Tips and Tricks for Hex "Brick" Meshing

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Tips and Tricks for Hex "Brick" Meshing

- How effective are you at creating a Brick Mesh?

- This webinar will:
  - Identify Hex meshable geometry
  - Prepare topology for meshing and diagnosis why models don't sweep
  - Provide info on when to use Sweep vs. Multi-Zone Methods
  - Demonstrate combined Hex and Tetrahedron elements in a flow through mesh
Tips and Tricks for Hex "Brick" Meshing

- **When should I Hex Mesh?**
  - **Require Computational Efficiency:** When less nodes and elements are required but need to achieve high solution accuracy.
  - **Have Limited Computer Resources:** A brick meshed model can save orders of magnitude’s of CPU time and require significantly less RAM and disk space over an all tetrahedron mesh with often better accuracy.
  - **Need Controlled Mesh Metrics:** A mesh where all elements contain three mostly parallel faces is easy to check since the exterior faces provide enough detail to fully comprehend the entire mesh geometry.
  - **Geometry is Amenable:** Unlike tetrahedron meshing that can be performed on nearly any geometry, hex meshing requires a certain amount of topology cleaning and decomposition to achieve an all or nearly all brick mesh.
Identify Hex Meshable geometry

- All Brick Mesh Examples
General Rules of Thumb for Hex Meshing

- For simple geometry with clean topology (no slivers, gaps, steps, small fillets etc)
  - Hex Mesh using Sweep Meshing
  - Slice and/or split bodies for more control and to meet topology requirement of map meshable sides
  - Use Multi-Zone with thicker solids, use Sweep with thinner parts
  - For thin walled bodies with regular geometry consider sweep mesh using Thin Body Sweep (SolidShell Elements)
General Rules of Thumb for Hex Meshing

- For medium topological complexity
  - Sweep using decomposition and/or Multi-Zone
  - Example Hybrid Mesh

- For Dirty Geometry (slivers, gaps, small fillets, little steps, etc.)
  - Consider Tetra Patch Independent Mesh or Mixed Mesh (Hex Dominant, Multi-Zone)
Hex meshing robustness

- Swept mesh along varying profiles for accurate results (blades, etc.)
Hex meshing robustness

- Hex vs. Tet

**Tet Mesh**
- Elements: 48K
- Statistics:
  - Nodes: 9296
  - Elements: 48738
  - Mesh Metric: Skewness
    - Min: 8.0759120277496E-05
    - Max: 0.809031191410968
    - Average: 0.236026063758096
    - Standard Deviation: 0.123317626353581

**Sweep Mesh**
- Elements: 19K
- Statistics:
  - Nodes: 21348
  - Elements: 19614
  - Mesh Metric: Skewness
    - Min: 1.79292772803879E-02
    - Max: 0.606963936309246
    - Average: 0.175918570374858
    - Standard Deviation: 0.118321537967619

Method = Tetrahedrons: 44963 elements, 76513 nodes

Method = Sweep: 9960 elements, 12628 nodes

4.5x less Elements
6x less Nodes
Prepare Topology for meshing

- Why models don't sweep (when they appear like they should!)?

Can be vertex related. Turn on vertices to visualize.

Correct with DM or Virtual Topology
Sweep vs. MultiZone Methods

- **Sweep**
  - Must Obey Edge Faceting

- Or switch to Multizone Method
  - Multizone with Defeaturing Option
Sweep Meshing: Complex geometry

**Details of "Inflation 2" - Inflation**

<table>
<thead>
<tr>
<th>Scope</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoping Method</td>
<td>Geometry Selection</td>
</tr>
<tr>
<td>Geometry</td>
<td>1 Face</td>
</tr>
<tr>
<td>Suppressed</td>
<td>Nn</td>
</tr>
<tr>
<td>Boundary</td>
<td>2 Edges</td>
</tr>
<tr>
<td>Inflation Option</td>
<td>First Layer Thickness</td>
</tr>
<tr>
<td>First Layer Height</td>
<td>150. mm</td>
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<tr>
<td>Maximum Layers</td>
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</tr>
<tr>
<td>Growth Rate</td>
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</table>

**Details of "Sweep Method" - Method**

<table>
<thead>
<tr>
<th>Scope</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoping Method</td>
<td>Geometry Selection</td>
</tr>
<tr>
<td>Geometry</td>
<td>1 Body</td>
</tr>
<tr>
<td>Suppressed</td>
<td>No</td>
</tr>
<tr>
<td>Method</td>
<td>Sweep</td>
</tr>
<tr>
<td>Element Midside Nodes</td>
<td>Use Global Setting</td>
</tr>
<tr>
<td>Src/Trg Selection</td>
<td>Manual Source</td>
</tr>
<tr>
<td>Source</td>
<td>1 Face</td>
</tr>
<tr>
<td>Target</td>
<td>Program Controlled</td>
</tr>
<tr>
<td>Free Face Mesh Type</td>
<td>Quad/Tri</td>
</tr>
<tr>
<td>Type</td>
<td>Number of Divisions</td>
</tr>
<tr>
<td>Sweep Num Divs</td>
<td>20</td>
</tr>
<tr>
<td>Sweep Bias Type</td>
<td>____ ____ ____ ____</td>
</tr>
<tr>
<td>Sweep Bias</td>
<td>2.</td>
</tr>
<tr>
<td>Element Option</td>
<td>Solid</td>
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</tbody>
</table>
MultiZone Meshing

- **Method Behavior**
  - Automatically decomposes geometry into blocks
  - Generates structured hex mesh where block topology permits
    - Remaining region (Free Mesh) filled with unstructured Hexa Core or Tetra or Hexa Dominant mesh.
  - Can select source & target faces automatically or manually
    - Can have multiple source faces
  - Compatible with 3D inflation

- **Access**
  - Insert Method and set to Multizone

*Target faces should also be selected as “Source” for Multizone Method as mesh is swept from both directions*
MultiZone Meshing

- Mapped Mesh Type – determines the shape of the elements used to fill structured regions (the default is Hexa).
  - Hexa - All hexahedral elements are generated
  - Hexa/Prism - For swept regions, the surface mesh can allow triangles for quality and transitioning
  - Prism - All prism elements are generated
  - This option is sometimes useful if the source face mesh is being shared with a tet mesh, as pyramids are not required to transition to the tet mesh
MultiZone Meshing

- Surface Mesh Method – specifies method to create the surface mesh.
  - Program Controlled - automatically uses a combination of Uniform and Pave mesh methods depending on the mesh sizes set and face properties.
- Uniform - uses a recursive loop-splitting method which creates a highly uniform mesh.
- Pave - creates a good quality mesh on faces with high curvature, and also when neighboring edges have a high aspect ratio.
Constraints Required for Sweeping

- When sweeping (Sweep/MultiZone) you have:
  - Pairs of free faces (sources/targets)
  - Constrained/mapped faces (sides)
- Software/User should decide best direction to sweep
- Rules:
  - User controls sweep direction by selecting source/target faces, otherwise software makes best guess
  - All source/target face topology needs to be same for all sources/targets
  - All side faces need to be able to be mapped meshed
MultiZone Meshing

- Single body automatically decomposed into three blocks
- Src/Trg Selection – Automatic
  - Results in all hex mesh
- Equivalent to manually decomposing by slicing off upper and lower cylinders to produce three bodies and applying sweep methods

![Image of multi-zone meshing process]

- Details of "MultiZone" - Method
  - Scope
    - Scoping Method: Geometry Selection
    - Geometry: 1 Body
  - Definition
    - Suppressed: No
    - Method: MultiZone
    - Mapped Mesh Type: Hexa
    - Free Mesh Type: Not Allowed
    - Element Midside Nodes: Use Global Setting
    - Src/Trg Selection: Automatic
    - Source: Program Controlled
  - Advanced
    - Mesh Based Defeaturing: Off
    - Minimum Edge Length: 0.5 m
    - Write ICEM CFD Files: No
MultiZone Meshing Cont.

- Blend on central body, Multizone no longer able to create structured block
  - Filled according to Free Mesh setting
  - Tetra, Hexa Core, Hexa Dominant

- Can specify type of surface mesh using Mapped Mesh Type (Hexa, Hexa/Prism, Prism)
Multizone Meshing Cont.

- Single Body that is not Sweepable but contains Mappable Face Mesh Surfaces

- Sub divide for meshing using Virtual Topology
  - Use Split Edge by selecting edges
  - Use Split Faces by selecting two vertices
Multizone Meshing Cont.

- Virtual Topology Blocking – Split Edges
  - Filter Edge Select
  - Click on the edge at the location of the desired split
  - RMB > Insert > Virtual Split Edge at +
Multizone Meshing Cont.

- Virtual Topology Blocking – Create Split Faces
  - Filter Vertex Select
  - Select 2 vertices
  - RMB > Insert > Split Face at Vertices

![Click](image.png)

![Split Face](image.png)
Multizone Meshing Cont.

- Virtual Topology Blocking – 2D Split Faces
Multizone Meshing Cont.

- Use Multizone and select 2 source faces

- Use Inflation on all exterior surfaces
Slice Model and use Sweep Meshing

- **Design Modeler:**
  - Extrude Edges
  - Slice Surfaces
    - Use planes etc.

<table>
<thead>
<tr>
<th>Extrude</th>
<th>Extrude4</th>
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</thead>
<tbody>
<tr>
<td>Geometry</td>
<td>1 Edge</td>
</tr>
<tr>
<td>Operation</td>
<td>Slice Material</td>
</tr>
<tr>
<td>Direction Vector</td>
<td>2D Edge</td>
</tr>
<tr>
<td>Direction</td>
<td>Reversed</td>
</tr>
</tbody>
</table>

- **Mechanical:**
  - Use Mapped Face Meshing on Ends
  - Use Edge Sizing
Slice Model and use Sweep Meshing

- Final Mesh
Often the Hybrid Mesh is the best option when considering modeling time and solution accuracy.
Mixed Order Meshing

- Mixed Order mesh transitions

Solid186 Brick w/ dropped midnodes
Solid186 Pyramid
Solid185 Brick
Solid186 Brick w/ dropped midnodes
Solid186 Pyramid
Solid187 Tet
Solid187 Tet

Edges of Meshed Volumes

Nodes
Elements (Side view of 1 row of elements from model above)
Combined Hex and Tetrahedron Mesh

- Example Blade / Platform

Multizone Mesh

Tet Meshed Regions

Sweep Mesh Region
Combined Hex and Tetrahedron Mesh

- Example Blade / Platform
Common Preprocessing Bottlenecks

- V15 Targeted improvements to reduce/eliminate these bottlenecks