ANSYS

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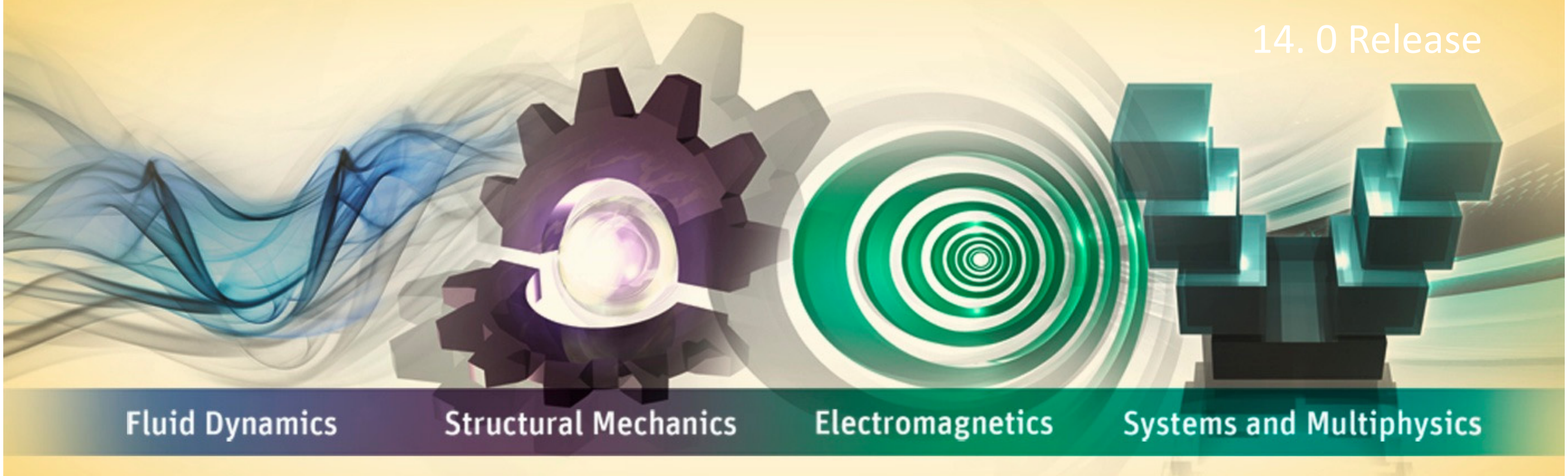
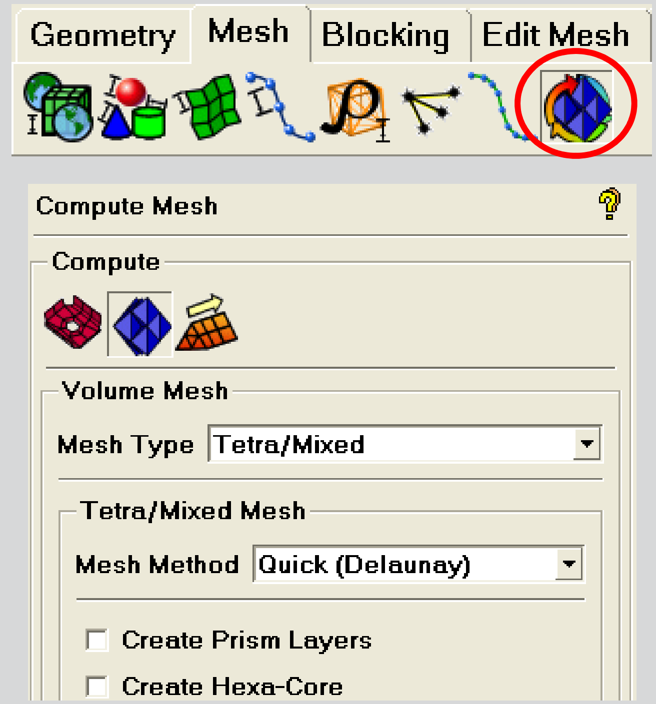
Lecture 4
Volume Meshing

14. 0 Release



Introduction to ANSYS ICEM CFD

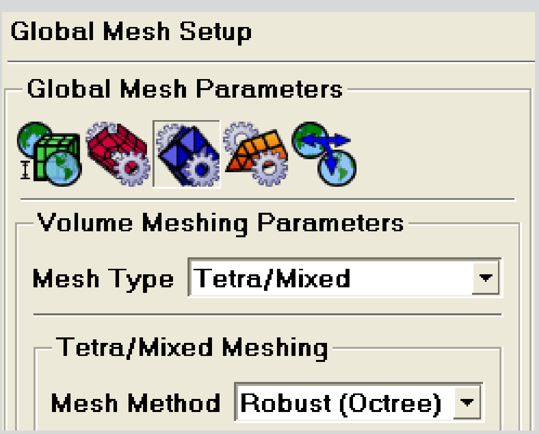
Introduction to Volume Meshing



- To automatically create 3D elements to fill volumetric domain
  - Generally termed “unstructured”
    - Mainly tetra
  - Full 3D analysis
    - Where 2D approximations don’t tell the full story
  - Internal/External flow simulation
  - Structural solid modeling
  - Thermal stress
  - Many more!
- Standard procedures
  - Start from just geometry
    - Octree tetra
      - Robust
      - Walk over features
    - Cartesian
      - Fastest
    - Have to set sizes
  - Start from existing shell mesh
    - Delauney/T-grid
      - Quick
    - Advancing Front
      - Smoother gradients, size transition
    - Hex Core
    - Hex Dominant
  - Both geometry and shell mesh
    - Octree tetra
      - Portions of model already meshed
      - Set sizes on rest
  - Prism layers
    - “Prism”

General Procedure

- First decide volume mesh parameters
  - *Global Mesh Setup > Volume Meshing Parameters*
  - Select *Mesh Type*
  - Select *Mesh Method* for selected *Type*
  - Set options for specific *Methods*



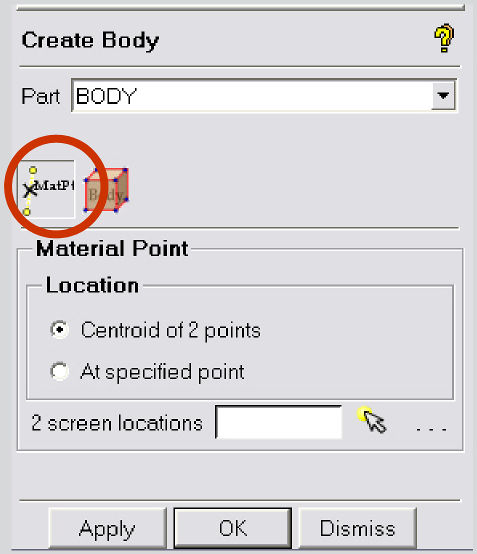
- Set mesh sizes
  - Globally
    - As in *Shell Meshing*
  - Locally
    - *Part/Surface/Curve Mesh Setup*
    - As in *Shell Meshing*
    - For *From geometry*:
      - Octree
      - Cartesian
- Define volumetric region
  - Typically for octree on complex models
  - Multiple volumes possible
- Define density regions (optional)
    - Applying mesh size within volume where geometry doesn't exist

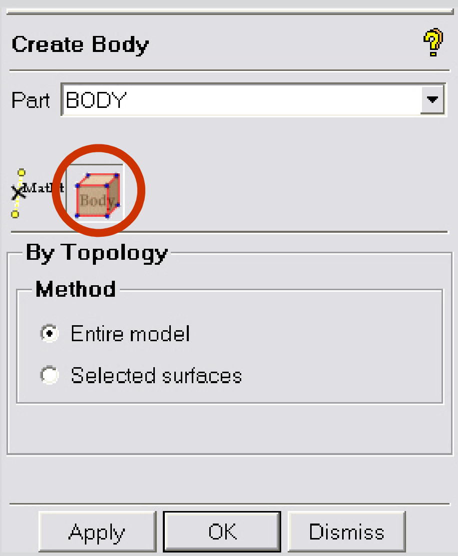
- Load/create surface mesh
  - As in Shell Meshing chapter
  - For Delauney, Advancing Front, ANSYS TGrid, Hex-Dominant
    - Either of these types run from geometry will automatically create surface mesh using global and local Shell Mesh settings without any user input/editing
    - If in doubt, run Shell Mesh first, then from existing mesh

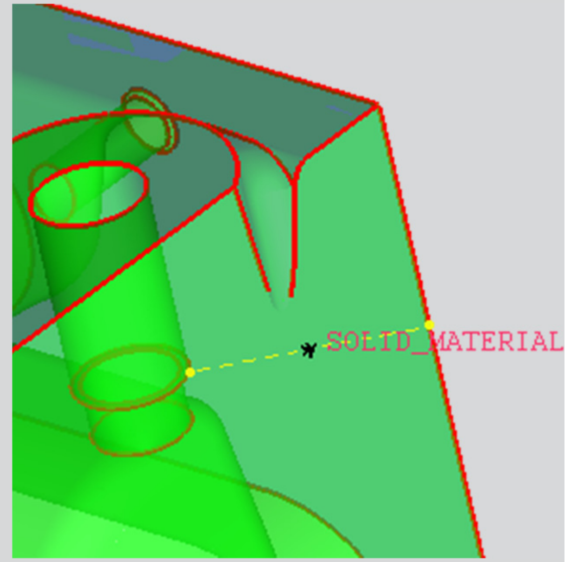
- Compute Mesh
  - Mesh > Compute
    Mesh > Volume Mesh

- Compute Prism (optional)
  - As separate process
  - Also option to run automatically following tetra creation

Body/Material Point





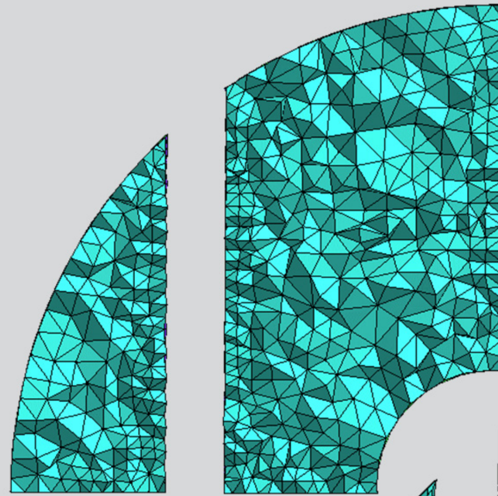


Define Volumetric Domain

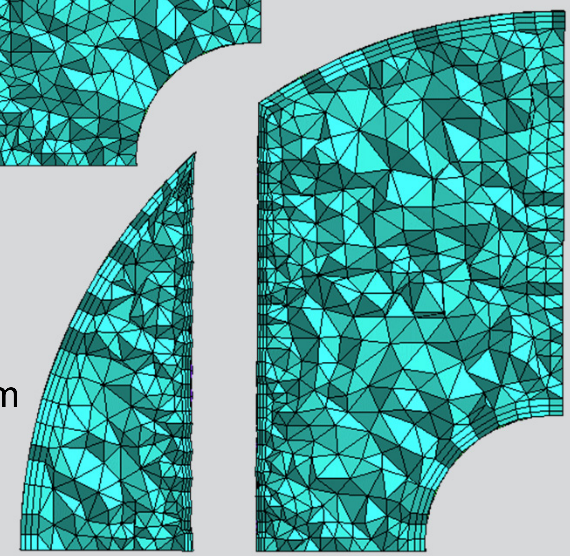
- Optional
  - Recommended for complex geometries
  - Or multiple volumes
- *Geometry -> Create Body*
- *Material Point*
  - Centroid of 2 points
    - Select any two locations whose mid-point is within volume
    - Preferred, because more robust than **By Topology** method
  - At specified point
    - Define volume region at a “point” within volume
- *By Topology*
  - Defines volume region by set of closed surfaces
  - Must first *Build Diagnostic Topology* to determine connectivity
    - Will fail if gaps/holes in body
  - *Entire model*
    - Automatically define all volumes
  - *Selected surfaces*
    - User selects surfaces that form a closed volume

Mesh Types

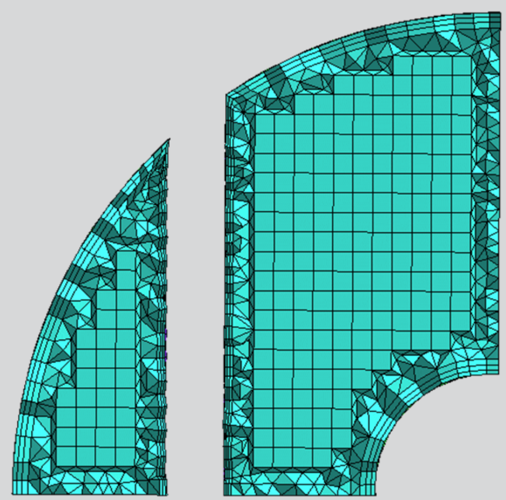
- ***Tetra/mixed***
  - Most used type
  - Pure tetra
  - With prism layers
    - Prisms from tri surface mesh
    - Hexas from quad surface mesh
    - Tetra and/or hex core filling interior
    - Pyramids to cap off any quad faces from prism sides, hex core, or hex prism layers
  - With hex core
    - Available in Cartesian type too
    - Hexa filling majority volume
    - Tetra (from Delauney algorithm) used to fill between surface or top of prism layers and hex core
    - Pyramids to make conformal between tetra and hex quad faces
  - Hybrid mesh can be created by merging with a structured hex mesh



Pure tetra



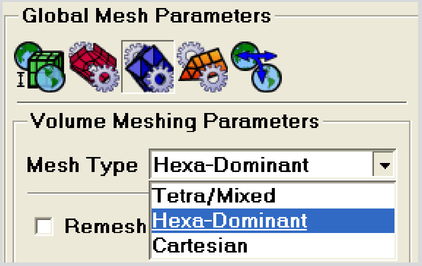
Tetra/Prism

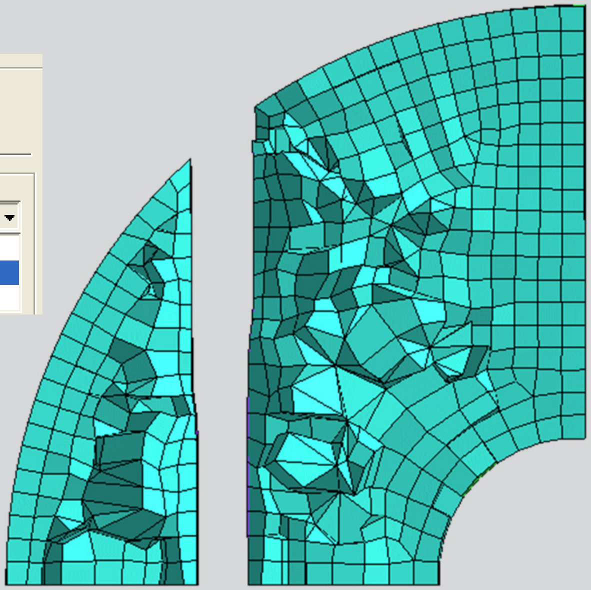


Tetra/Prism/Hexcore

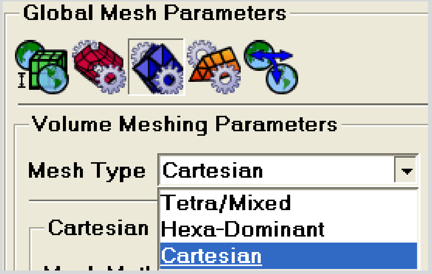
Mesh Types - Continued

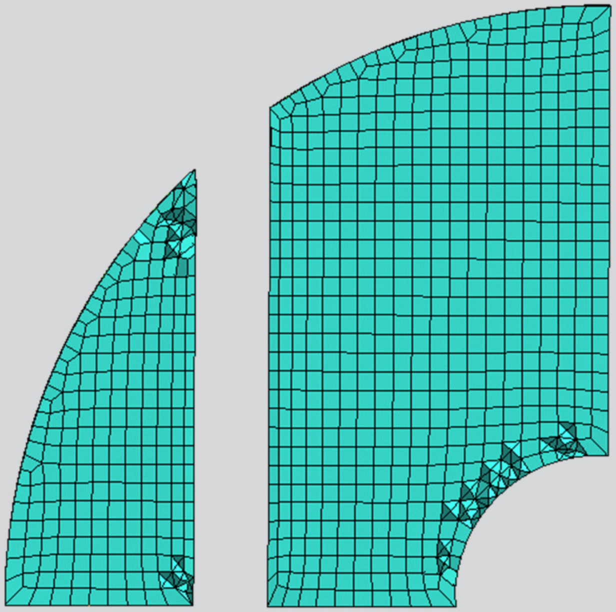
- **Hexa-Dominant**
  - Uses existing quad mesh
  - Good quality hex near surface
  - Somewhat poor in interior
  - Typically good enough for static structural analysis but not CFD
  - Not covered in detail here





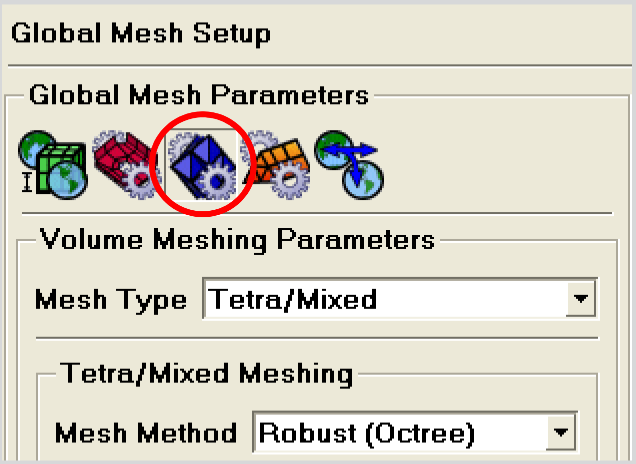
- **Cartesian**
  - Methods available in Cartesian
    - *Staircase*
    - *Body fitted*
    - *Hexa-Core*
  - Automatic pure Hexa
  - Rectilinear mesh
  - Fastest method for creating volume mesh
  - Not covered in detail here





Mesh Methods - Octree

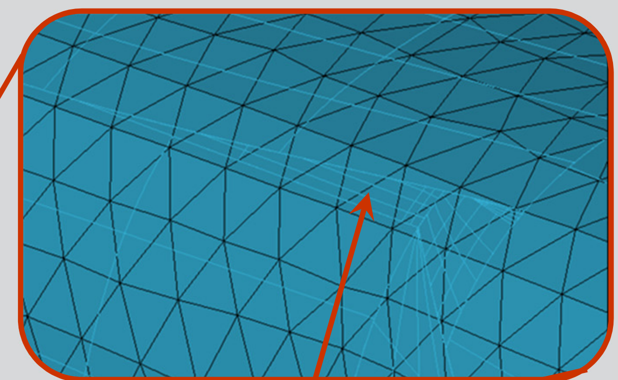
- Type - *Tetra/Mixed*
  - Method - *Robust (Octree)*
    - Same as Shell Meshing > Patch Independent
      - Retains volumetric tetras
    - Good choice for complex and/or dirty geometry
    - Good if you don’t want to spend too much time with geometry cleanup
    - Good if you don’t want to spend too much time with detailed shell meshing
    - Good if you don’t want to spend time defeaturing geometry
    - Just set appropriate mesh sizes on geometry
      - Global sizes (max size, curvature/proximity based)
      - By parts (*part mesh setup* spreadsheet)
      - Surfaces
      - Curves
      - Review *Shell Meshing* chapter
        - *Part/Surface/Curve Mesh Setup*

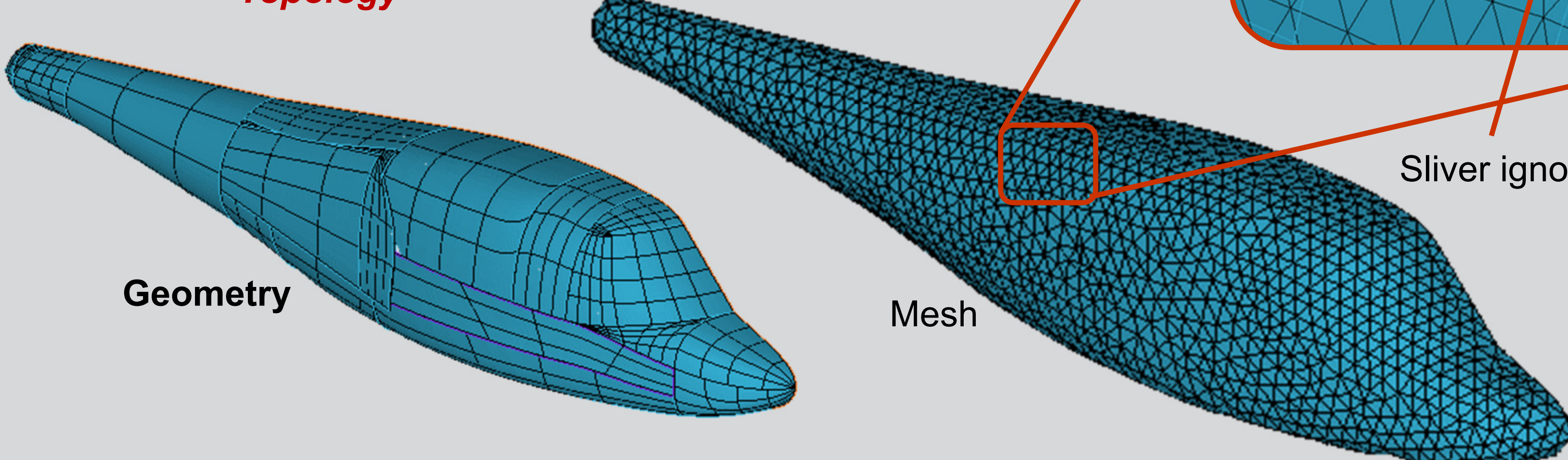


Octree Method Characteristics

- **Octree process**
  - **Volume first generated independent of surface model**
  - **Tetras divided near regions where sizes are set smaller**
  - **Nodes are projected to model surfaces, curves and points**
  - **Surface mesh is created when outside tetras are cut away**
- **Resulting mesh is independent of the underlying arrangement of surfaces**
  - **Not all surface edges need to be captured!**
  - **Surfaces edges only captured if curve exists there**
    - **Delete curves to ignore hard edges**
    - **Or filter points/curves under *Build Diagnostic Topology***

Mesh detail

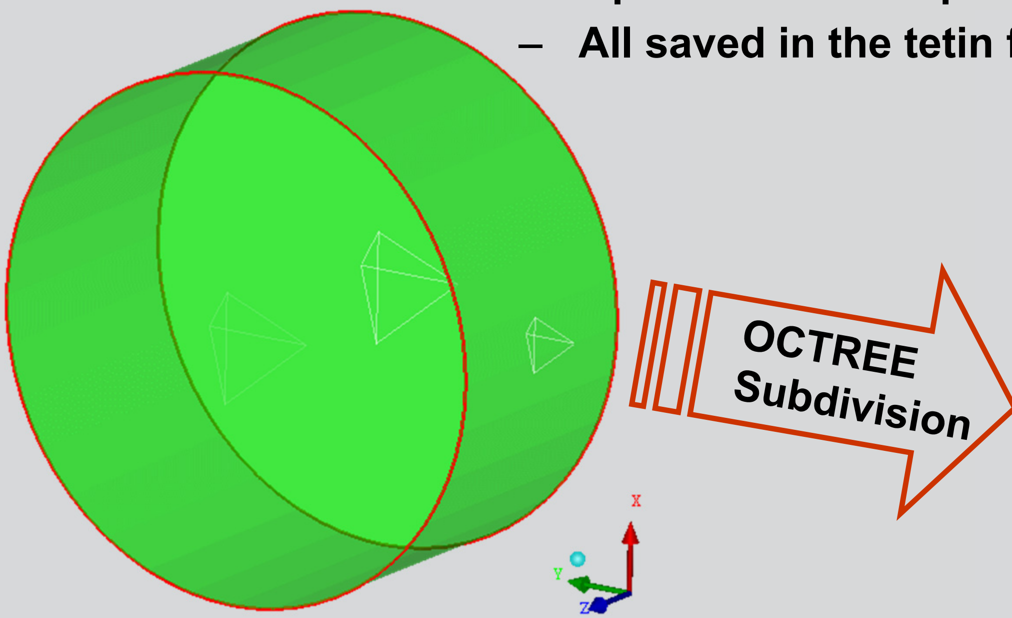


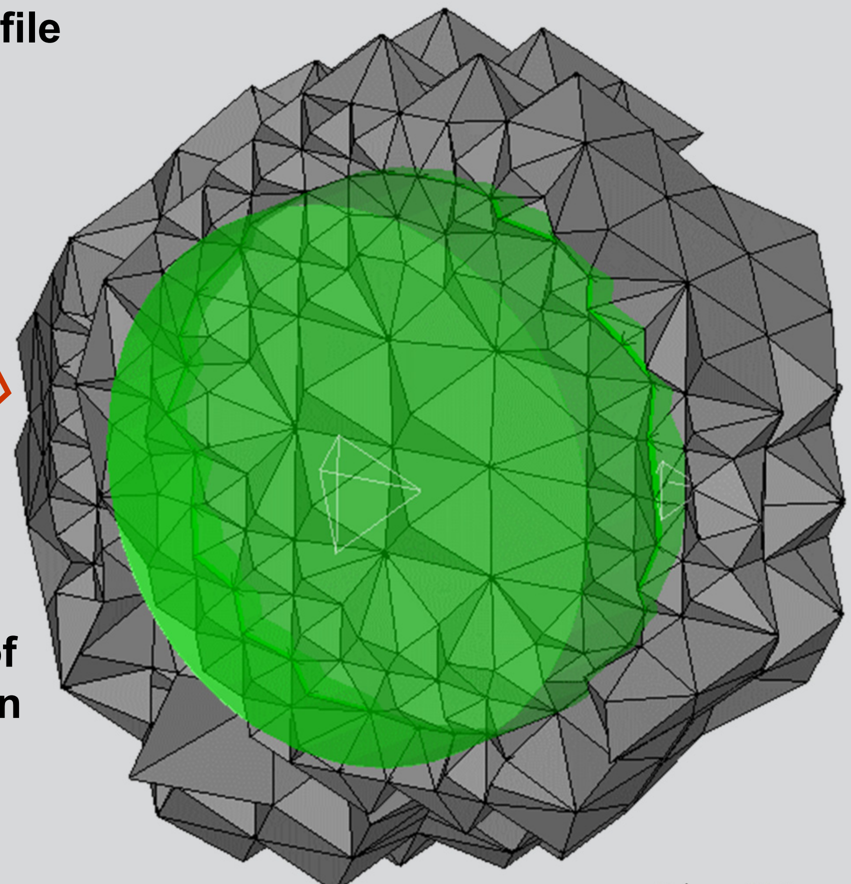


Octree Tetra Process

Initial conditions

- **Geometry including surfaces, curves and points (from Build Topology)**
- **Mesh size set globally and/or on surfaces/curves/densities**
- **Optional material point could also be created**
- **All saved in the tetin file**

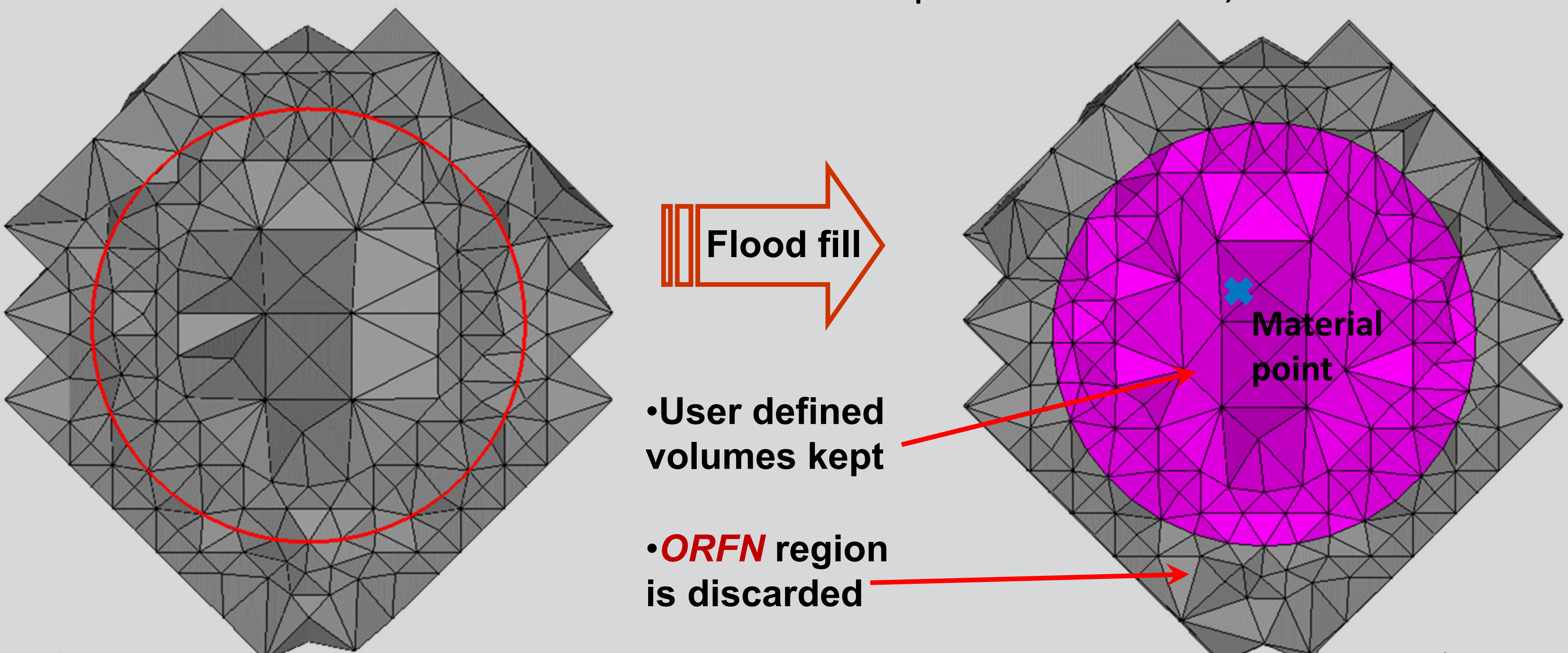




The Octree process creates an initial mesh of "Maximum size" elements which fills a region around and through a bounding region completely encapsulating the geometry.

Tetra Process, Cont’d

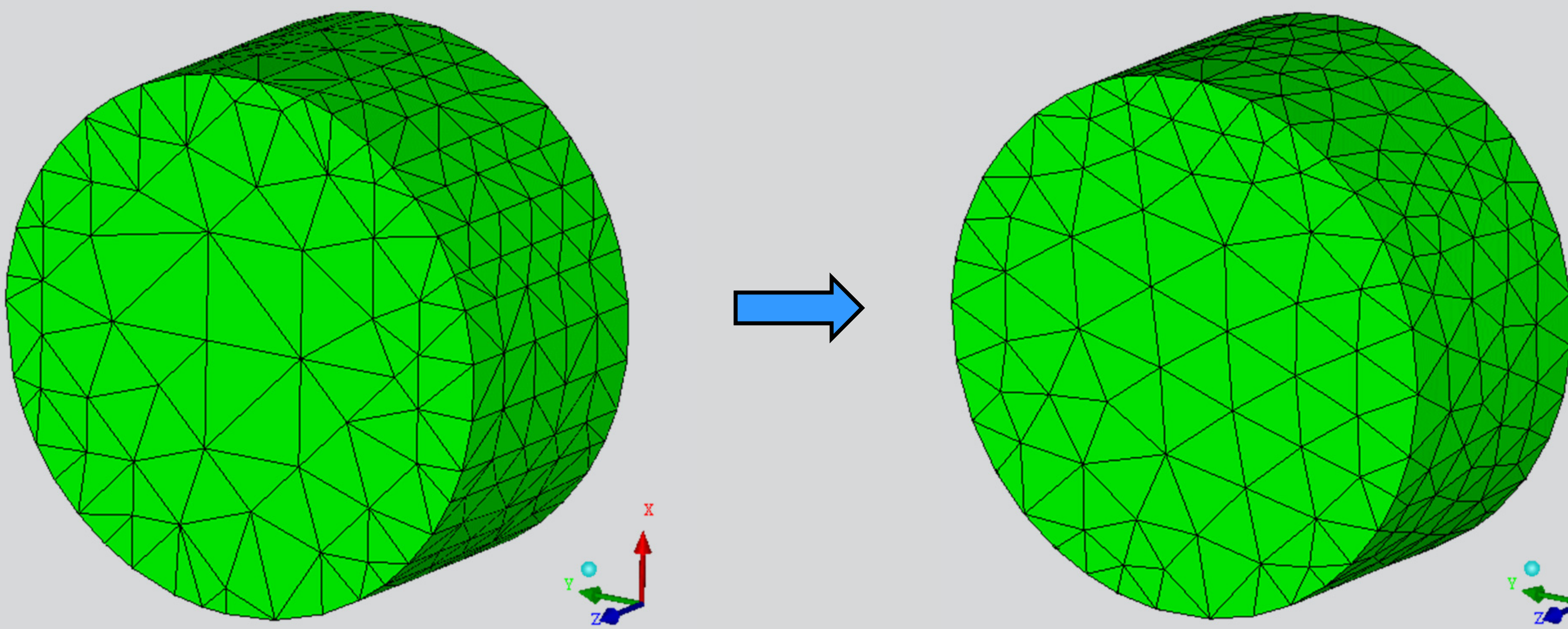
- **Mesh then subdivided to meet the entity size parameters**
  - **Factor of 2 in 3-dimensions, hence the name Octree**
- **Nodes are adjusted (projected) and edges are split/swapped to conform to the geometry**
- **Automatic “flood fill” process finds volume boundaries**
  - **Initial element assigned to part name of material point**
  - **Adjacent layers added to same part until boundary surfaces are reached**
  - **Multiple volumes are supported for multi-region or multi-material problems**
  - **Elements outside the domain are marked into a reserve part name called *ORFN*, then deleted**



Tetra Process, Cont'd

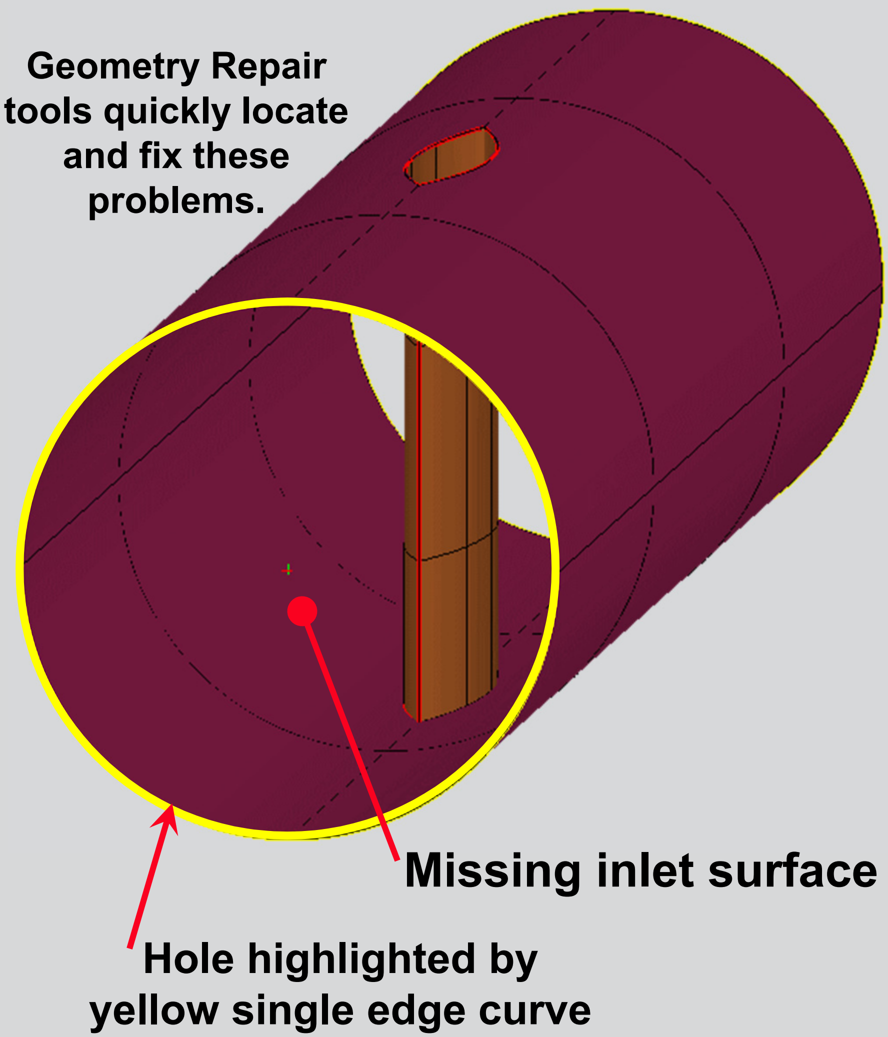
- Smooth
  - Octree mesh is initially composed of regular right angle tetras
  - Smoother can be set to run to improve quality
  - Or run afterwards:

Edit Mesh -> Smooth Mesh Globally

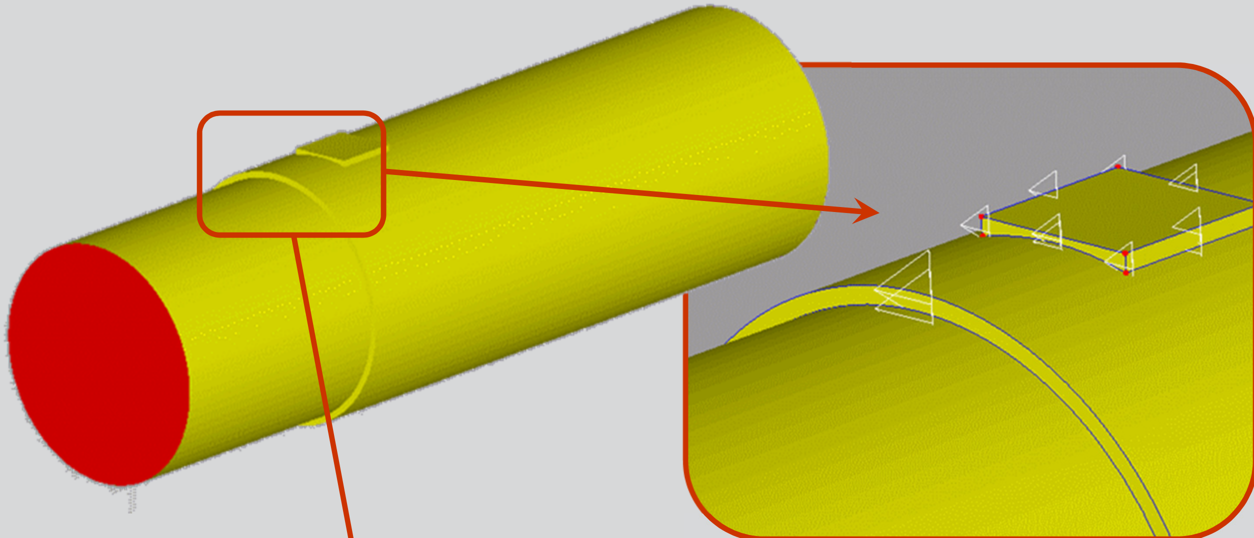


Geometry Requirements for Octree Tetra

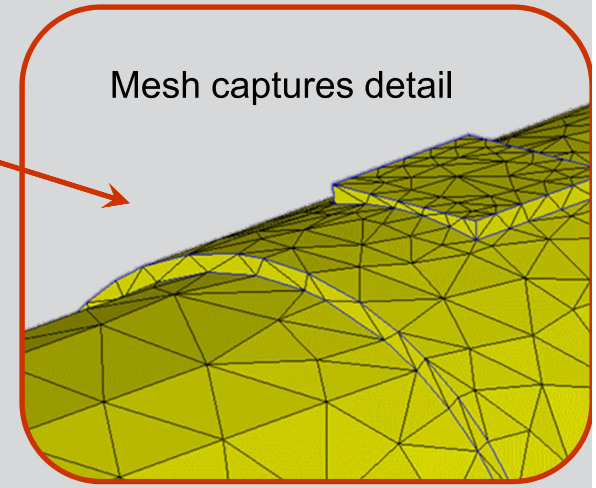
- **Tetra requires a reasonably enclosed surface model**
  - Run *Build Diagnostic Topology* to find gaps/holes
  - Octree can tolerate gaps smaller then the local element size (1/10th the element size or less)
- **Keep points and curves at key features and hard edges**
  - *Filter curves and points* by angle with *Build Diagnostic Topology*
- **Create Material points to define volumes**
  - Will create a material point if none exists (named *CREATED_MATERIAL#*)
- **Set Global, Part, Surface, Curve Size Parameters**
  - Similar to *Shell Meshing* section

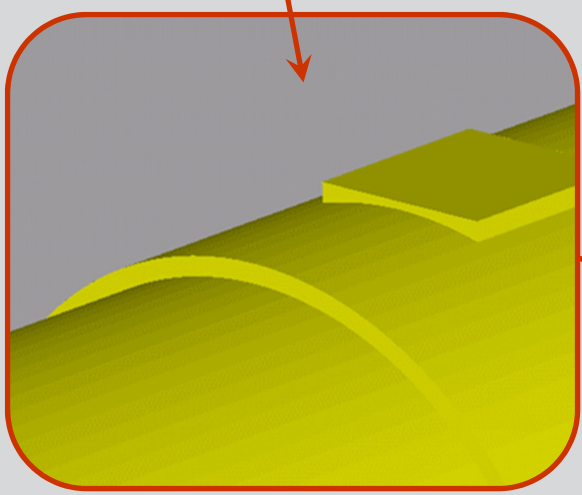


Using Points and Curves with Tetra Octree

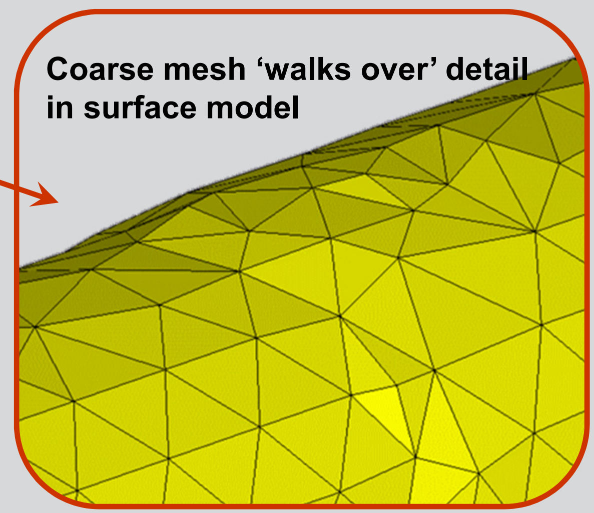


- **Curves and points included**
- **Mesh size specified on curves and surfaces**



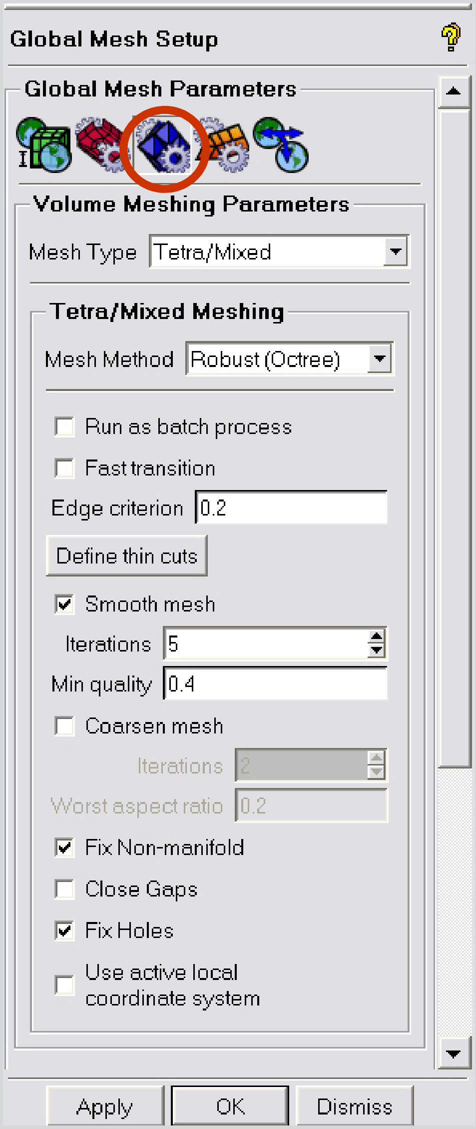


- **Curves and points not included**
- **Mesh size specified only on surfaces**



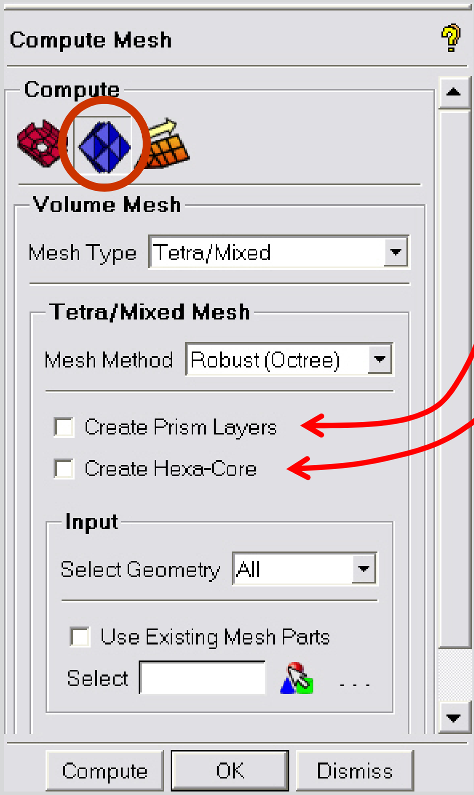
- **Curves and points affect which features are captured by the mesh!**
- **Build Topology easily creates the necessary points and curves easily with filter by angle**

Tetra Octree - Options



- **Setup options:**
- ***Global Mesh Setup > Volume Meshing parameters***
  - ***Run as batch process***
    - **Runs as a separate process. GUI will stay interactive.**
  - ***Fast Transition***
    - **Allows for a faster transition in element size from finer to coarser**
    - **Reduced element count**
  - ***Edge Criterion***
    - **Split elements at a factor greater than set value to better capture geometry**
  - ***Define Thin cuts***
    - **Tool for resolving thin gaps, sharp angles**
    - **User selects pairs of opposing parts**
    - **Resolves elements jumping from one side to another**
  - **Smooth**
    - **Automatically smoothes after grid generation process**
  - ***Coarsen***
  - ***Fix Non-manifold***
    - **Automatically tries to fix elements that jump from surface to another surface**
  - **For a more detailed description go to *Help > Help Topics > Help Manual > Mesh > Global Mesh Setup > Volume Meshing Parameters > Tetra/Mixed > Robust (Octree)***

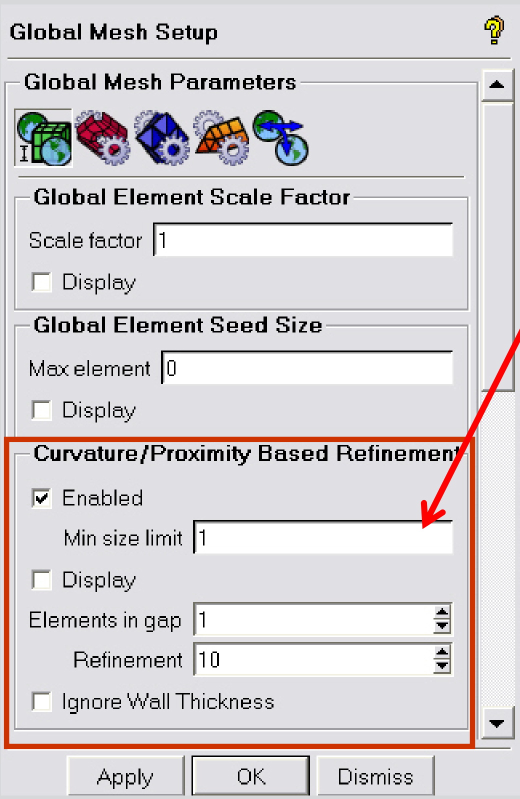
Compute Mesh – Tetra Octree

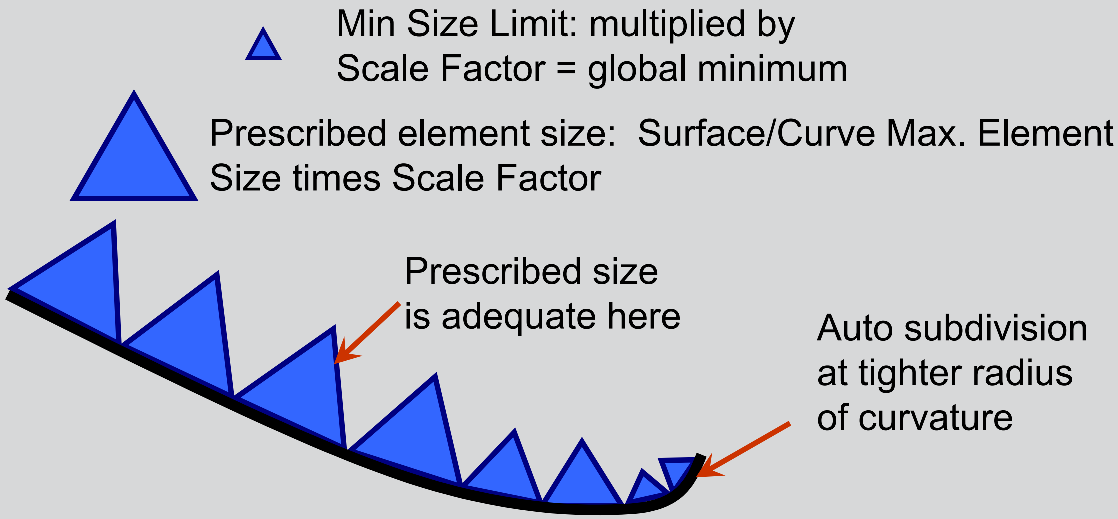


- Run options: *Compute Mesh > Volume Meshing Parameters*
  - *Create Prism Layers*
    - Will create prisms marked under *Part Mesh Setup*
    - Immediately after tetra calculation
    - Prism layers grown into existing tetra mesh
  - *Create Hexa-Core*
    - Will retain tri surface mesh (or tri and prisms), throw away tetra mesh and regenerate volume
    - Fill volume interior with Cartesian hexas
    - Cap off hexas with pyramids
    - Map tetra to tri or top prism face with Delaunay filling algorithm
  - *Input*
    - Select Geometry
      - *All, Visible*
      - *Part by Part*
        - Meshes each part separately
        - Mesh not conformal between parts
      - *From file*
        - Select tetin file (save memory by not have it loaded)
  - *Use Existing Mesh Parts*
    - Select *Parts* that are already surface meshed
    - Merges nodes to preexisting surface mesh
    - Uses *Make Consistent* to match octree volume mesh to existing surface mesh

Curvature/Proximity Based Refinement

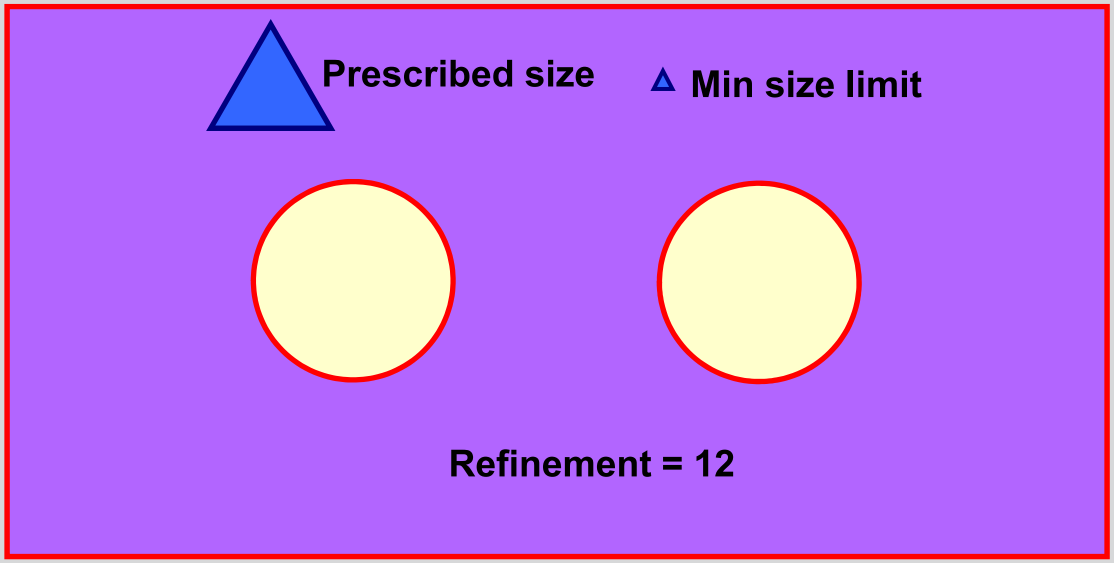
- ***Curvature/Proximity Based Refinement***
  - *Octree* **only**
  - **Automatically subdivides to create elements that are smaller than the prescribed entity size in order to capture finer features**
  - ***Min size limit value*** **entered is multiplied by the global** ***Scale Factor*** **and is the minimum size allowed for the automatic subdivision**
  - **Used primarily to avoid setting up meshing parameters specifically for individual entities thus allowing the geometry to determine the mesh size**
  - **Convenient for geometry with many fillets of varying curvature**

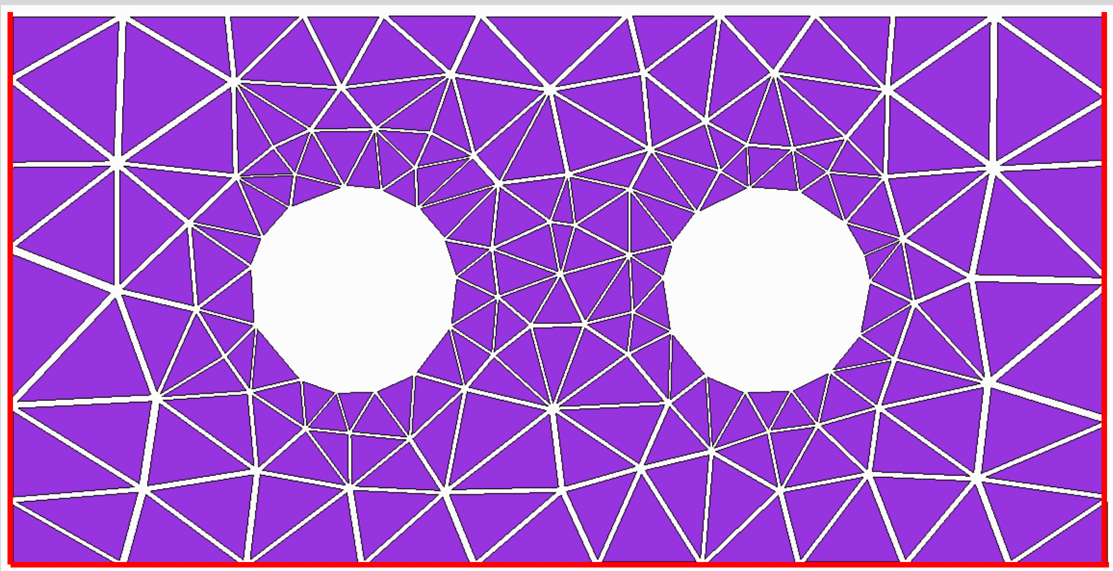




Curvature Based Refinement

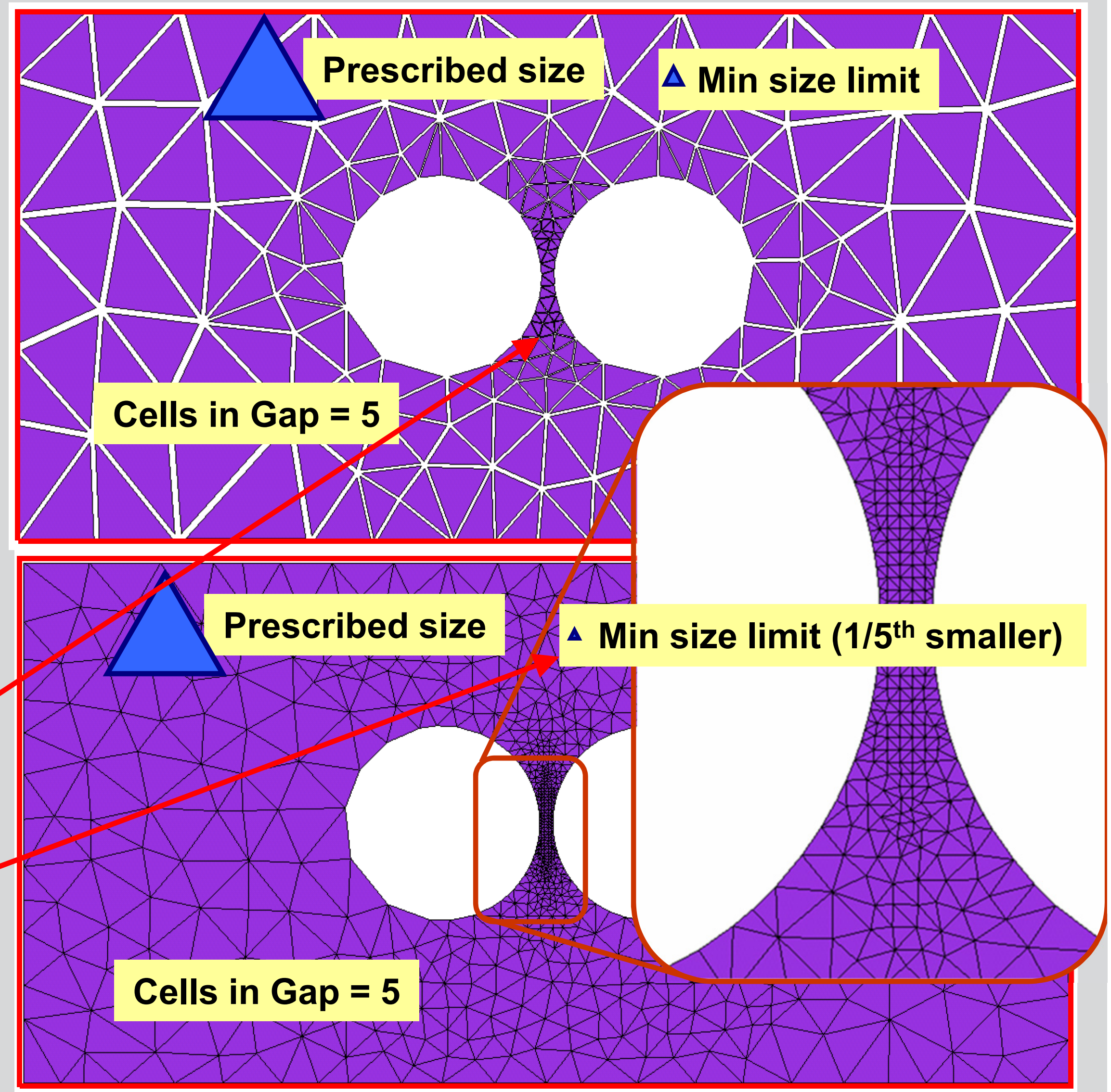
- ***Refinement***
  - Approximate number of elements along curvature if extrapolated to 360°
  - To avoid subdivision always to global minimum which would otherwise result in too many elements
    - Subdivision will stop once number of elements along curvature is reached
  - Won't exceed global minimum set by ***min size limit*** value
- **Example**
  - Specified refinement achieved with larger elements
  - Global minimum (***min size limit***) not realized, not necessary to capture curvature





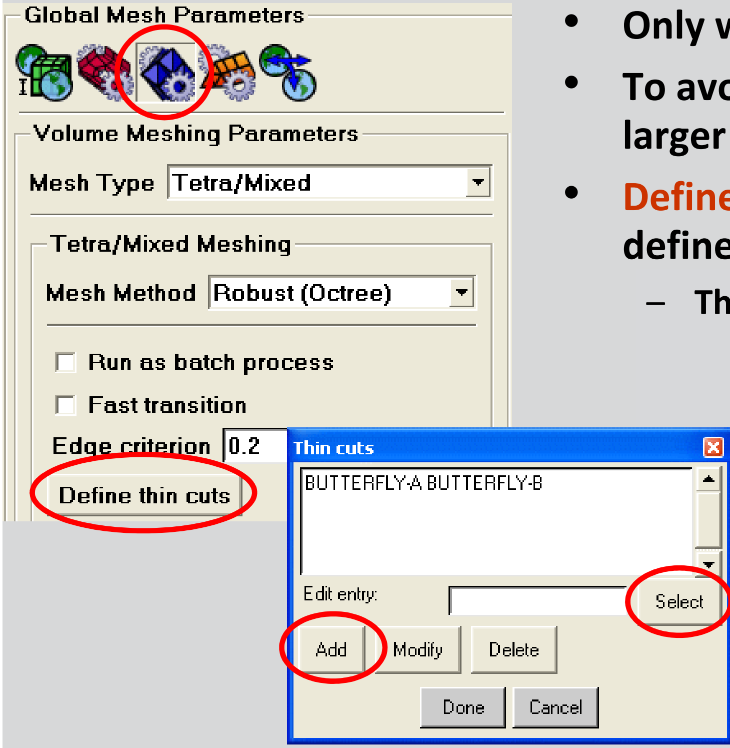
Proximity Refinement, Elements in Gap

- ***Elements in Gap***
  - Number of cells desired in narrow gaps
  - To avoid subdivision always to global minimum which would otherwise result in too many elements
    - Subdivision will stop once number of cells in gap is reached
  - Will not override global minimum (*Min size limit*)
- Example
  - Only one element in gap
  - Can't go smaller than Min size limit
  - Have to set smaller Min size limit

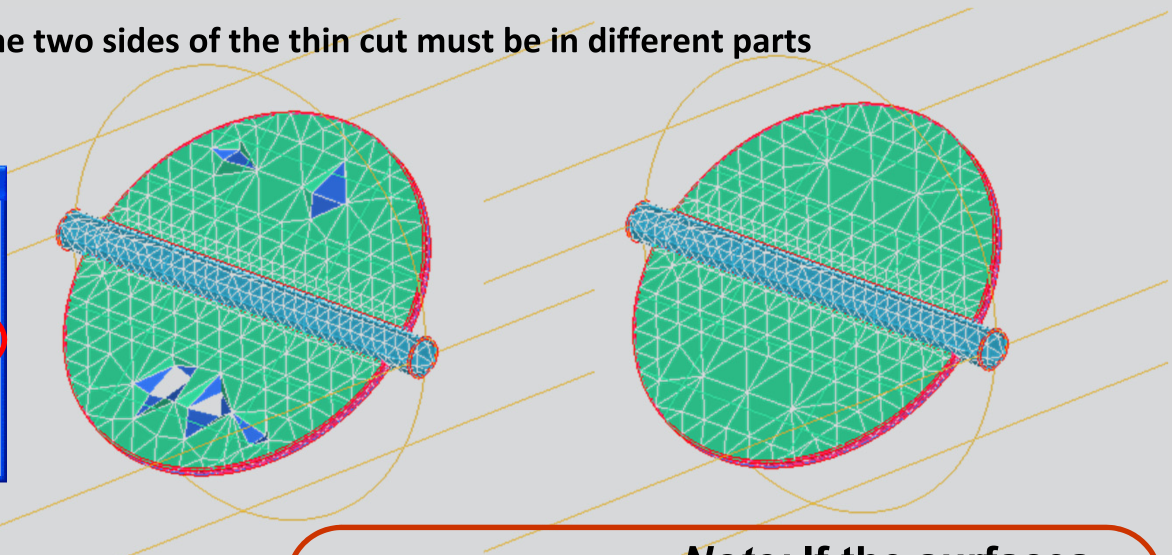


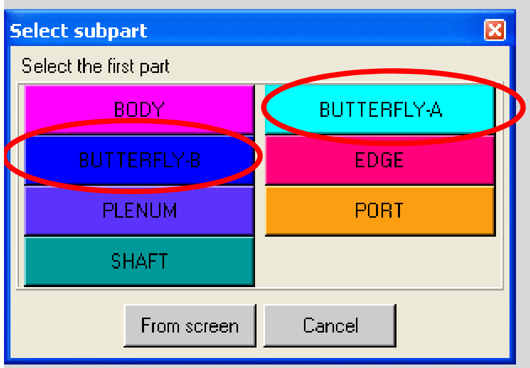
Thin Cuts

Define thin Cuts

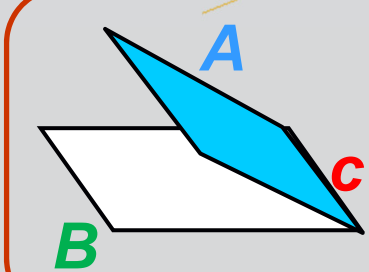


- Only works with Tetra Octree
- To avoid 'holes' in thin solids/narrow gaps when mesh size is much larger than gap
- Define thin cuts by selecting two parts and then Add them to the list of defined Thin cuts
  - The two sides of the thin cut must be in different parts



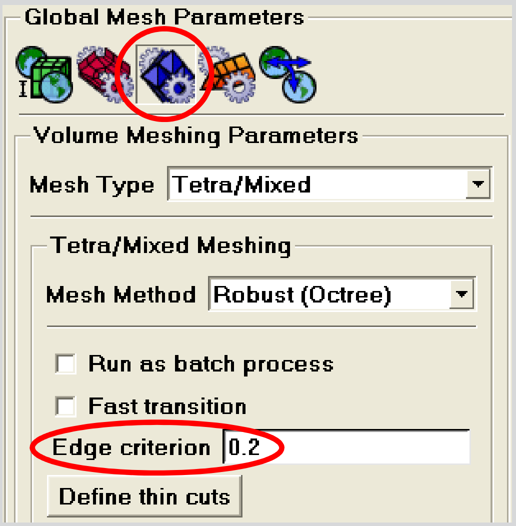


If the face of a tetra element has a surface/line node on part "*A*" then it may not have a surface/line node on part "*B*"

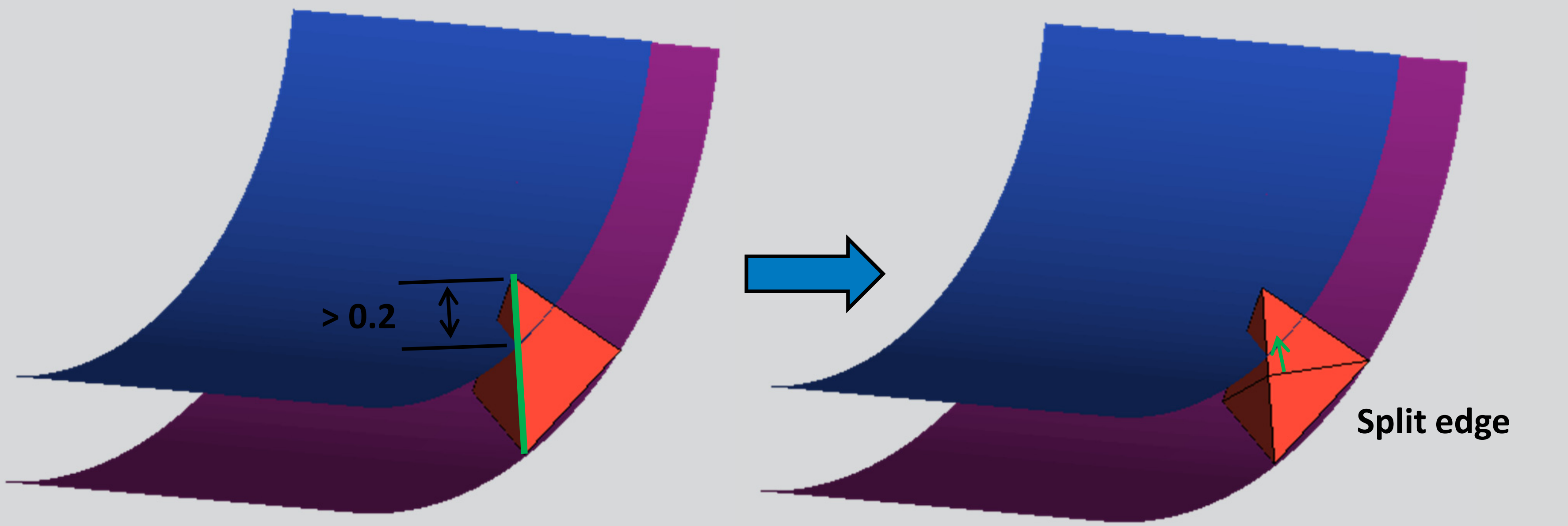


Note; If the surfaces of the two parts, *A* and *B*, meet, then the contact curve must be in a third part, *c*, or the thin cut will fail.

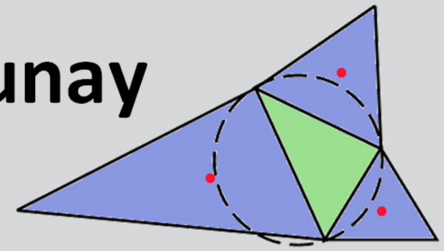
Edge Criterion



- *Edge criterion*
  - For *tetra octree* only
  - A number 0 – 1
  - 0.2 (the default) means if more than 20% of an edge crosses a surface or curve, then split the edge
  - Has an effect similar to globally applying a *thin cut*
  - Smaller numbers will cause more splitting. The closeest node will be projected to the surface
  - Use prudently. Too small a number results in strange globs of refined mesh

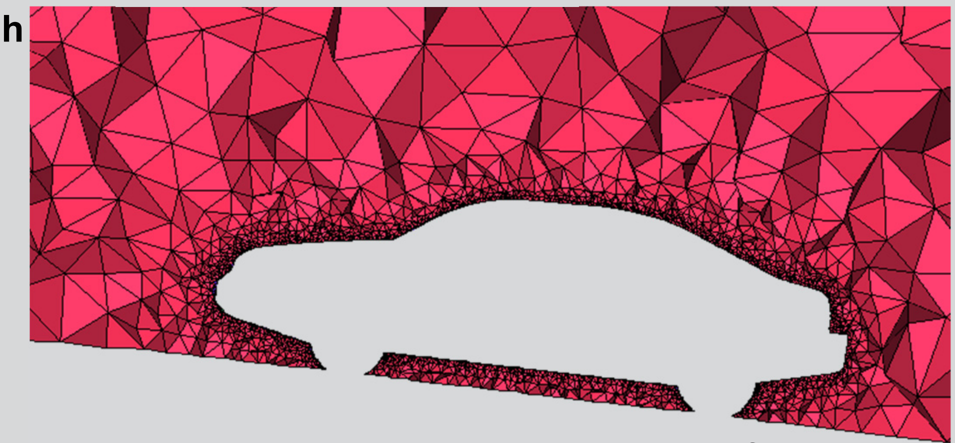


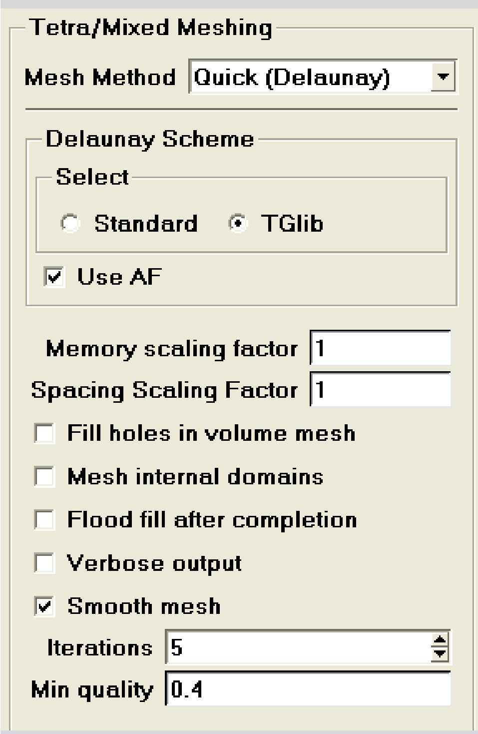
Mesh Methods - Delaunay



Initially distributes nodes so as the centroid of any tetra is outside the circumsphere of any neighboring tetra

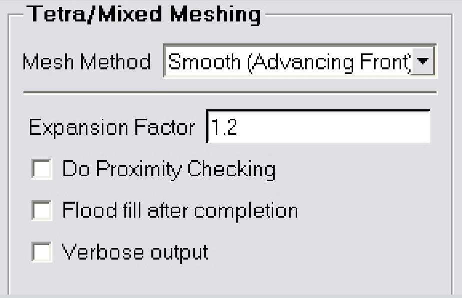
- *Type - Tetra/Mixed*
  - Method - *Quick (Delauney)*
  - Start from a good quality, closed surface mesh
    - Can be quad and tri elements
    - From Shell Mesh
    - From Octree
    - From imported surface mesh

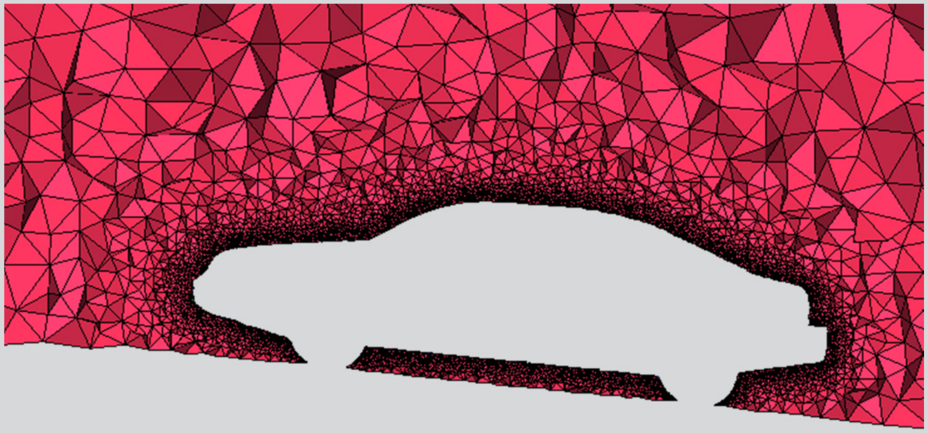




- Setup Options:
  - Delaunay Scheme
    - *Standard*: Delaunay scheme with a skewness-based refinement
    - *TGlib*: TGrid Delaunay volume grid generation algorithm that utilizes a more gradual transition rate near the surface and faster towards the interior
  - Use AF: TGrid Advancing Front Delaunay algorithm which has smoother transitions than the pure Delaunay algorithm.
  - Memory Scaling Factor: To allocate more memory than originally
  - Spacing Scaling Factor: Growth ratio from surface (1 – 1.5 typically)
  - Fill holes in volume mesh: Use to fill holes/voids in existing volume mesh . E.g. if bad quality region is deleted
  - Mesh internal domains: For multiple sets of closed volumes in one model
  - Flood fill after completion: For multiple volumes – Will assign tetras within closed volume to Part designated by Body or Material Point
  - Verbose output: For troubleshooting

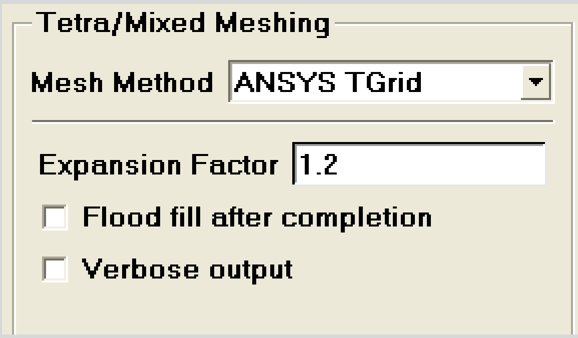
Mesh Methods – Advancing Front

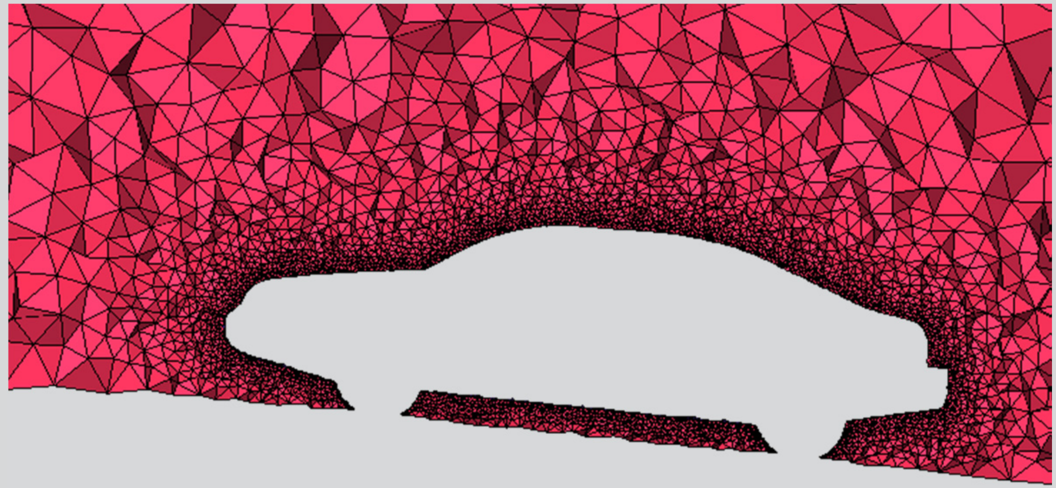




- Type - *Tetra/Mixed*
  - Method - *Smooth (Advancing Front)*
    - Same as *Quick (Delauney)* but
    - Uses advancing front method that marches tetras from surface into interior
    - Algorithm from GE/CFX
    - Results in more gradual change in element size
      - "Better" but finer mesh, more elements than Delaunay
      - Elements grow slowly for first few layers from surface, then growth rate increases into volume more
      - Input surface mesh has to be of fairly high quality
    - Setup Options: *Do Proximity Checking*
      - Check to properly fill small gaps
      - Longer run time
    - Can create pyramids from quads
      - Quads need to be a 10 aspect ratio or less
      - Delaunay can handle much higher quad aspect ratios
    - Respects densities

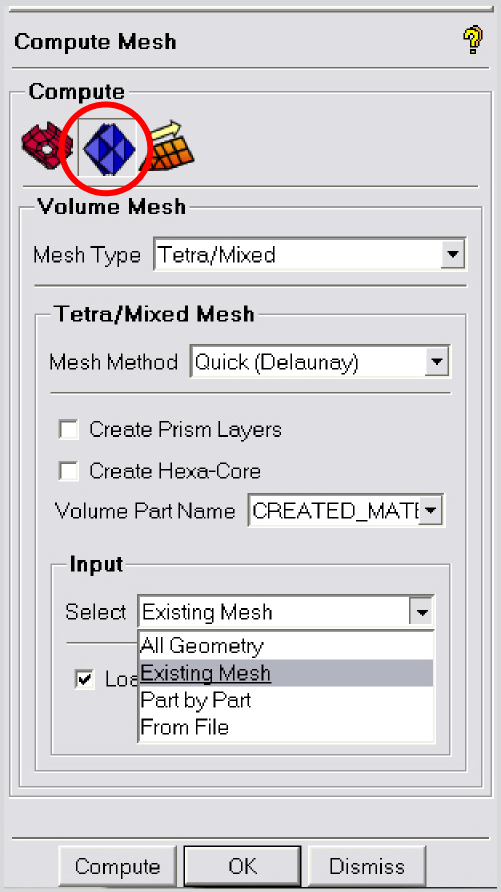
Mesh Methods – ANSYS TGrid





- *Tetra/Mixed*
  - *ANSYS TGrid*
    - Runs Tgrid through an extension module
    - Good mesh quality
    - Fast mesh generation
    - Setup Options:
      - *Flood fill after completion*: Same as octree Flood fill
      - *Verbose output*: This option writes more messages to help in debugging any potential problem
    - Will not respect densities
    - Will not mesh to quads. It converts them to triangles
    - Similar to Advancing Front, but does not group elements as close near surface

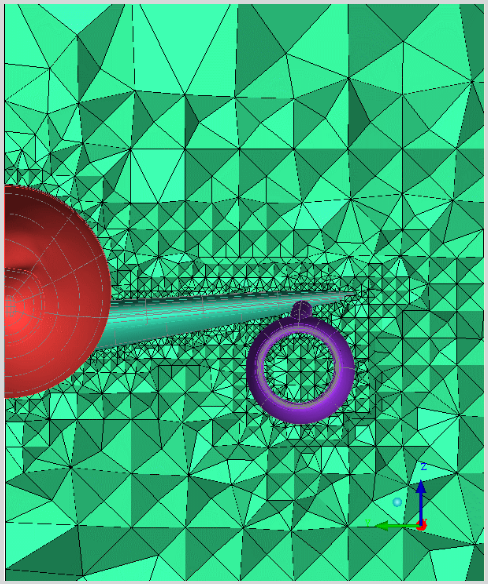
Compute Mesh – Delaunay, Adv. Front, TGrid



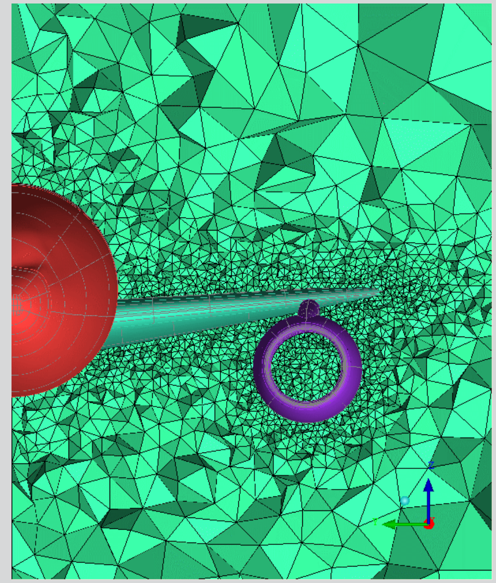
- **Run Options:**
  - Similar options as octree except cannot mesh to part geometry and part mesh (option: *Use existing mesh parts*)
  - *Create Prism Layers* available for both
  - *Hexa-Core* not available for *Advancing Front, ANSYS TGrid*
  - *Volume Part Name*
    - For newly created tetras
    - Can choose *Inherited* to use material
  - *Input*
    - *All Geometry*
      - Will run shell mesh first with no user input/editing
      - Using parameters from *Model/Part/Surface/Curve Mesh Setup*
      - Review *Shell Meshing* chapter
      - If doubtful as to shell mesh quality, run *Shell Mesh* first, then use *Existing Mesh*
    - *Existing Mesh*
      - Most common method. Surfaces already meshed
    - *Part by Part*
      - Meshes each part separately. Nodes are not connected
    - *From File*
      - Saves memory. Surface mesh does not need to be loaded

Comparison

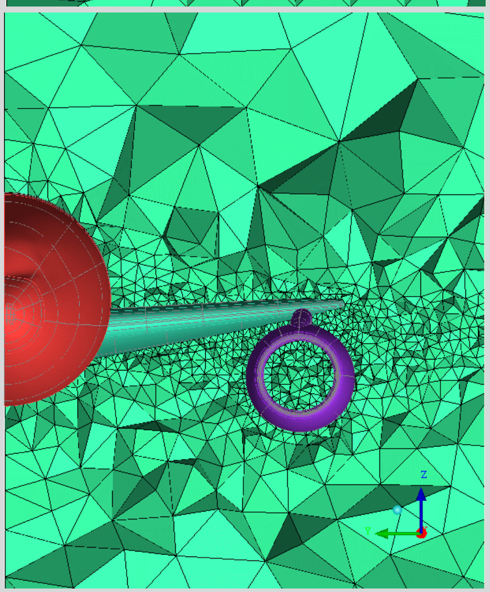
Octree



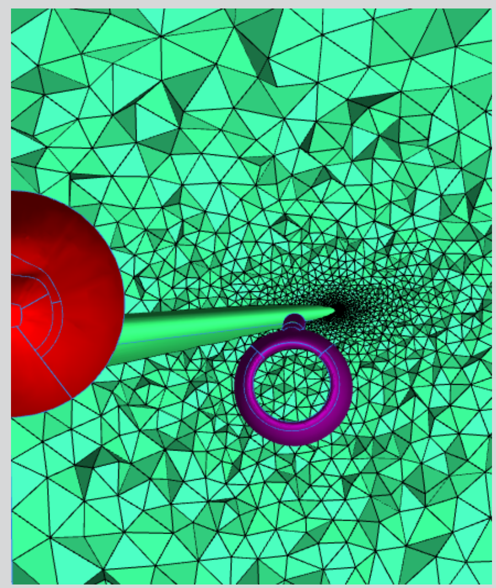
Adv.front



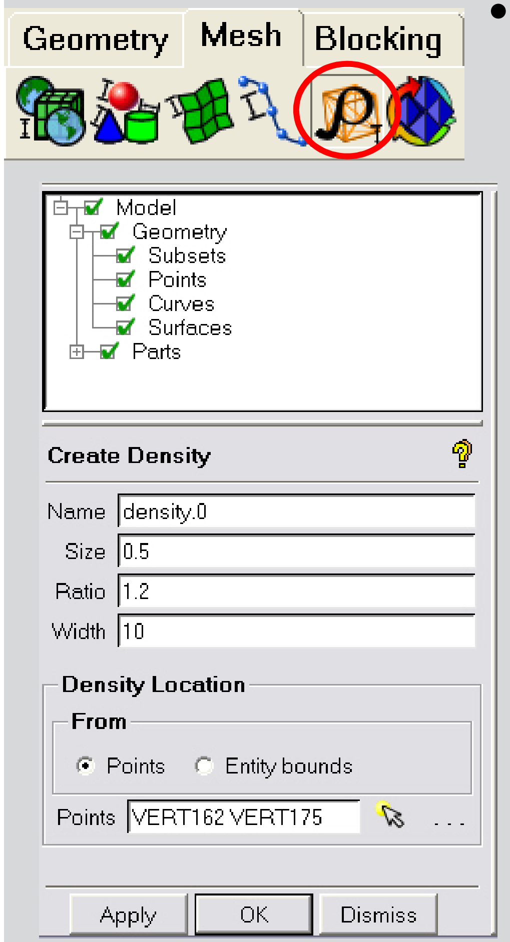
Delauney



ANSYS TGrid

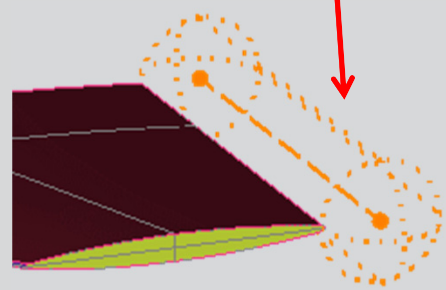


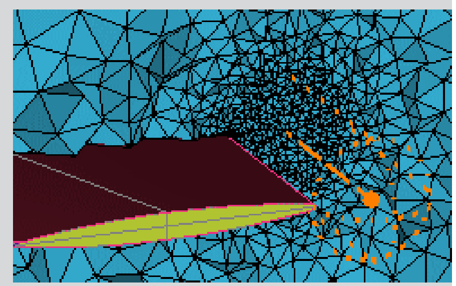
Density Region



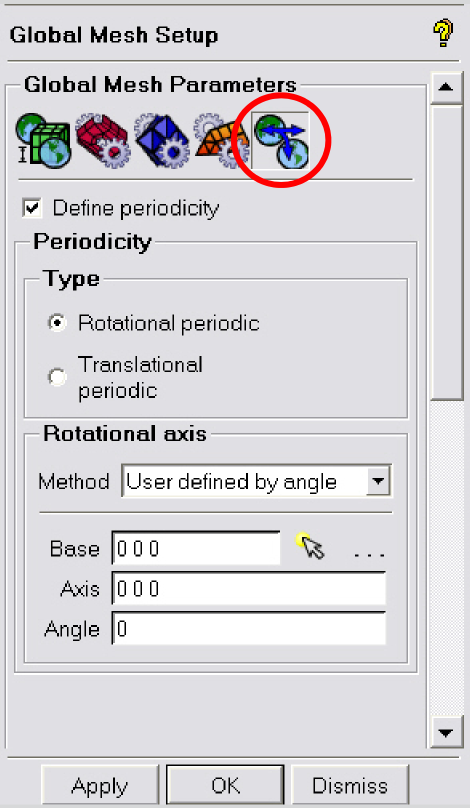
- ***Create Mesh Density***
  - Define volumetric region with smaller mesh size where no geometry exists, e.g. wake region behind a wing
  - Not actual geometry!
    - Mesh nodes not constrained to density object
    - Can intersect geometry
  - Can create densities within densities
    - Always subdivides to smallest set size
  - Set *Size*
    - Max size within – multiplied by global *Scale Factor*
    - *Ratio* – expansion ratio away from density object
    - *Width* – Number of layers from object before mesh size is allowed to growth
  - *Type*
    - *Points* – Select any number of points
      - *Size* and *Width* (number of layers) will determine "thickness" of volume if number of points selected is 1-3
      - 4-8 creates polyhedral volume
    - *Entity bounds* – define region by bounding box of selected entities

Density from 2 points makes a line. The *width* defines the radius of the cylinder



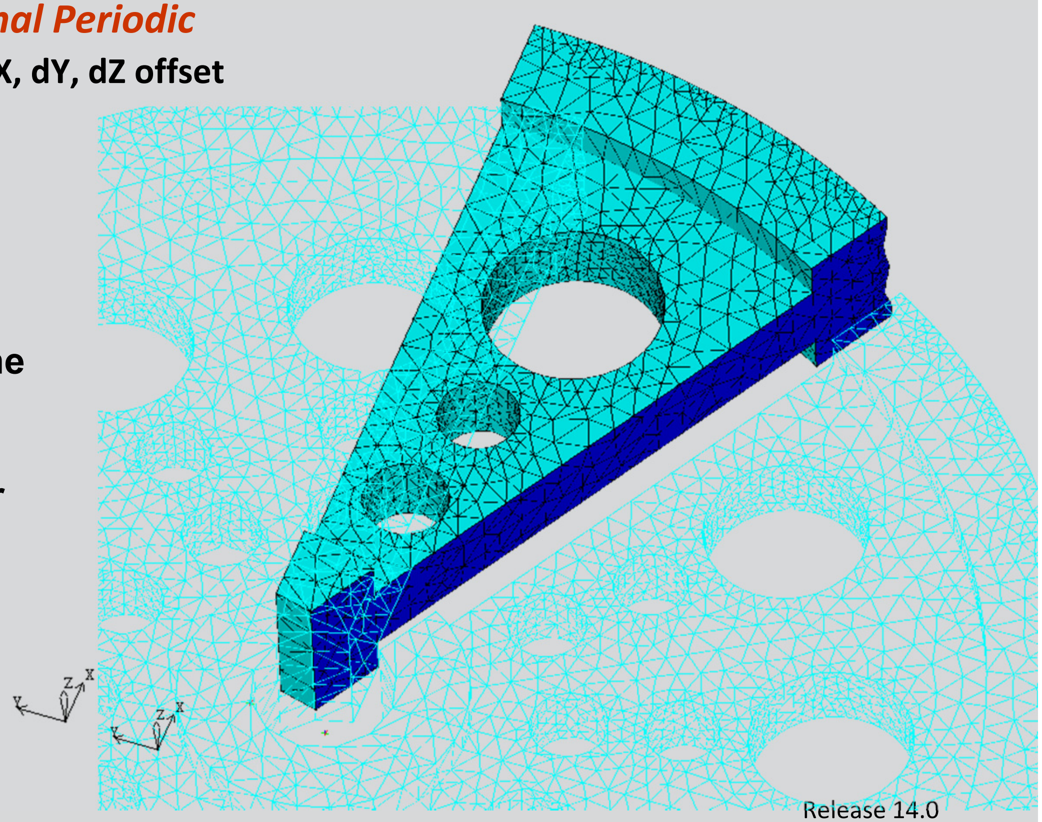


Periodicity



- ***Define Periodicity***
- **Forces mesh alignment across periodic sides**
- **For meshing and solving only one section of symmetrically repeatable geometry**
  - ***Rotational Periodic***
    - **Enter *Base*, *Axis*, and *Angle***
  - ***Translational Periodic***
    - **Enter dX, dY, dZ offset**

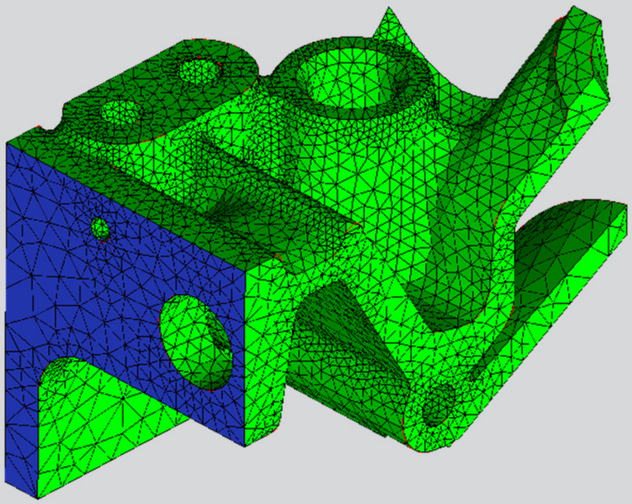
Tip: Placing material point close to mid-plane makes tetra octree obey periodictiy easier



Workshops

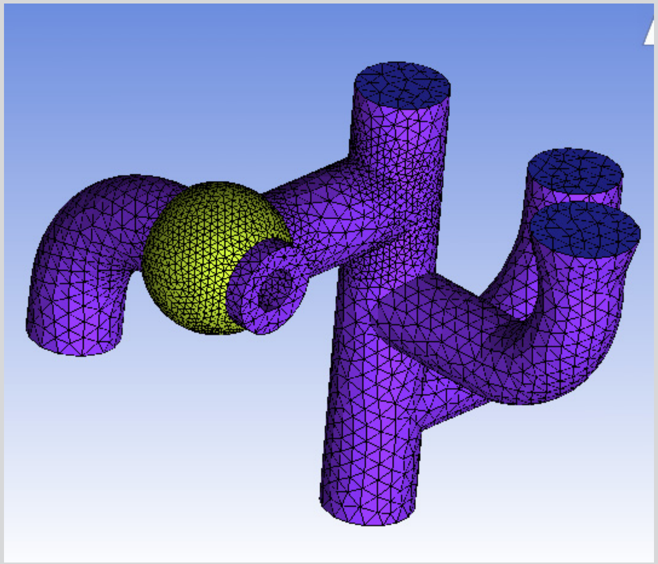
Workshop 4.1 – Engine Block Model

- Build diagnostic topology
- Octree mesh
- Smooth mesh
- Curvature/proximity refinement
- Delaunay mesh

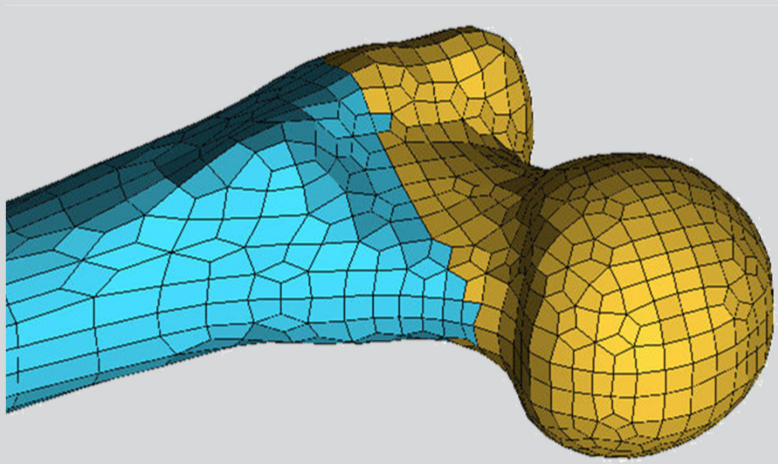


Workshop 4.2 – Valve Model

- Build diagnostic topology
- Create parts, Create body
- Set sizes – Global, Surface, Curves, density
- Octree mesh



Workshops



Workshop 4.3 – Body Fitted Cartesian

- Import Design Modeler file into ICEM
- Create Parts from Subsets
- Global, Part mesh set up
- Using ANSYS ICEM CFD Hexa to create a Cartesian initial grid with biasing
- Computing the mesh
- Viewing cut-planes