GMGW-1 Participant Questionnaire

1st AIAA Geometry and Mesh Generation Workshop

The purpose of this document is to collect data for an assessment of the current state of the art in mesh generation for a variety of mesh types and a variety of software tools. The comparisons will be made in terms of the quality of each mesh submitted (either from a priori metrics or from the quality of the CFD solutions that were produced using the mesh) as well as the resources (human and computer) required to generate the meshes.

For GMGW-1, the geometry and meshes referred to below are for the NASA High Lift Common Research Model (HL-CRM).

Completion of this questionnaire is required of all participants in GMGW-1 and participants in the 3rd High Lift Prediction Workshop (HiLift-PW3) who generate their own meshes (versus using the supplied baseline meshes). A separate copy of this Questionnaire should be completed for each family of meshes.

Geometry

1. Software
   a. What software tool(s) did you use to import and prepare the HL-CRM geometry model for meshing?

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2. Import & Preparation for meshing
   a. Which of the supplied geometry files did you use:
      - [ ] Native: NX (prt) file (HL-CRM gapped config)
      - [ ] CREO file (HL-CRM gapped config)
      - [x] IGS file (HL-CRM gapped config)
      - [ ] STP file (HL-CRM gapped config)
      - [ ] Parasolid (x_t) (HL-CRM gapped config)
      - [ ] Native: NX (prt) file (HL-CRM partially-sealed config)
      - [ ] CREO file (HL-CRM partially-sealed config)
      - [ ] IGS file (HL-CRM partially-sealed config)
      - [ ] STP file (HL-CRM partially-sealed config)
      - [ ] Parasolid (x_t) (HL-CRM partially-sealed config)

   b. What problems, if any, did you identify immediately after importing the geometry model (eg, missing geometry, poorly translated geometry, other)?

      None

   c. What steps did you take after import to make the geometry model ready for meshing? (Choose all that apply)
      - [x] None
      - [ ] Layering (hiding components)
      - [ ] Simplification/defeaturing (removing components)
      - [ ] Repair (fixing/recreating components that didn't import properly)

- [ ] Modification (changing components)
- [ ] Shrink-wrapping
- [ ] Other

d. What was required level of user expertise (novice, intermediate, expert) for this task?

Novice

e. How long did import take (both elapsed time and labor required --- in hours)?

0.1 hours

Initial Meshing

1. What type of mesh family did you generate?

- [ ] Structured multi-block
- [ ] Unstructured tetrahedra
- [ ] Unstructured hexahedra
- [ ] Hybrid
- [ ] Overset
- [ ] Cartesian
- [x] other (please specify)

The wing, slat and flap surface mesh elements are made of quad cells mostly, and the fuselage are made of triangles. Therefore, the viscous layers are made of hexa and prismatic cells. The volume mesh are made of tetrahedral cells with pyramid cells for the hexa-tetra transition. In summary this is a Hexa-Prism-Tetra-Pyra unstructured mesh.)

2. Surface Meshing

a. What software tool(s) did you use to generate your initial surface mesh?

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b. How long did it take (elapsed time and labor – in hours)?

5.5 hours (coarse), 6 hours (medium), 8 hours (fine)

c. Provide a brief description of how mesh resolution was specified (explicit user inputs, sources, curvature based sizing, background distribution function, …)

The surface mesh of the wing, slat and flaps are essentially a structured mesh built up from quad elements. Therefore the mesh resolution is defined by how many points are in each direction and how they are distributed along it.

Due to the high degree of freedom and control of the surface mesh element size and distribution a structured mesh can offer, it was possible to fulfill the HiLift-PW3 meshing guidelines to its full extent.

MEDIUM MESH
WING:
Chordwise No. of Cells: 457
Spanwise No. of Cells: 1064
LE Chordwise Spacing: 0.1% local wing chord
TE Chordwise Spacing: 0.1% local wing chord
Chordwise Growth Factor: 1.05
Chordwise Max Spacing: 0.6% local wing chord
Root Spanwise Spacing: 0.1% wing span
Tip Spanwise Spacing: 0.02% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.15% wing span
TE No. of Cells: 8

SLAT:
Chordwise No. of Cells: 246
Spanwise No. of Cells: 2215
LE Chordwise Spacing: 0.1% local slat chord
TE Chordwise Spacing: 0.1% local slat chord
Chordwise Growth Factor: 1.05
Chordwise Max Spacing: 2.5% local slat chord
Root Spanwise Spacing: 0.008% wing span
Tip Spanwise Spacing: 0.008% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.06% wing span
TE No. of Cells: 4

FLAP:
Chordwise No. of Cells: 316
Spanwise No. of Cells: 1245
LE Chordwise Spacing: 0.1% local flap chord
TE Chordwise Spacing: 0.1% local flap chord
Chordwise Growth Factor: 1.05
Chordwise Max Spacing: 1.1% local flap chord
Root Spanwise Spacing: 0.02% wing span
Tip Spanwise Spacing: 0.02% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.09% wing span
TE No. of Cells: 8

FUSELAGE:
The fuselage surface mesh is made of triangular type element with variable size based on local curvature.

Distortion Angle (refinement based on curvature) [1-90]:10
Minimum Target Length (Cell Size Nose/Tail): 1% Cref (Wing reference lenght)
Maximum Target Length: 4% Cref
Growth Factor: 1.1
Box mesh refinement around the wing-fuselage junction: 0.9% - 1.4% Cref

COARSE MESH
WING:
Chordwise No. of Cells: 294
Spanwise No. of Cells: 741
LE Chordwise Spacing: 0.15% local wing chord
TE Chordwise Spacing: 0.15% local wing chord
Chordwise Growth Factor: 1.1
Chordwise Max Spacing: 0.9% local wing chord
Root Spanwise Spacing: 0.15% wing span
Tip Spanwise Spacing: 0.03% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.22% wing span
TE No. of Cells: 4

SLAT:
Chordwise No. of Cells: 138
Spanwise No. of Cells: 1480
LE Chordwise Spacing: 0.15% local slat chord
TE Chordwise Spacing: 0.15% local slat chord
Chordwise Growth Factor: 1.1
Chordwise Max Spacing: 3.5% local slat chord
Root Spanwise Spacing: 0.012% wing span
Tip Spanwise Spacing: 0.008% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.09% wing span
TE No. of Cells: 2

FLAP:
Chordwise No. of Cells: 203
Spanwise No. of Cells: 818
LE Chordwise Spacing: 0.15% local flap chord
TE Chordwise Spacing: 0.15% local flap chord
Chordwise Growth Factor: 1.1
Chordwise Max Spacing: 1.7% local flap chord
Root Spanwise Spacing: 0.03% wing span
Tip Spanwise Spacing: 0.03% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.14% wing span
TE No. of Cells: 4

FUSELAGE:

The fuselage surface mesh is made of triangular type element with variable size based on local curvature.
Distortion Angle (refinement based on curvature)[1-90]:10
Minimum Target Length (Cell Size Nose/Tail): 1.5% Cref (Wing reference lenght)
Maximum Target Length: 6% Cref
Growth Factor: 1.1
Box mesh refinement around the wing-fuselage junction: 1.3% - 2.9% Cref

FINE MESH
WING:
Chordwise No. of Cells: 686
Spanwise No. of Cells: 1574
LE Chordwise Spacing: 0.07% local wing chord
TE Chordwise Spacing: 0.07% local wing chord
Chordwise Growth Factor: 1.03
Chordwise Max Spacing: 0.4% local wing chord
Root Spanwise Spacing: 0.08% wing span
Tip Spanwise Spacing: 0.01% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.1% wing span
TE No. of Cells: 12

SLAT:
Chordwise No. of Cells: 384
Spanwise No. of Cells: 3266
LE Chordwise Spacing: 0.07% local slat chord
TE Chordwise Spacing: 0.07% local slat chord
Chordwise Growth Factor: 1.03
Chordwise Max Spacing: 1.5% local slat chord
Root Spanwise Spacing: 0.008% wing span
Tip Spanwise Spacing: 0.008% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.04% wing span
TE No. of Cells: 6

FLAP:
Chordwise No. of Cells: 496
Spanwise No. of Cells:: 1731
LE Chordwise Spacing: 0.07% local flap chord
TE Chordwise Spacing: 0.07% local flap chord
Chordwise Growth Factor: 1.03
Chordwise Max Spacing: 0.7% local flap chord
Root Spanwise Spacing: 0.01% wing span
Tip Spanwise Spacing: 0.01% wing span
Spanwise Growth Factor: 1.01
Spanwise Max Spacing: 0.06% wing span
TE No. of Cells: 12

FUSELAGE:
The fuselage surface mesh is made of triangular type element with variable size based on local curvature.
Distortion Angle (refinement based on curvature)[1-90]:10
Minimum Target Length (Cell Size Nose/Tail): 0.6% Cref (Wing reference length)
Maximum Target Length: 0.8% Cref
Growth Factor: 1.1
Box mesh refinement around the wing-fuselage junction: 0.6% - 0.9% Cref

d. When/how did you judge surface mesh generation to be complete?

1- When all the mesh elements are nice and smoothly distributed. With no strong size difference between neighbor cells.
2- When the surface mesh topology is good enough for the resulting layers mesh to grow all the way up to the required boundary layer´s height. Minimizing collapsed elements in concave areas.

3. Volume Meshing
   a. What software tool(s) did you use to generate your initial volume mesh?

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   b. How long did it take (elapsed time and labor – in hours)?

   1 hour (coarse), 6 hours (medium), 20 hours (fine)

   c. Provide a brief description of how mesh resolution was specified (explicit user inputs, sources, curvature based sizing, background distribution function, …)

MEDIUM MESH
LAYERS:
Layers mesh around the wing, slat and flaps are made of hexahedral elements mostly. Around the fuselage we have prismatic elements.
Layers First Height (normal dist): 0.00117 inches (Y+ = 2/3). (wing, slat, flap, fuselage)
No. of Constant Spacing Layers: 5 (wing, slat, flap, fuselage)
Layers Growth Ratio: 1.15 (wing, slat, flap, fuselage)
Wing No. of Layers: 49 (wing, slat, flap)
Fuselage No. of Layers: 64 (fuselage)

VOLUME:
Volume mesh consists of tetrahedral elements mostly and pyramids between hexa and tetra elements.
Tetra Growth Ratio: 1.15
Max Tetra Size: 3.2 wing span
Box mesh refinement around the wing-fuselage junction: 0.6% - 0.9% Cref

COARSE MESH
LAYERS:
Layers mesh around the wing, slat and flaps are made of hexahedral elements mostly. Around the fuselage we have prismatic elements.
Layers First Height (normal dist): 0.00175 inches (Y+ = 1.0). (wing, slat, flap, fuselage)
No. of Constant Spacing Layers: 3 (wing, slat, flap, fuselage)
Layers Growth Ratio: 1.23 (wing, slat, flap, fuselage)
Wing No. of Layers: 33 (wing, slat, flap)
Fuselage No. of Layers: 43 (fuselage)

VOLUME:
Volume mesh consists of tetrahedral elements mostly and pyramids between hexa and tetra elements.
Tetra Growth Ratio: 1.23
Max Tetra Size: 4.8 wing span
Box mesh refinement around the wing-fuselage junction: 0.6% - 0.9% Cref

FINE MESH
LAYERS:
Layers mesh around the wing, slat and flaps are made of hexahedral elements mostly. Around the fuselage we have prismatic elements.
Layers First Height (normal dist): 0.00078 inches (Y+ = 4/9). (wing, slat, flap, fuselage)
No. of Constant Spacing Layers: 7 (wing, slat, flap, fuselage)
Layers Growth Ratio: 1.10 (wing, slat, flap, fuselage)
Wing No. of Layers: 72 (wing, slat, flap)
Fuselage No. of Layers: 94 (fuselage)

VOLUME:
Volume mesh consists of tetrahedral elements mostly and pyramids between hexa and tetra elements.
Tetra Growth Ratio: 1.1
Max Tetra Size: 2 wing span
Box mesh refinement around the wing-fuselage junction: 0.6% - 0.9% Cref

d. For resolving surface boundary layers, what cell size growth rate did you use? Was it constant or variable? If variable, describe.

1.23 (coarse), 1.15 (medium), 1.10 (fine)

e. When/how did you judge volume mesh generation to be complete?

1- When [FLUENT] Solid Maximum Skewness is below 0.95
2- When [FLUENT] Solid Non Orthogonality is below 0.02
3- When [IDEAS] Solid Maximum Warping is below 60

4-When minimum volume is greater than 1e-5 mm3

4. Adherence to HiLift-PW3 meshing guidelines
    a. To what extent did your mesh(es) adhere to the HiLift-PW3 meshing guidelines?

       Full extent

    b. Was it possible to adhere to the guidelines on the first attempt, or were there iterations involved?

       First attempt

    c. What were the reasons that you did not adhere to the guidelines? (chose all that apply)
       - [ ] The guideline does not pertain to the type of mesh generated
       - [ ] The guidelines were (locally) inconsistent and therefore could not all be satisfied
       - [ ] The tools used do not give enough control to adhere to the guideline
       - [ ] Adhering to the guideline would have required more resources than were available
       - [ ] The guidelines were not appropriate for the CFD solver being used
       - [ ] Other (describe):

5. A priori metrics (such as skew, or maximum stretching ratio, maximum deviation of mesh nodes from OML or …)
    a. What a priori metrics did you apply on the initial mesh?

       1- [FLUENT] Solid Maximum Skewness
       2- [FLUENT] Solid Non Orthogonality
       3- [IDEAS] Solid Maximum Warping
       4- Minimum volume

    b. What was the average and range of the metrics?

       1- [FLUENT] Solid Maximum Skewness [0.85 to 0.95]
       2- [FLUENT] Solid Non Orthogonality [0.1 to 0.02]
       3- [IDEAS] Solid Maximum Warping [40 to 60]
       4- Minimum volume greater than 1e-5 mm3

    c. Did the a priori metrics point out any problems that needed to be fixed? If so, which metric and how many times did you need to re-mesh?
       Yes.
       [FLUENT] Solid Maximum Skewness and [FLUENT] Solid Non Orthogonality. There were bad tetra and pyramid elements with extreme skewness and non orthogonality values. It took a few tries to get the right mesh quality settings to avoid bad elements and keep maximum skewness and non orthogonality within the desired limits.

6. Were there any additional best practices that you used in generating the meshes?

   The surface mesh is essentially a structured 2D mesh of quad elements. In order to avoid problems with tetra generation, one must keep the aspect ratio of the quad elements on the top cap of the last layer below 8. Otherwise the tetra algorithm will have difficulty in creating the transition between hexa and tetra elements.

7. What was the required level of user expertise (novice, intermediate, expert) for this task?

   Expert

Adaptive Meshes (Only answer if you generated an adapted mesh)

1. What adaptive meshing strategy did you use (technique and software)?
2. What criteria were used for mesh adaptation (e.g., pressure, vorticity, …)?
3. What, if any, further treatments (e.g. smoothing) were applied? (Please describe)

Mesh Families

1. What strategy did you use to generate the family of meshes (coarse, medium, fine, extra fine)? For example, did you generate the coarse mesh first and refine it, or did you start each mesh generation task essentially from the beginning?

   At first we started by the medium mesh, then moved to coarse mesh and finally to fine mesh. But it was necessary to make some adjustments in the initial surface mesh topology to avoid a large area of collapsing layers due to difficulties in growing layers on concave areas of the model. Therefore, the medium and coarse meshes were modified to have the same mesh topology as the fine mesh. There were 5 iterations until the final mesh family was ready to run. In my experience with these meshes, next time I would prefer to start from the finest mesh first and then move to the coarse ones.

2. In your opinion, what was the most time-consuming or tricky aspect of generating a family of meshes?

   The ANSA´s MAP Mesh tool was the key to create a family of meshes which are consistent with each other and in full adherence to the HiLift-PW3 meshing guidelines. However, despite the MAP Mesh tool provides total control during the specifications of the surface mesh resolution, it ´s a very time consuming task when you have to mesh complex geometries like the HL-CRM model. One must be careful about how the surface mesh elements are distributed in order to avoid problems with layers mesh growth and tetra volume generation.

3. How did the times (labor, CPU, etc.) needed to generate them compare?

   The first mesh takes more time because one must first define and create the surface mesh topology on the wing, slat and flap which meets the meshing guidelines requirements. Defining the topology means creating the MAP Mesh boundaries and how the mesh points are distributed in them. Once the topology is done, the other meshes of the family are defined by the required resolution. For the coarse mesh it took 6.5 hours, 12 hours for the medium and 28 hours for the fine mesh. This is the time needed for the whole process. The difference in mesh size between each mesh level is a factor of approximately 3X, as required, and the difference in generation time is a factor of 2X between each mesh level.

4. Were there any problems that you encountered in one mesh resolution that you did not encounter in another resolution?

   We had some issues with the fine mesh where the tetra algorithm crashed or blocked during volume generation. A workaround for this problem was to change the surface mesh resolution in order to keep the aspect ratio of the quads on the top cap of the last layer at a maximum value of 8.

Post-Solution Mesh Modifications

1. After generating an initial flow solution, where additional mesh modifications made to improve solver convergence or solution accuracy?

   Yes. We found some strange behavior of the shearlines at the wing upper surface for the fine mesh. The shearlines were distorted like there were something disturbing the flow upstream. We believe the observed behavior is not physical and we started looking for what could be causing this numerical problem. The answer was bad pyramids and tetrahedral with extreme skewness all over the wing and slat top cap quad elements. The poor accuracy due to this bad elements caused a numerical flow perturbation that was convected downstream the slat and wing upper surface.

2. Describe any post solution mesh modifications that were made?

   It was created a volume mesh improvement approach in order to avoid extreme bad elements like the pyramids and tetrahedrals mentioned above. Those are the quality criteria used in the volume improvement process:
   1- [FLUENT] Solid Maximum Skewness [0.85 to 0.95]
   2- [FLUENT] Solid Non Orthogonality [0.1 to 0.02]
   3- [IDEAS] Solid Maximum Warping [40 to 60]
   4- Minimum volume greater than 1e-5 mm3

3. How long did these modifications take (elapsed time and labor – in hours)?

   The volume improvement takes about 0.25 hours for the coarse mesh, 1.5 hours for the medium mesh and about 5 hours for the fine mesh.

I/O

1. In which format did you export your meshes? (CGNS, Solver-native, …):

CFD++

2. What are the names of the files you uploaded to the GMGW-1 server?

   19-hl-crm-gapped-flaps-CFDpp_coarse_M5.tar.gz
   19-hl-crm-gapped-flaps-CFDpp_medium_M5.tar.gz
   19-hl-crm-gapped-flaps-CFDpp_fine_M5.tar.gz
   GMGW-1-Participant-Questionnaire-Version1p0-Embraer_M5.pdf

Miscellaneous

1. Are there any other aspects of your HL-CRM mesh generation experience that you would like to draw our attention to?