructured

- ADF
- HDF5

Mixed element type
- Separated element type
- NGON (facet based)

(Element based)
Performance improvements in ANSA v19
Metrics for the same mesh of 325 million elements (ANSA file size ~ 10Gb)

<table>
<thead>
<tr>
<th></th>
<th>ANSA v17</th>
<th>ANSA v19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak RAM usage to generate mesh (Gb)</td>
<td>140</td>
<td>83 (-41%)</td>
</tr>
<tr>
<td>Time to open ANSA file (min)</td>
<td>36</td>
<td>7 (-81%)</td>
</tr>
<tr>
<td>Time to output CGNS NGON (min)</td>
<td>25</td>
<td>4 (-84%)</td>
</tr>
</tbody>
</table>
Closing remarks

ANSA v19.0.1 was effectively used to generate a high quality medium size mesh of around 300 million elements, satisfying strict quality requirements.

The process was mostly automatic, however still requiring manual anisotropic surface meshing.

Improvements from previous GMGW-2 include: higher total layer height inflation and the ability to grow layers with different growth rate for each layer.

The latest developments in v19 with respect to handling large volume meshes have set solid foundations for the generation of billion size meshes in ANSA within 2019.

It may be better if we had a more complex geometry than that of the CRM model in order to mesh it with billion cell meshes.
Thank you

Stay connected

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