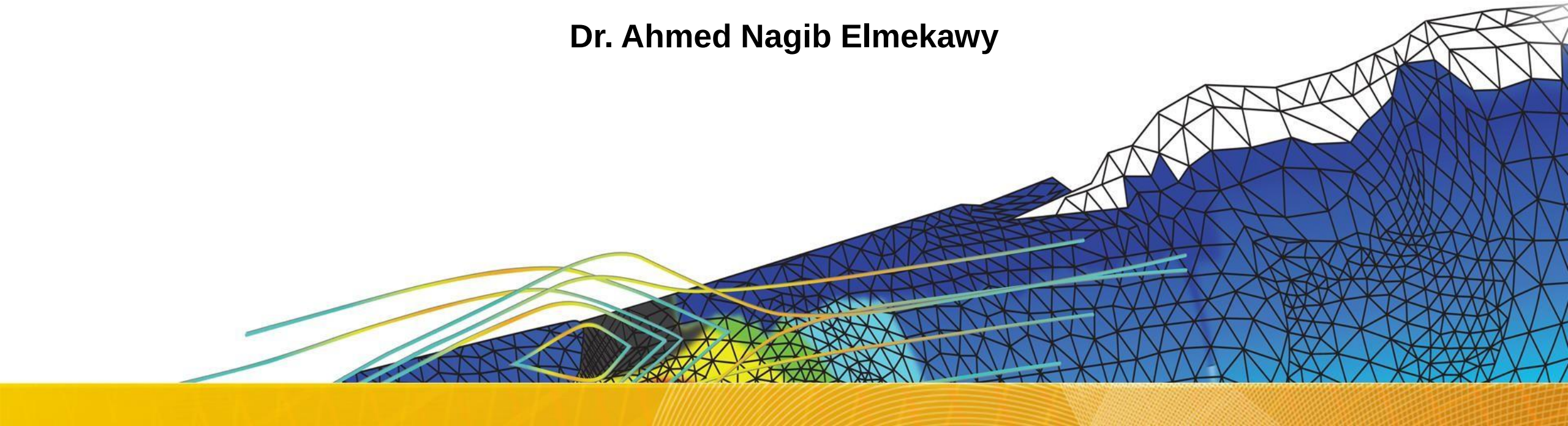
Introduction to ANSYS Meshing

Module 3: Global Mesh Controls

Dr. Ahmed Nagib Elmekawy

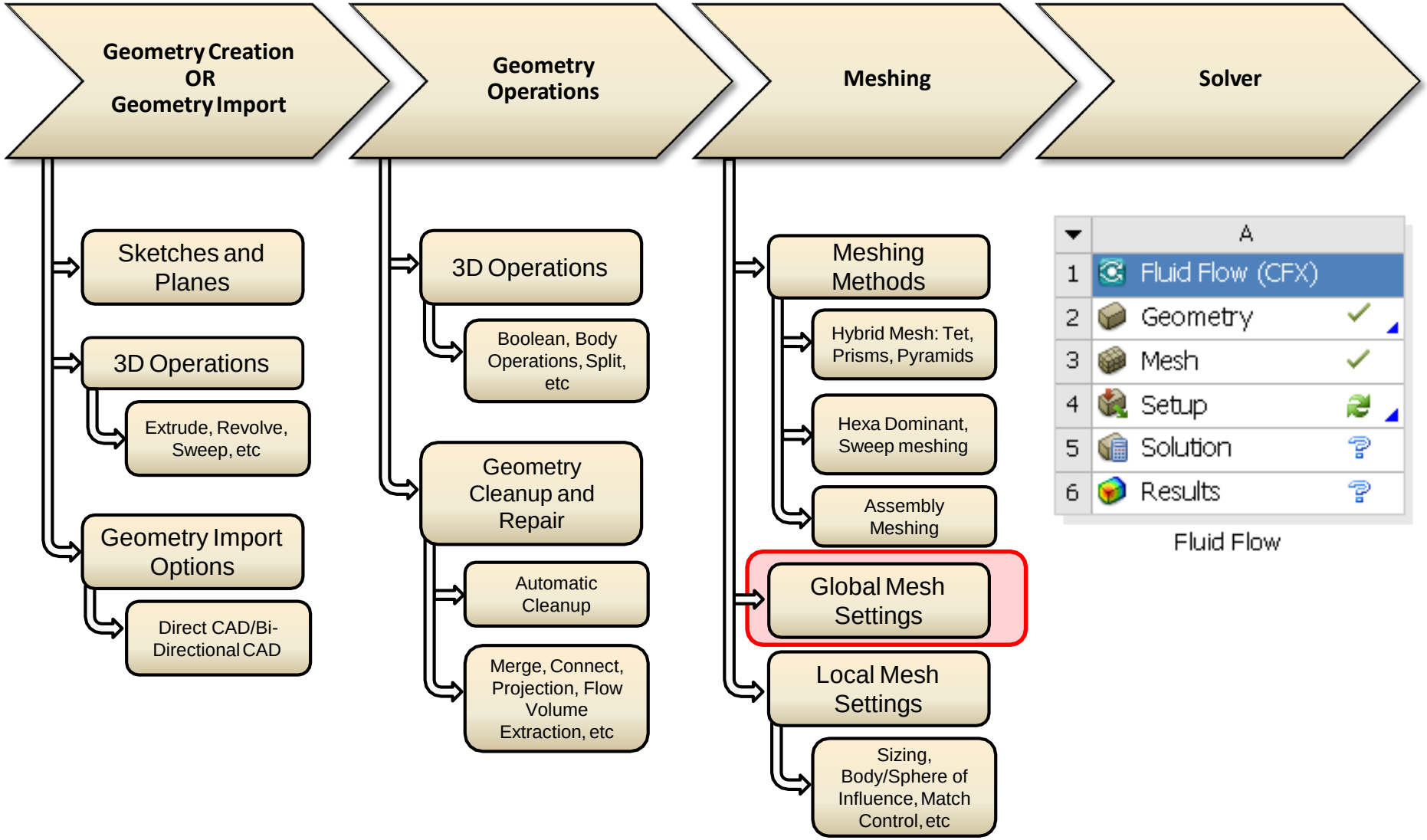


Global Mesh Controls

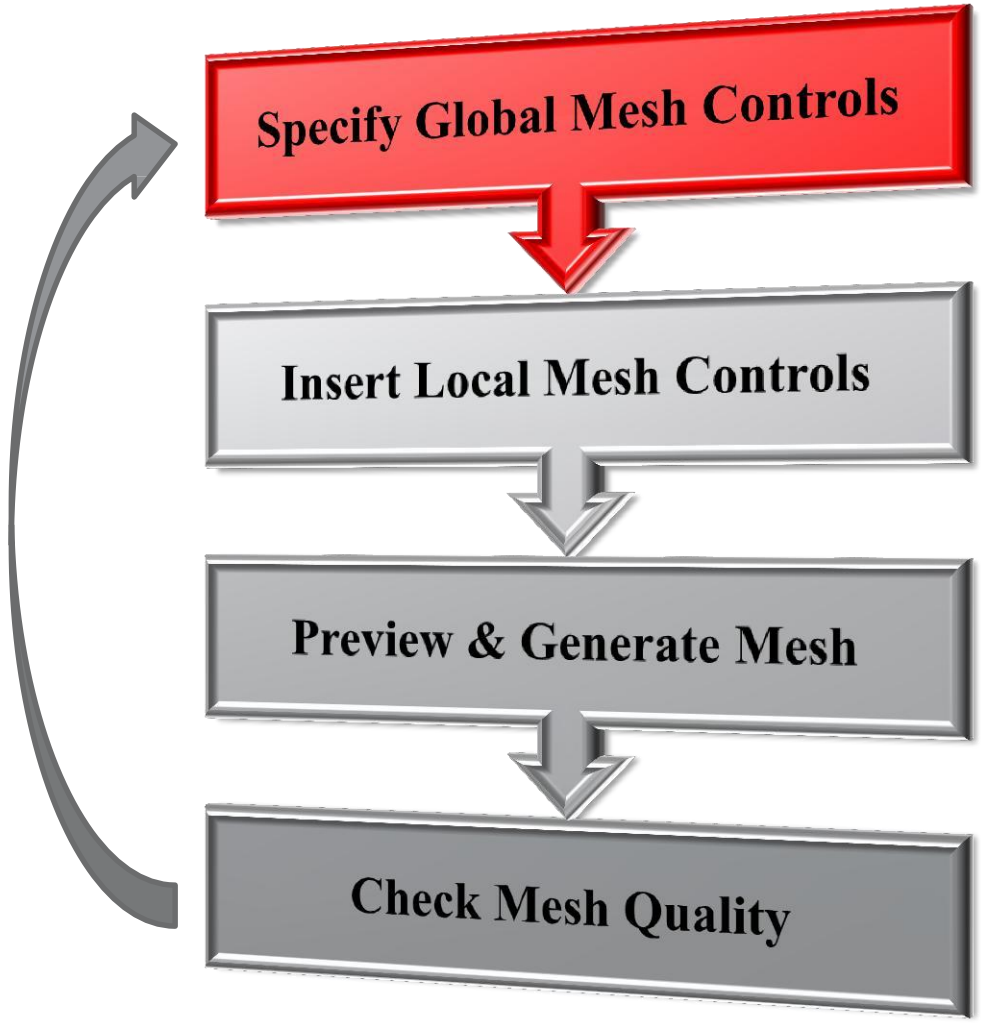
What you will learn from this presentation

- **Introduction to Global Mesh Controls**
- **Defaults**
- **General Sizing Controls & Advanced Size Functions**
- **Global Inflation**
- **Assembly Meshing Controls**
- **Statistics**

Preprocessing Workflow

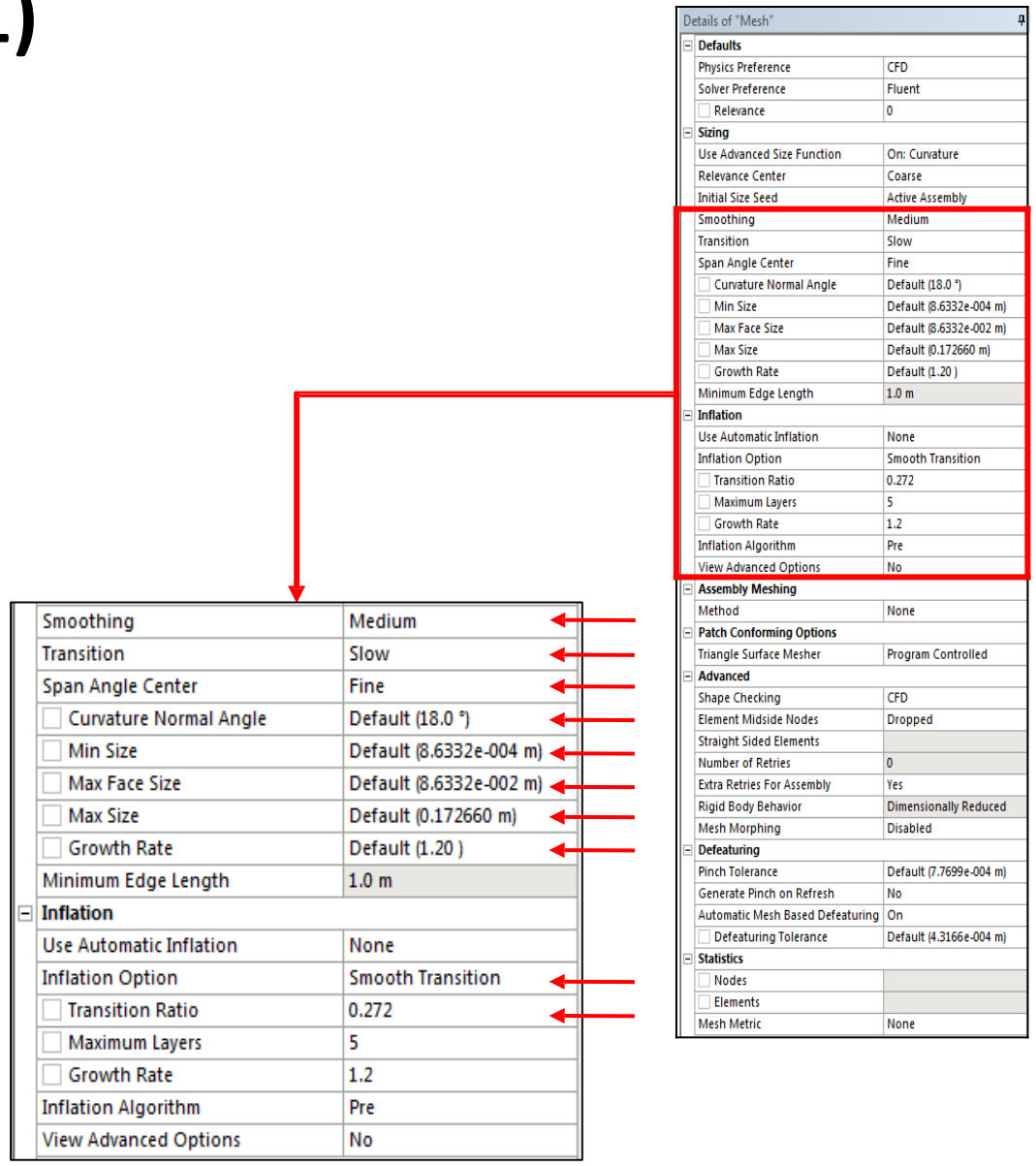


Meshing Process in ANSYS Meshing



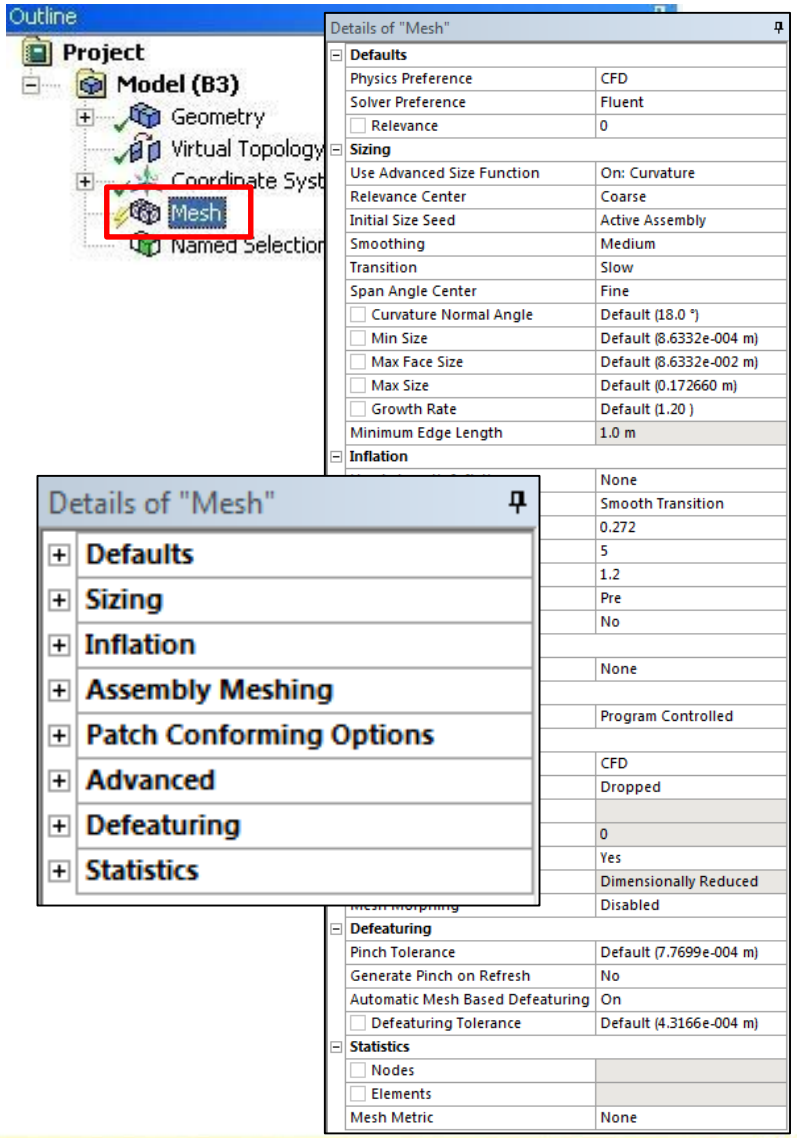
Global Mesh Controls (1)

- **Global mesh controls are used to make global adjustment in the meshing strategy, which includes sizing functions, inflation, smoothing, defeaturing, parameter inputs, assembly meshing inputs, etc.**
- **Minimal inputs**
  - Automatically calculates global element sizes based on the smallest geometric entity
  - Smart defaults are chosen based on physics preference
- **Makes global adjustments for required level of mesh refinement**
- **Advanced Size Functions for resolving regions with curvatures and proximity of surfaces**



Smart defaults !

Global Mesh Controls (2)



Physics Based Settings
- Physics and Solver Preferences

Global Mesh Sizing Controls
- Relevance and Relevance Center
- Advanced Size Functions
- Smoothing and Transition
- Span Angle Center
- Curvature Normal Angle
- Proximity Accuracy and Cells Across Gap

Inflation
- Inflation Option, Inflation Algorithm
- Collision Avoidance
- Maximum Angle, Fillet Ratio, Smoothing

Assembly Meshing
- Activation of CutCell/Tetrahedrons Meshing

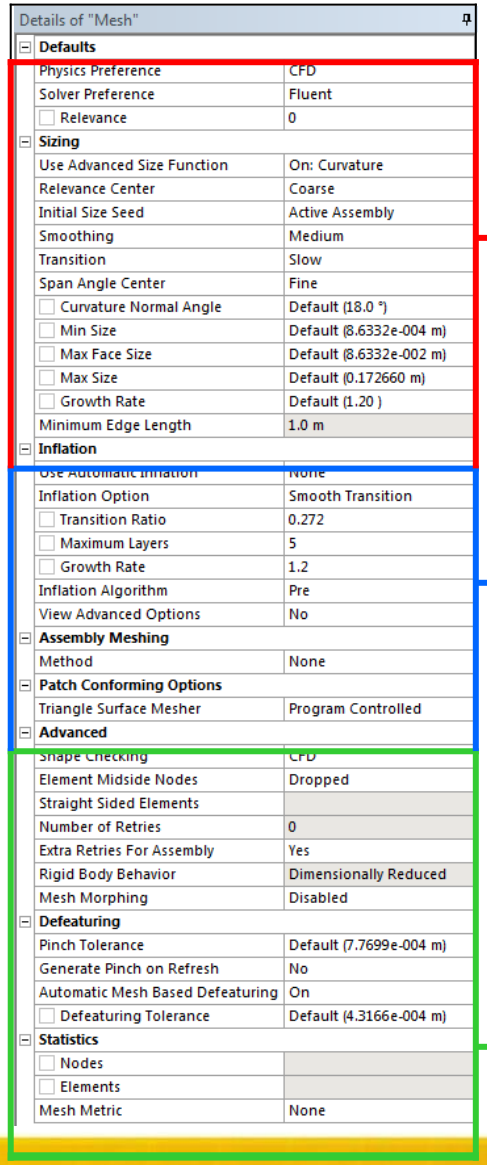
Patch Confirming Options
- Activation of Advancing Front Method

Advanced
- Shape Checking
- Element midside nodes

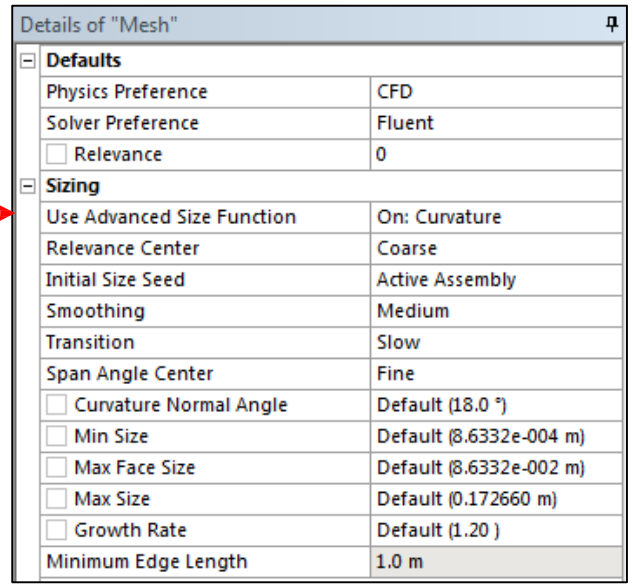
Defeaturing
- Pinch based
- Automatic Mesh Based

Statistics
- Mesh statistics, Quality criteria

Global Mesh Controls (3)



Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (8.6332e-004 m)
Max Face Size	Default (8.6332e-002 m)
Max Size	Default (0.172660 m)
Growth Rate	Default (1.20)
Minimum Edge Length	1.0 m



Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (8.6332e-004 m)
Max Face Size	Default (8.6332e-002 m)
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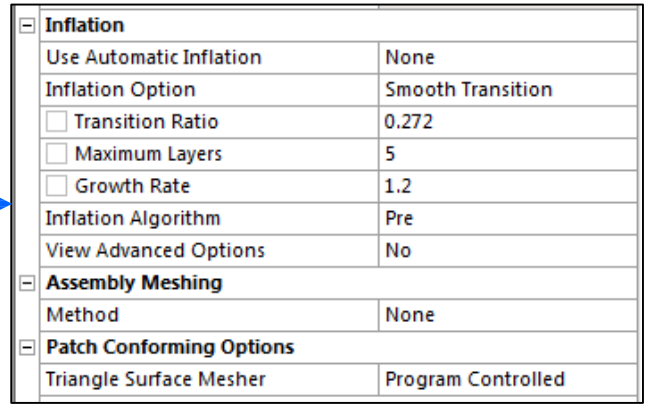
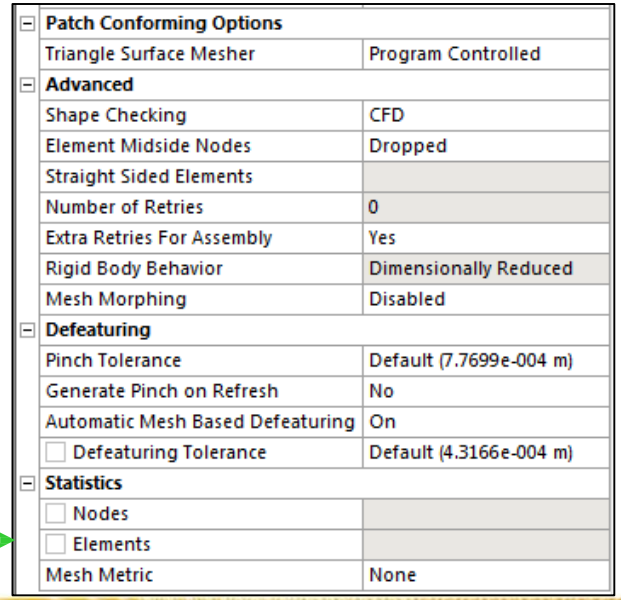
Growth Rate	Default (1.20)
Minimum Edge Length	1.0 m



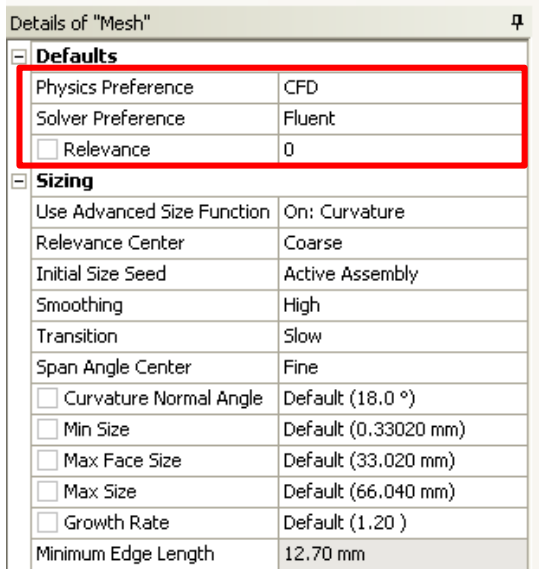
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Assembly Meshing	
Method	None
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled

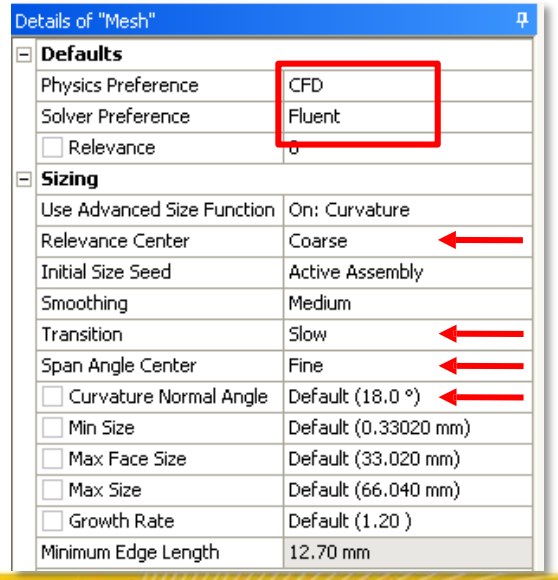


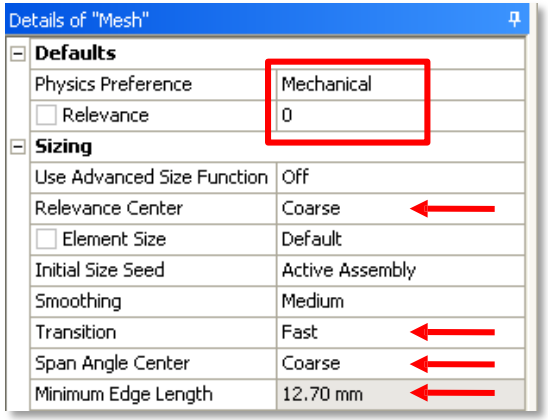
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	CFD
Element Midside Nodes	Dropped
Straight Sided Elements	
Number of Retries	0
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Pinch Tolerance	Default (7.7699e-004 m)
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default (4.3166e-004 m)
Statistics	
Nodes	
Elements	
Mesh Metric	None

Defaults

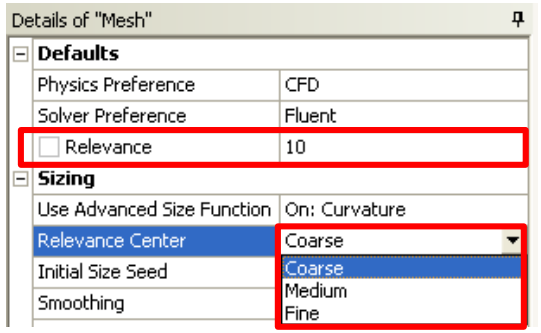
- **Four options under “Physics Preference”**
  - CFD, Mechanical, Explicit and Electromagnetic
- **Three options under “Solver Preference” when CFD is selected:**
  - Fluent, CFX and POLYFLOW
- **Mesh setting defaults are automatically adjusted to suit the “Physics Preference” and “Solver Preference”**
- **Assembly Meshing is active only when Physics Preference is CFD and Solver Preference is Fluent**





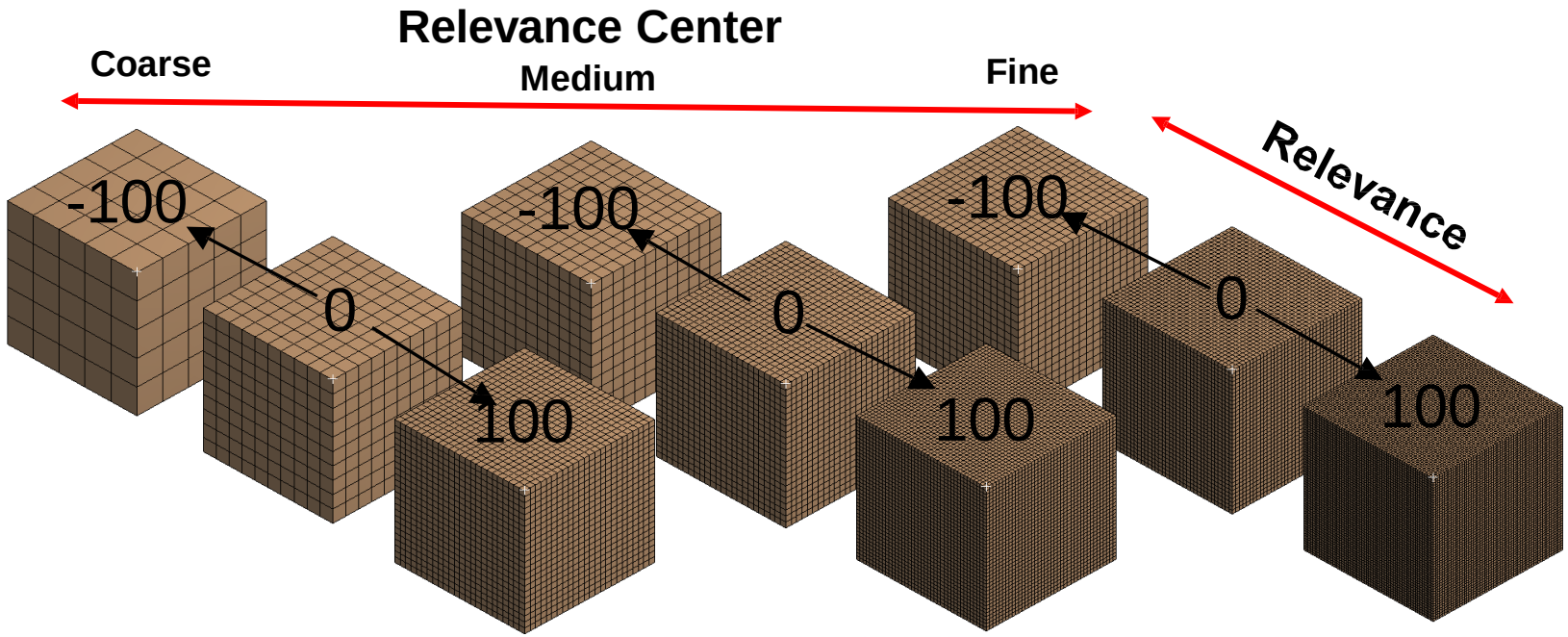


Defaults : Relevance

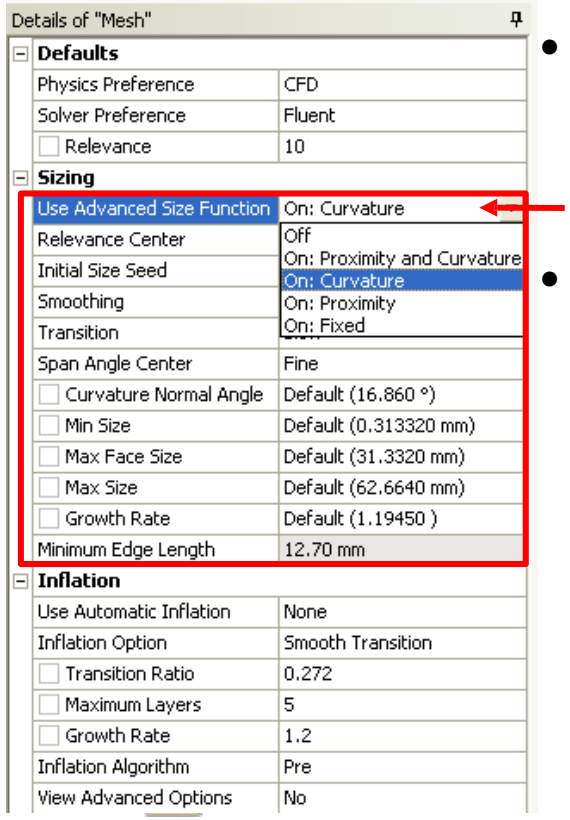


Relevance and Relevance Center

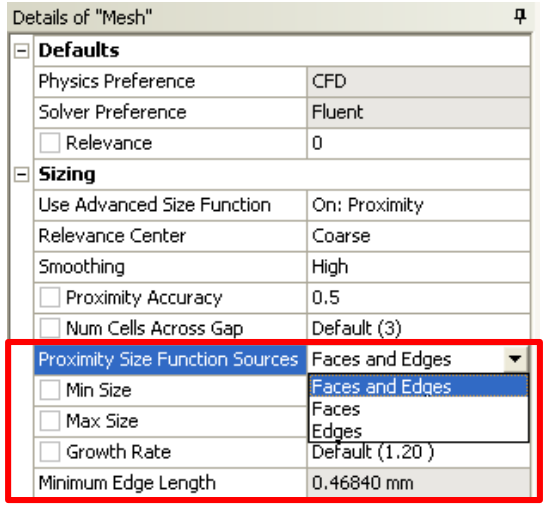
- Useful for automatic Global Refinement or Coarsening of the mesh



Sizing : Advanced Sizing Functions

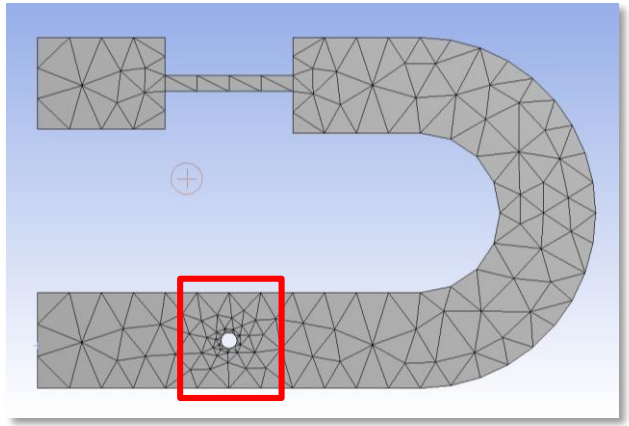


- **Controls the growth and distribution of mesh in important regions of high curvature or close proximity of surfaces**



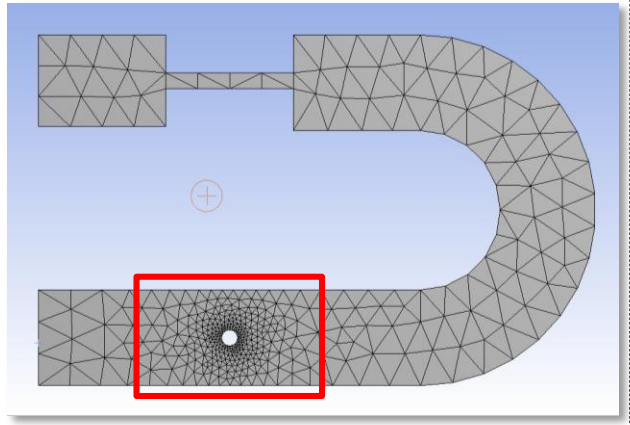
- **Five Options:**
  - Off.
  - Proximity and Curvature
  - Curvature
  - Proximity
  - Fixed

Sizing : Advanced Sizing Function (ASF) Examples



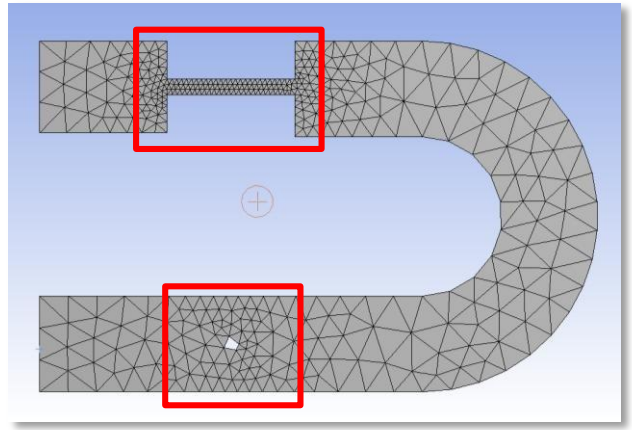
ASF: Off

- The edges are meshed with global **Element Size**
- Then the edges are refined for curvature and 2D proximity
- At the end, corresponding face and volume mesh is generated
- Transition of cell size is defined by ***Transition***



ASF: Curvature

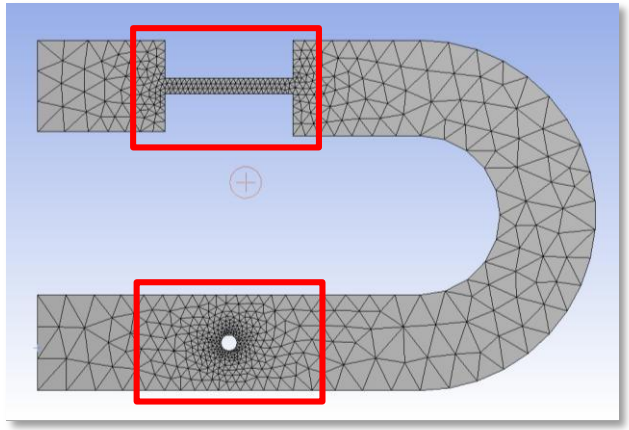
- Determines the Edge and Face sizes based on **Curvature Normal Angle**
- Finer Curvature Normal Angle creates finer surface mesh
- Transition of cell size is defined by **Growth Rate**



ASF: Proximity

- Controls the mesh resolution on proximity regions in the model
- Fits in specified number of elements in the narrow gaps
- Higher **Number of Cells Across Gap** creates more refined surface mesh
- Transition of cell size is defined by **Growth Rate**

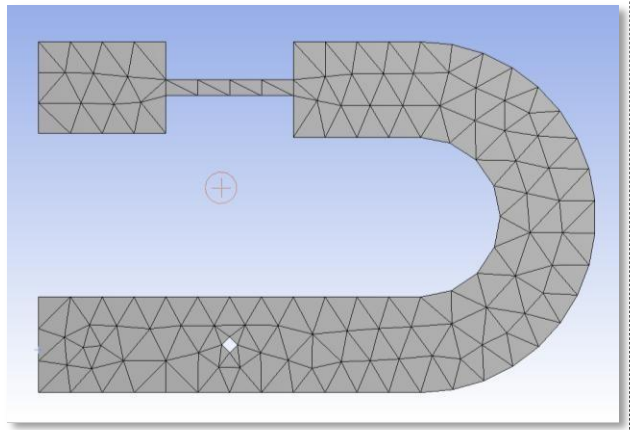
Sizing : Advanced Sizing Function Examples



ASF: Proximity & Curvature

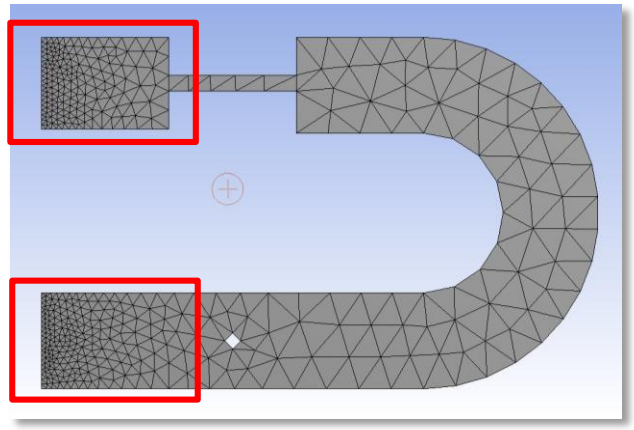
- Combines the effect of ‘Proximity’ and ‘Curvature’ size function

More computational time



ASF: Fixed

- Constant mesh size through out
- No refinement due to curvature or proximity in the model
- Surface mesh is generated with specified **Max Face Size**
- Volume mesh is generated with specified **Max Size**



ASF: Fixed + Local Sizings

- Mesh is refined locally due to sizing (on 2 edges for that example)
- Elsewhere size is defined by **Max (Face) Size**
- Transition of cell size is defined by **Growth Rate**

Sizing : Element Size

Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (0.33020 mm)
Max Face Size	Default (33.020 mm)
Max Size	Default (66.040 mm)
Growth Rate	Default (1.20)
Minimum Edge Length	12.70 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No

Element Size

- Element size used for the entire model
  - This size will be used for meshing all edges, faces and bodies
- Default value based on Relevance and Initial Size Seed
  - User can input required value as per geometry dimensions

Element size option available when Advanced Size Function is not used

Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Minimum Edge Length	311.760 mm

Sizing : Min and Max Size

Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (0.33020 mm)
Max Face Size	Default (33.020 mm)
Max Size	Default (66.040 mm)
Growth Rate	Default (1.20)
Minimum Edge Length	12.70 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No

Min Size

- Minimum element size that the size function will generate
- Some element sizes may be smaller than this size depending on the edge length

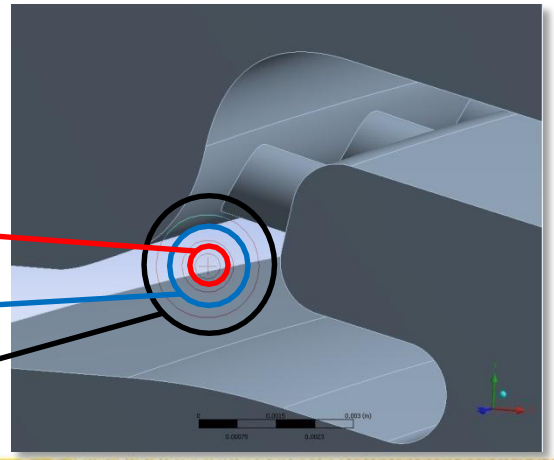
Max Face Size

- Maximum face size that the size function will generate

Max Size

- Maximum element size that can be grown in the interior of volume mesh

Mouse Pointer serves to estimate mesh sizes



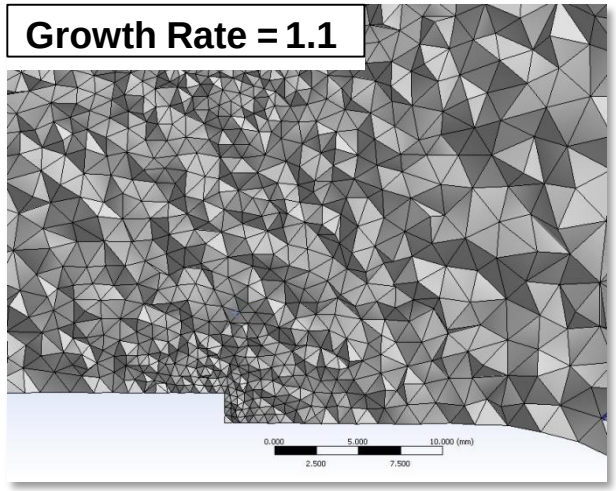
Min Size ≤ Max Face Size ≤ Max Size

Sizing : Growth Rate

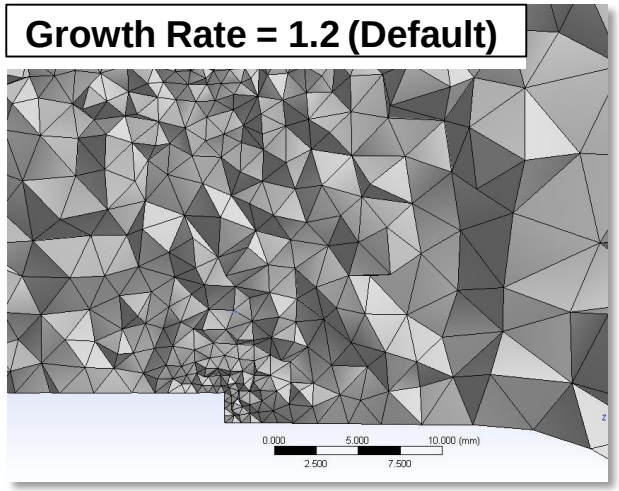
- **Define the ratio between sizes of adjacent cells**
  - On surfaces and inside the volumes

Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (0.33020 mm)
Max Face Size	Default (33.020 mm)
Max Size	Default (66.040 mm)
Growth Rate	Default (1.20)
Minimum Edge Length	12.70 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No

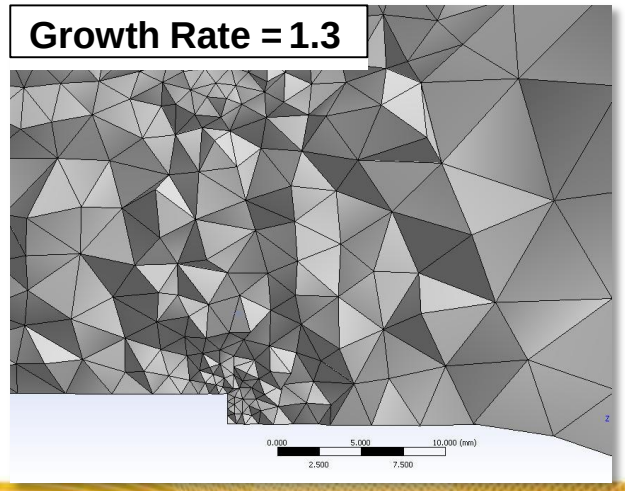
Growth Rate = 1.1



Growth Rate = 1.2 (Default)



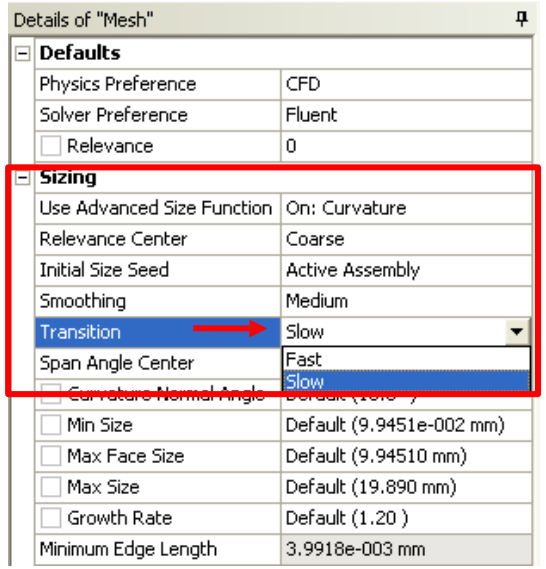
Growth Rate = 1.3

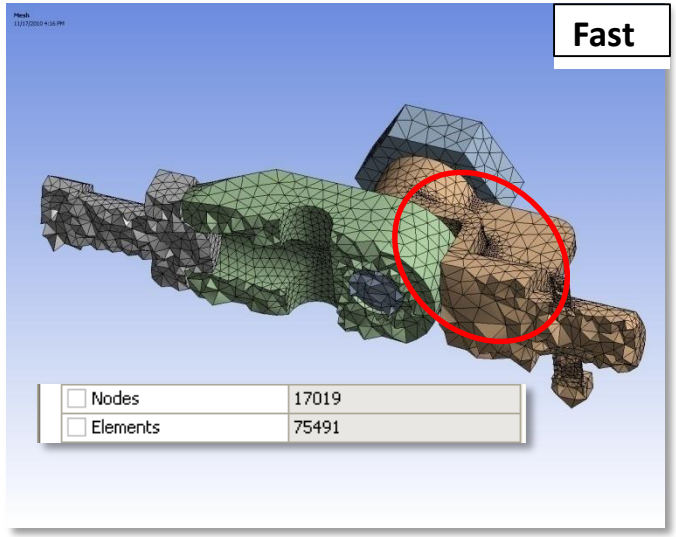


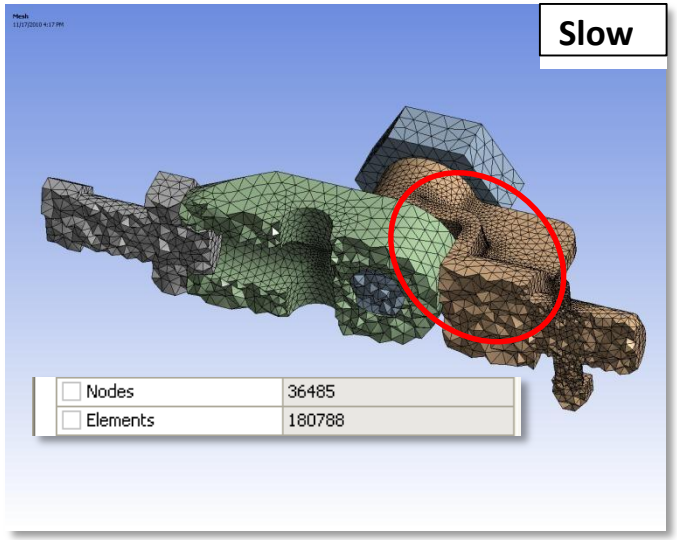
Mesh size:
GR = 1.1 : 1,263,297 cells
GR = 1.2 : 587,026 cells
GR = 1.3 : 392,061 cells

Sizing : Transition

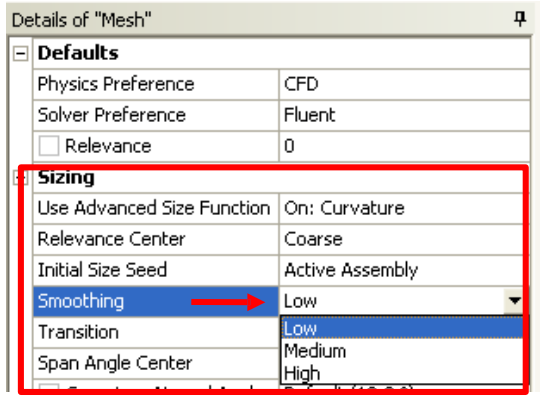
- **Controls the rate at which elements grow**
- **Two level control for transition**
  - Slow (Default for CFD, Explicit), produces smooth transitions
  - Fast (Default for Mechanical and Electromagnetic), produces more abrupt transitions
- **Hidden for sheet models, ignored for assemblies containing sheets, when ASF is On**



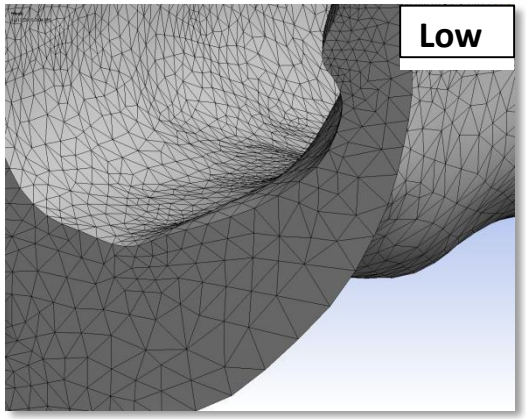




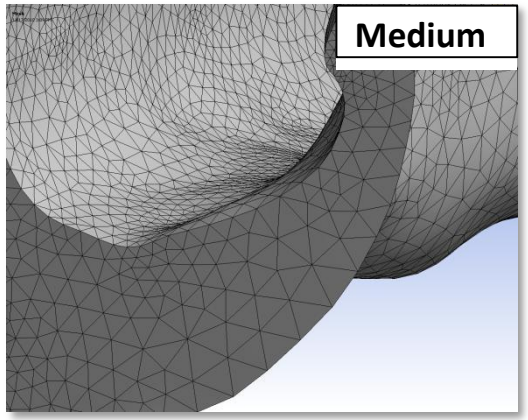
Sizing : Smoothing



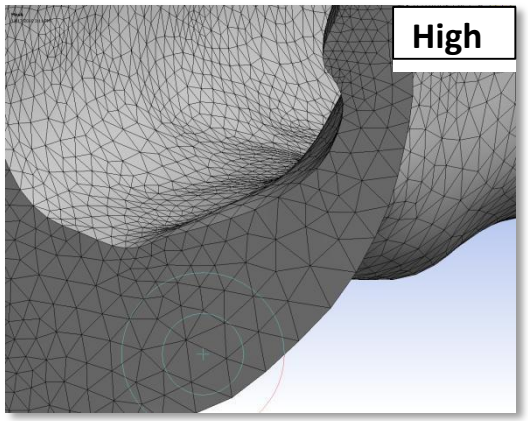
- **Improves quality by moving locations of nodes with respect to surrounding nodes**
- **Three level control for smoothing iterations**
  - High (Default for Explicit)
  - Medium (Default for Mechanical, Electromagnetic and CFD)
  - Low
- **For Cutcell meshing, the Smoothing option controls the quality threshold at which it will start smoothing. High is recommended.**



Statistics	
Nodes	35289
Elements	178171
Mesh Metric	Orthogonal Quality
Min	0.159433237759087
Max	0.994295045184473
Average	0.842949718413022
Standard Deviation	9.29869563499239E-02

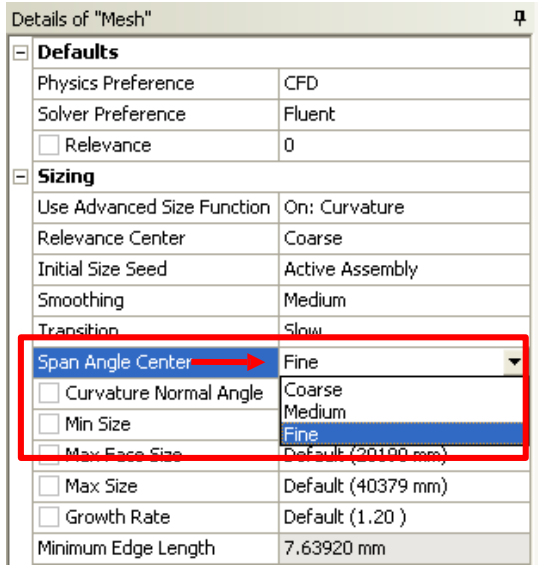


Statistics	
Nodes	35880
Elements	181504
Mesh Metric	Orthogonal Quality
Min	0.219234540928443
Max	0.997558407575095
Average	0.849759914459716
Standard Deviation	8.88455263724525E-02

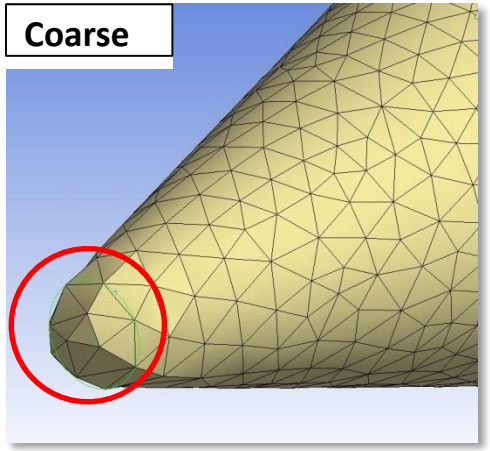


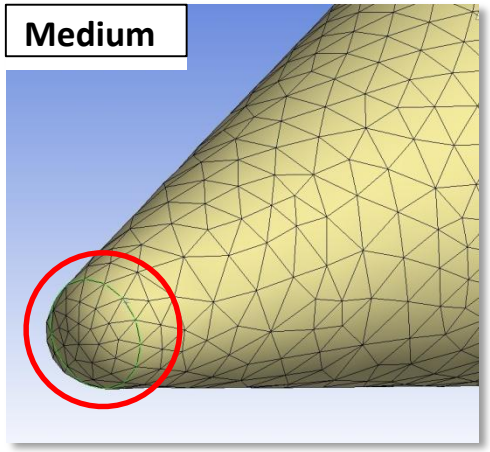
Statistics	
Nodes	35716
Elements	180536
Mesh Metric	Orthogonal Quality
Min	0.267566660927052
Max	0.995350440465592
Average	0.850145343728712
Standard Deviation	8.86677556985072E-02

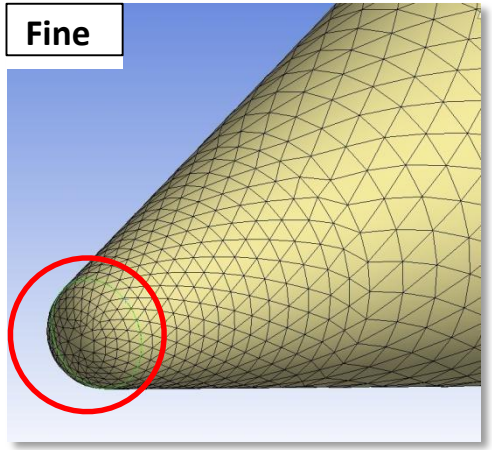
Sizing : Span Angle Center



- **Controls curvature based refinement for Edges**
- **Three options and corresponding span angle ranges are**
  - Coarse: 91° to 60°
  - Medium: 75° to 24°
  - Fine: 36° to 12°





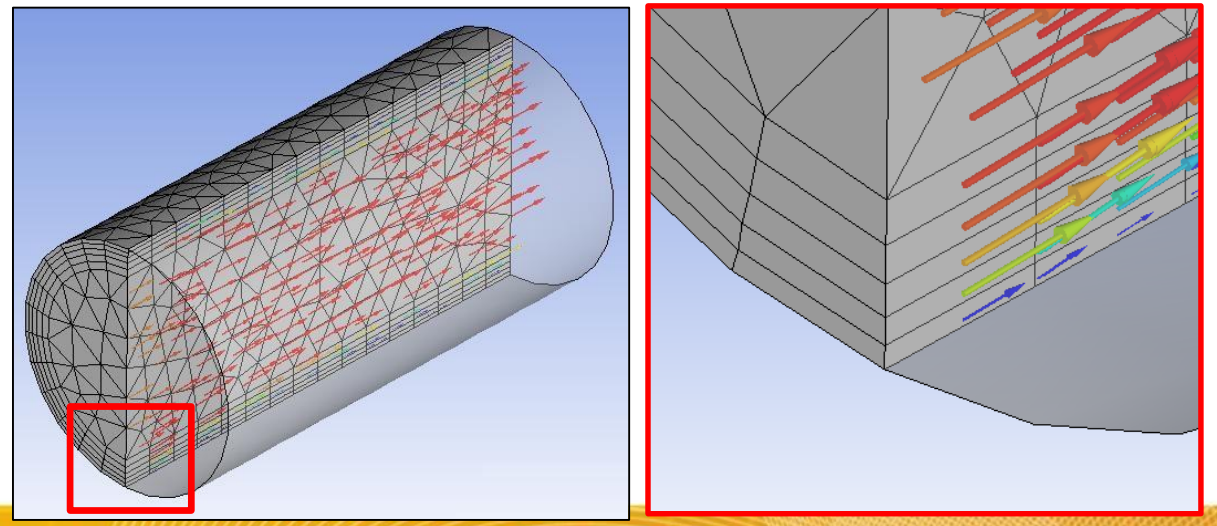


Inflation

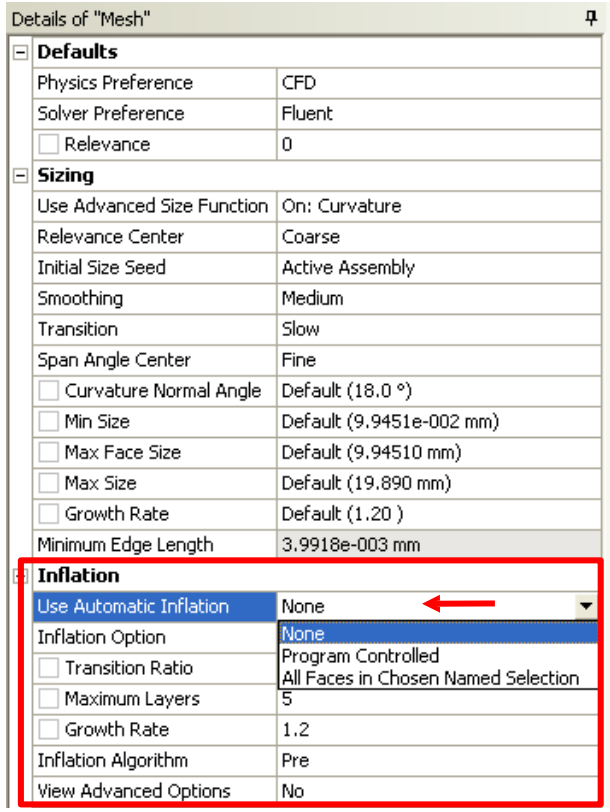
Details of "Mesh"	
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (9.9451e-002 mm)
Max Face Size	Default (9.94510 mm)
Max Size	Default (19.890 mm)
Growth Rate	Default (1.20)
Minimum Edge Length	3.9918e-003 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No

Inflation

- **Used to generate thin cells adjacent to boundaries**
- **Required for capture of wall adjacent boundary layers**
  - Resolve viscous boundary layer in CFD
  - Resolve thin air gaps in Electromagnetic analysis
  - Resolve high stress concentration regions in Structures
- **Cells are created by 'inflating' from the surface mesh into the volume (3d) or inflating from the boundary edge onto the face (2d)**
- **Options to control growth**



Inflation : Automatic Inflation



- **Three options**
  - **None**
    - Select this for manual inflation settings using local mesh controls
  - **Program Controlled**
    - All the faces are selected for inflation except:
    - Faces scoped to a Named Selection
    - Faces with manual inflation defined
    - Faces in contact regions
    - Faces in symmetry
    - Faces that belong to a part or body that has a mesh method defined that does not support 3D inflation, such as hex-dominant
    - Faces in sheet bodies
  - **All Faces in chosen Named Selection:** can grow inflation layers from faces grouped in one named selection

Inflation : Inflation Options

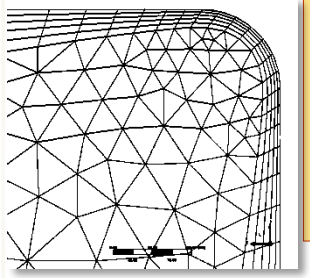
Five options:

All available for PC tets and Assembly meshing

Details of "Mesh"

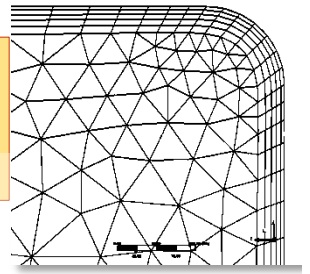
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	1.60 mm
Max Face Size	Default (238.760 mm)
Max Size	Default (477.510 mm)
Growth Rate	Default (1.20)
Minimum Edge Length	0.303010 mm
Inflation	
Use Automatic Inflation	Program Controlled
Inflation Option	Smooth Transition
Transition Ratio	
Maximum Layers	
Growth Rate	
Inflation Algorithm	
View Advanced Options	No

Total Thickness
First Layer Thickness
Smooth Transition
First Aspect Ratio
Last Aspect Ratio



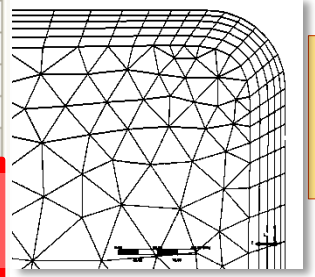
Smooth Transition

Maintains smooth volumetric growth between each adjacent layer. Total thickness depends on the variation of base surface mesh sizes (Default)



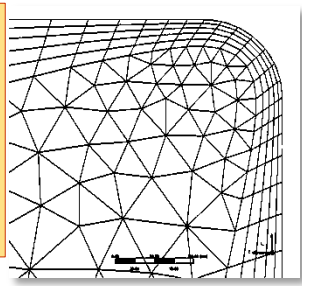
First Layer Thickness

Maintains constant first cell height throughout



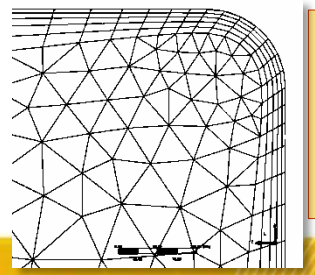
Total Thickness

Maintains constant total height of inflation layer throughout



First Aspect Ratio

Controls the heights of the inflation layers by defining the aspect ratio of the inflations that are extruded from the inflation base

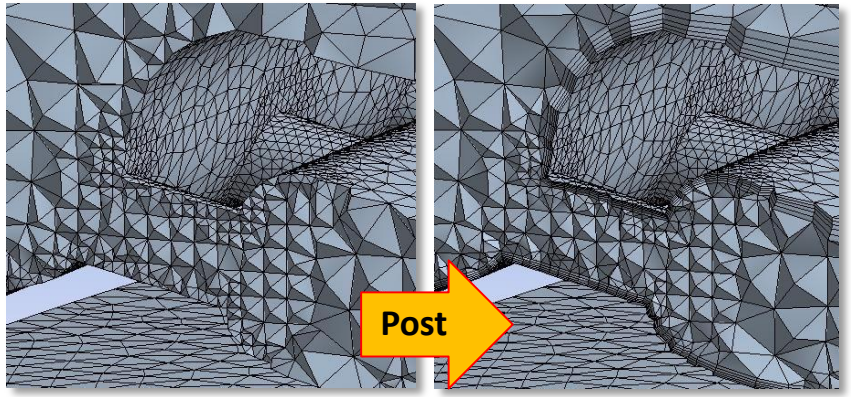


Last Aspect Ratio

Creates inflation layers using the values of the first layer height, maximum layers, and aspect ratio controls

Inflation : Inflation Algorithms

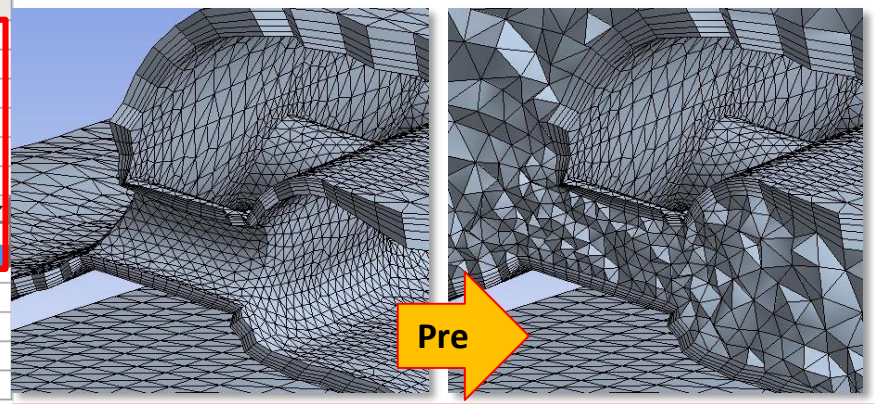
- Two Algorithms
  - Post
  - Pre
- Patch independent meshes use Post



- First Tet grows then Inflation process starts
- Tet mesh is undisturbed, if the inflation options are altered
- Default option for Patch Independent Tetrahedrons

Details of "Mesh"

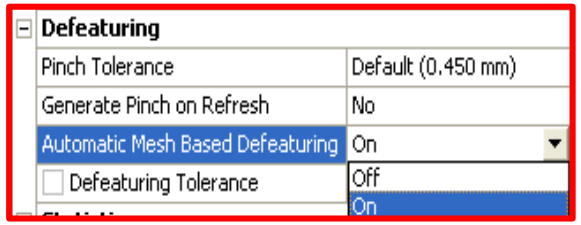
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (7.7699e-005 m)
Max Face Size	Default (7.7699e-003 m)
Max Size	Default (1.554e-002 m)
Growth Rate	Default (1.20)
Minimum Edge Length	3.e-002 m
Inflation	
Use Automatic Inflation	Program Controlled
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	Post / Pre
Assembly Meshing	
Patch Conforming Options	
Advanced	
Defeaturing	
Statistics	

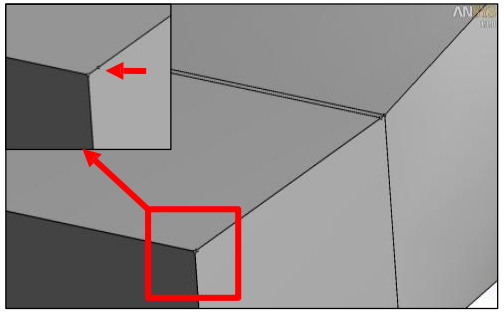


Preview Inflation is available only with Pre Algorithm

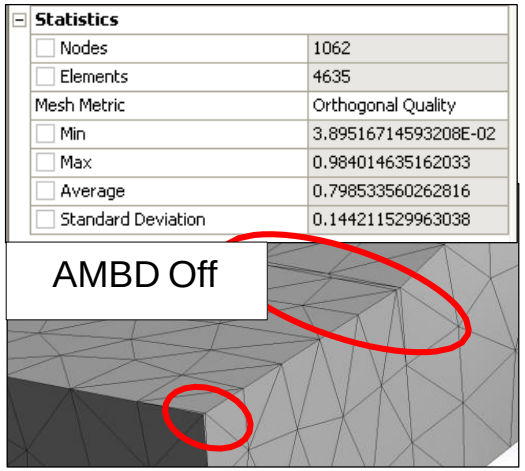
- Surface mesh is inflated first, then rest of the volume mesh grows
- Default method for Patch Conforming Tetrahedrons

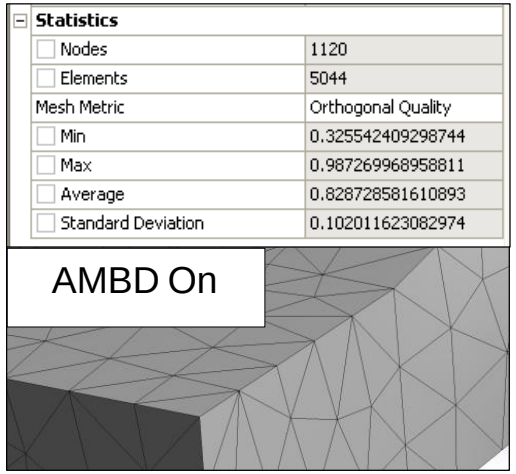
Defeaturing



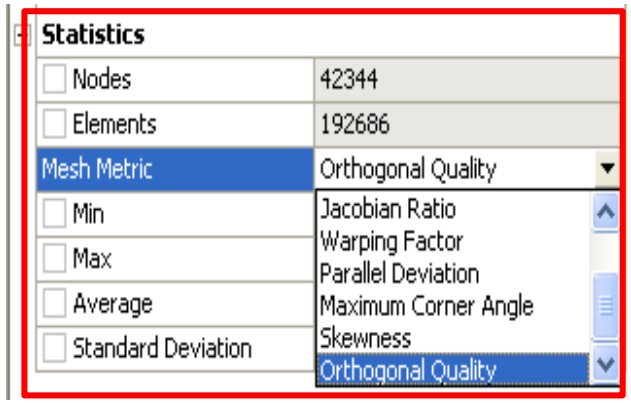


- Removes small geometry features meeting the tolerances using Pinch or/and Automatic Mesh Based Defeaturing controls in order to improve the mesh quality. Not all meshing methods can take advantage of these controls
- Automatic Mesh Based Defeaturing (AMBD) when it is 'On', features smaller than or equal to the value of Defeaturing Tolerance are removed automatically

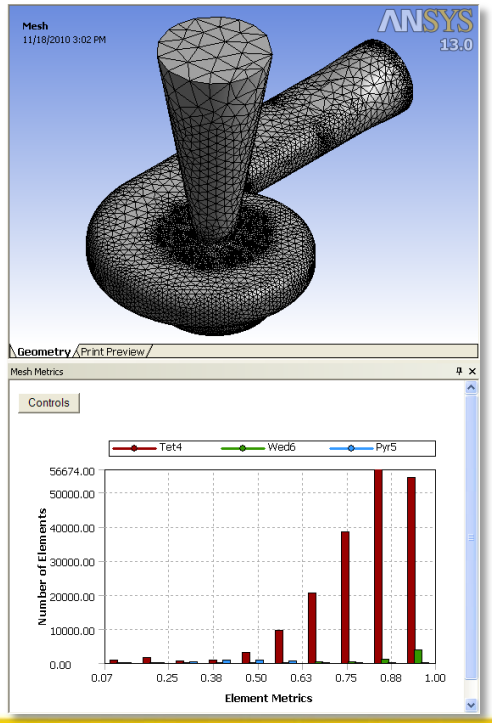


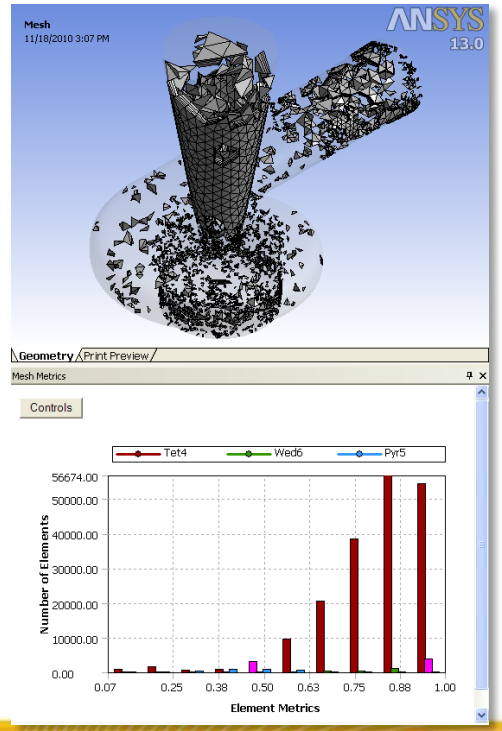


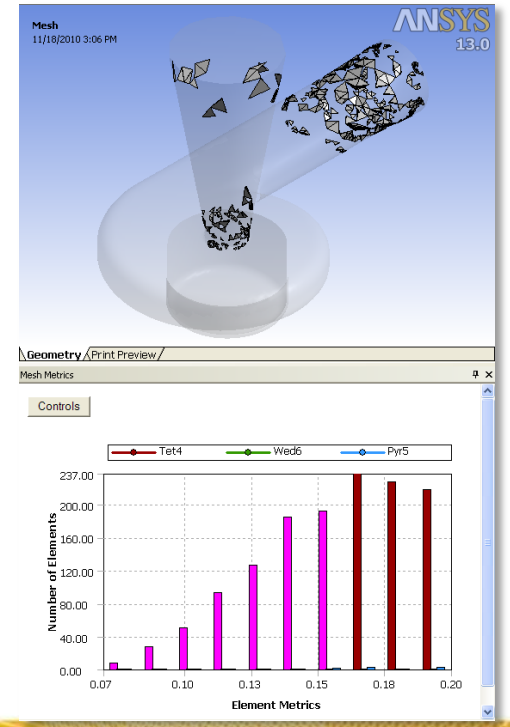
Statistics



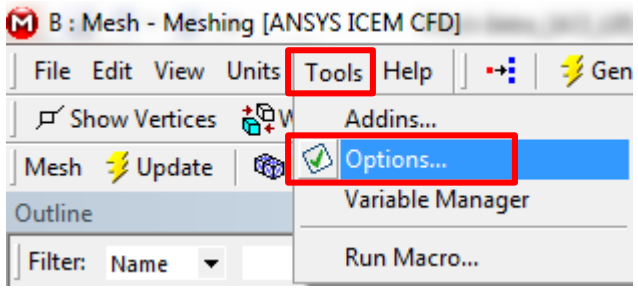
- Option to view the mesh quality metric
- Exhaustive list of quality metrics
- Orthogonal Quality mesh quality metrics
- Option to view the Mesh Metric chart
  - Intuitive controls available under Mesh Metric Chart
  - Various options to explore under the ‘Controls’
- See Module 5 for details

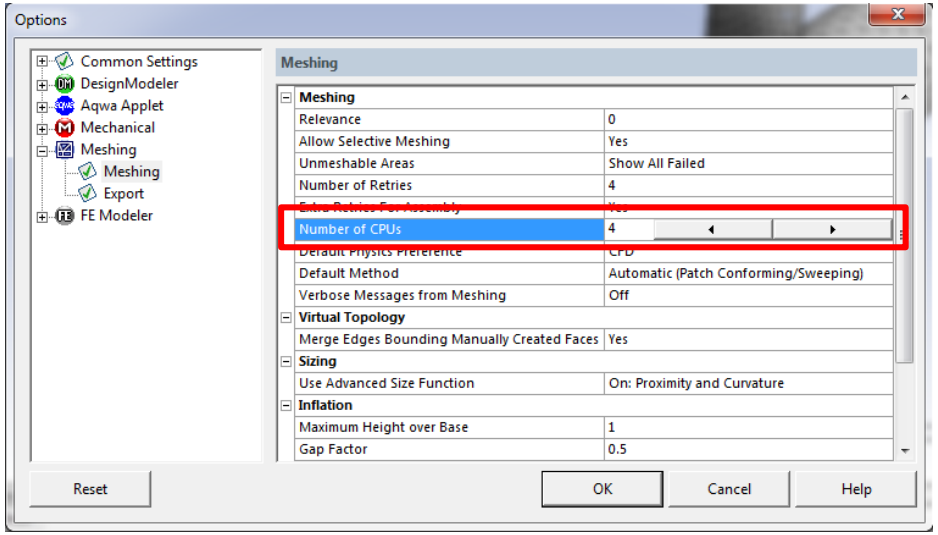






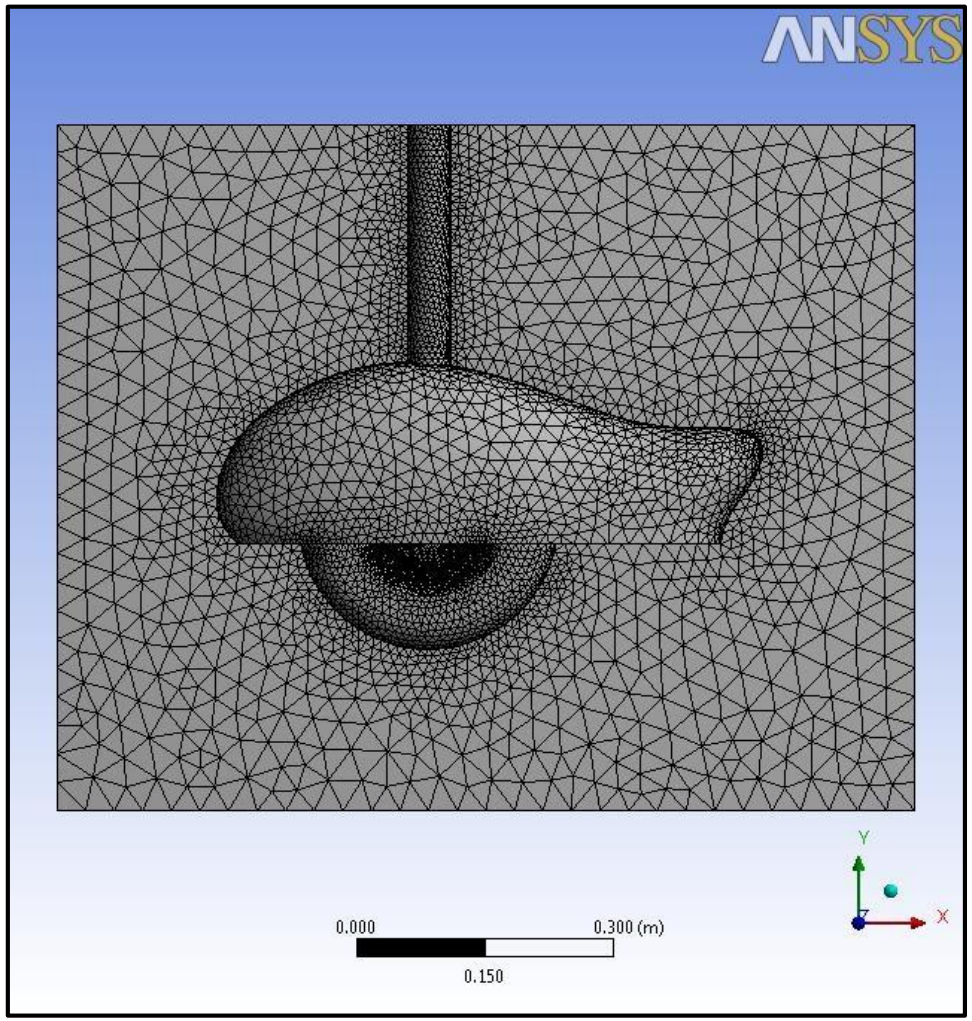
Parallel Statistic Calculations





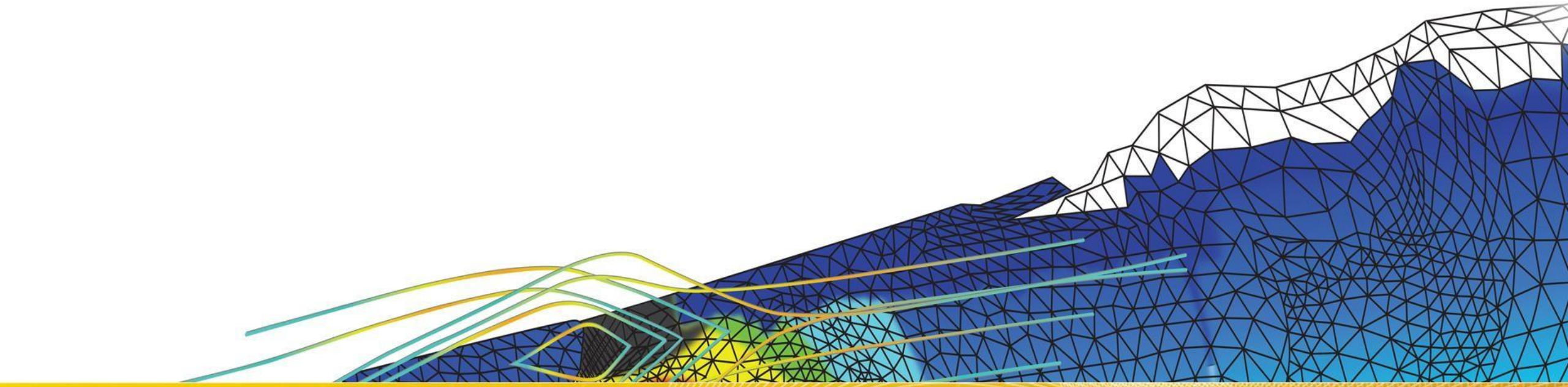
- Note that statistics can utilize multi-core machines to speed up calculations in parallel
- Specify your core count in Tools > Options to allow this
- Note that options set here will be remembered for future sessions so you can set physics preference default etc here.

Workshop 3 – Global Mesh Controls



Introduction to ANSYS Meshing

Module 4: Local Mesh Controls

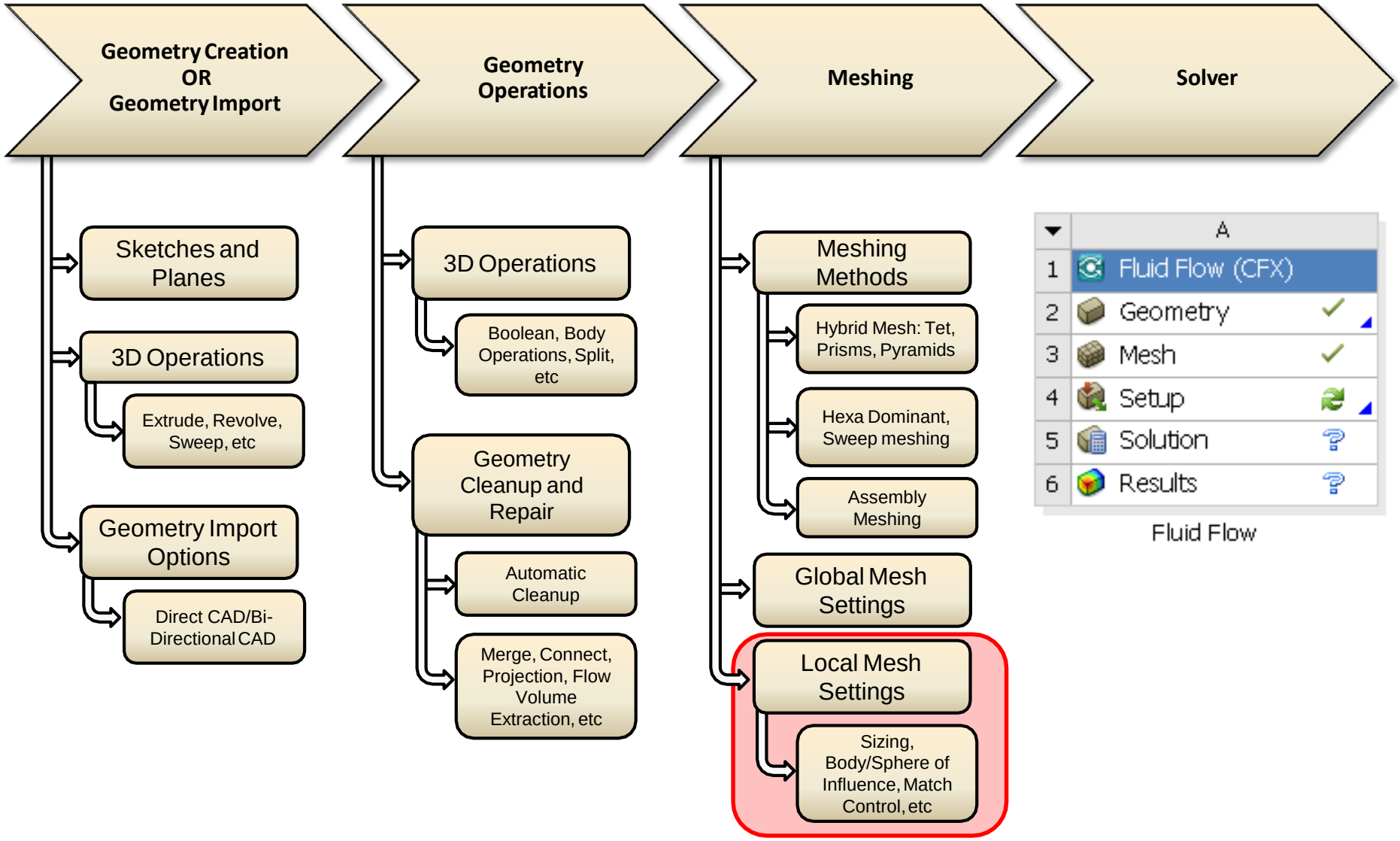


Local Mesh Controls

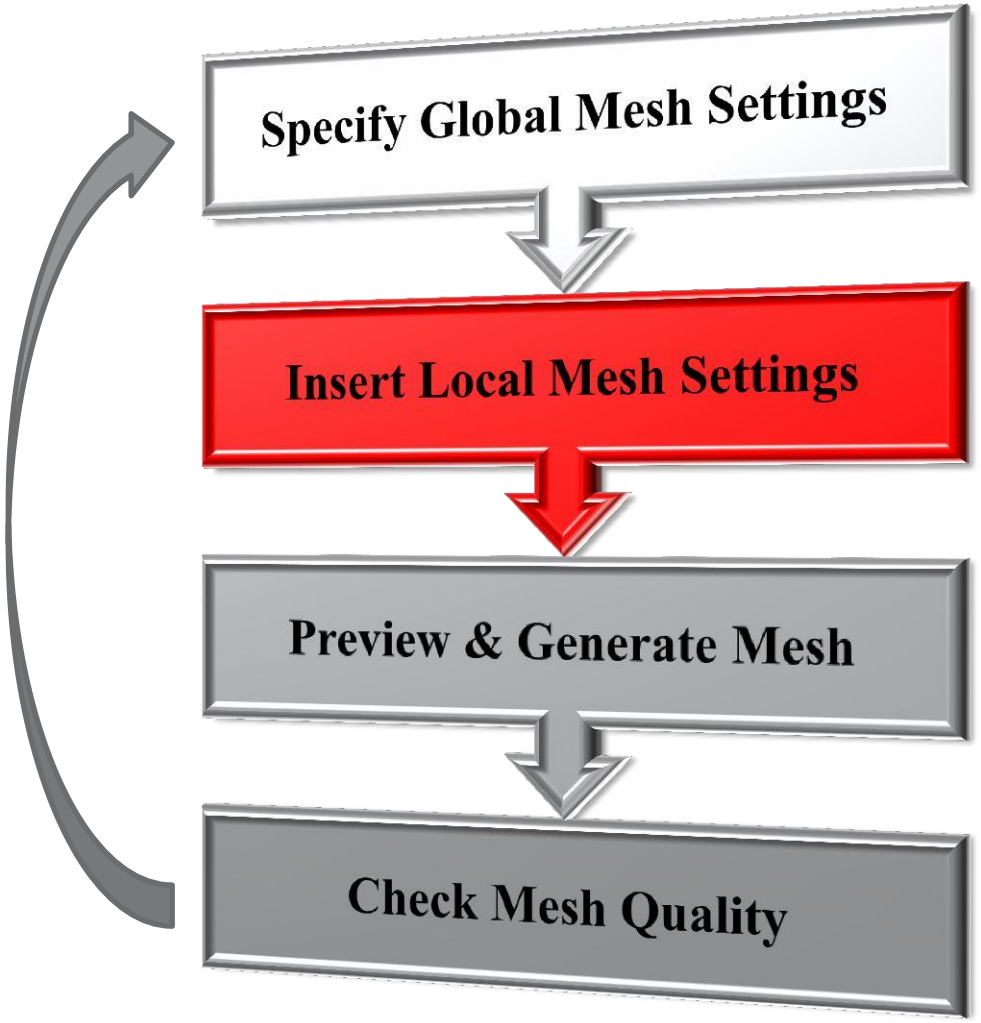
What you will learn from this presentation

- **Local mesh controls (Mesh sizing, Refinement, Match control, Inflation, etc)**
- **How to apply local controls?**
- **Effect of local controls on mesh**

Preprocessing Workflow



Meshing Process in ANSYS Meshing



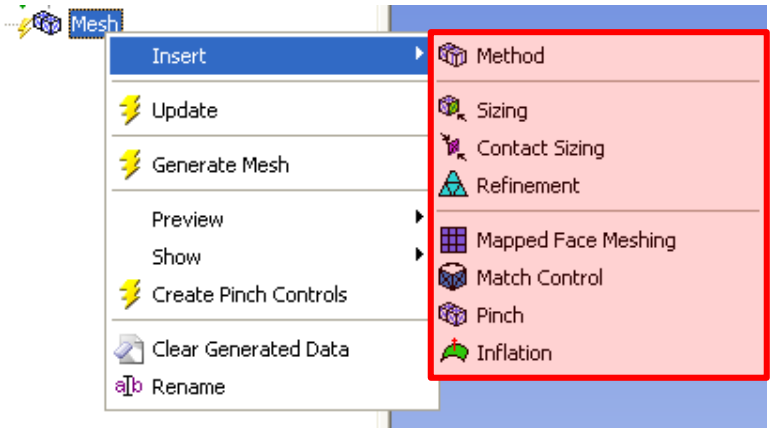
Local Mesh Controls

Control the mesh locally

- **Depends on the "Mesh Method" used**

Local Mesh Controls are:

- **Sizing**
  - **For Vertex, Edge, Face and Body**
- **Contact Sizing**
  - **For Edge and face**
- **Refinement**
  - **For Vertex, Edge and Face**
- **Mapped Face Meshing**
  - **For Face**
- **Match Control**
  - **For Edge and Face**
- **Pinch**
  - **For Vertex and Edge**
- **Inflation**
  - **For Edge and Face**



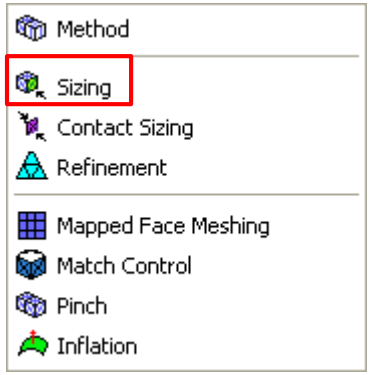
The latest control added on a particular entity overrides any prior controls

Sizing

Recommended for locally defining the mesh sizes

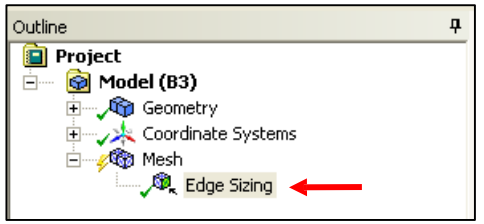
You can only scope sizing to one geometry entity type at a time

- **For example: you can apply sizing to a number of edges or a number of faces, but not a mix of edges and faces.**



Four Types of Sizing option

- **Element Size specifies average element edge length on bodies, faces or edges**
- **Number of Divisions specifies number of elements on edge(s)**
- **Body of Influence specifies average element size within a body**
- **Sphere of Influence specifies average element size within the sphere**



Sizing options vary depending on the entity type chosen

Entity/Option	Element Size	Number of Divisions	Body of Influence	Sphere of Influence
Vertices				x
Edges	x	x		
Faces	x			
Bodies	x		x	x

Requires a Coordinate system for the sphere

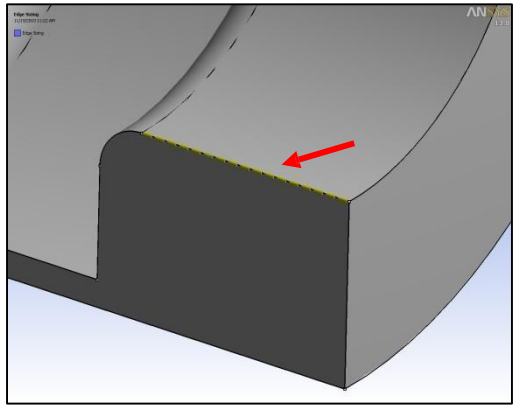
Advanced Size Function in Global settings should be disabled

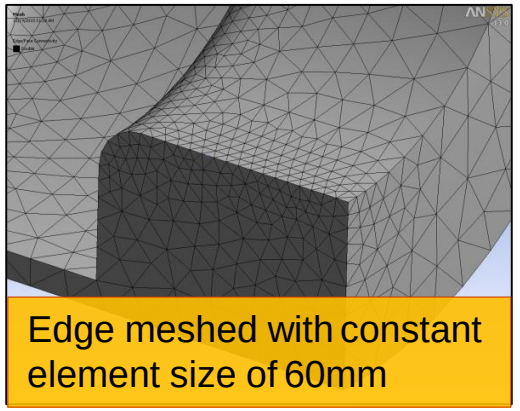
Only Element Size type is available for CutCell meshing

Sizing : Edges

Sizing Type:
Element Size

Details of "Edge Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Edge
Definition	
Suppressed	No
Type	Element Size
Element Size	60. mm
Behavior	Soft
Curvature Normal Angle	Default
Growth Rate	Default
Bias Type	No Bias

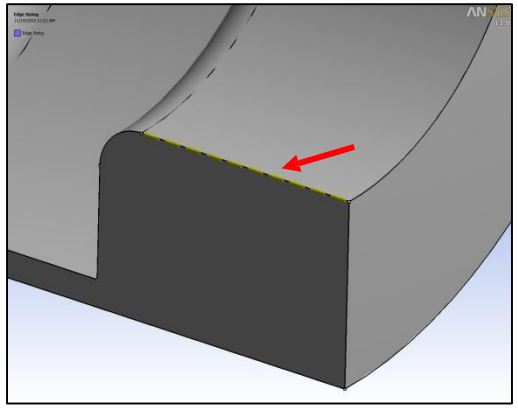


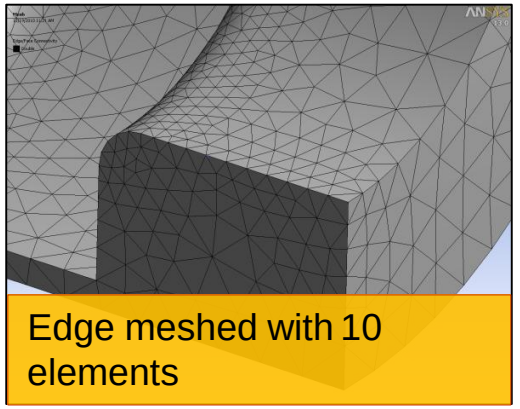


Edge meshed with constant element size of 60mm

Sizing Type:
Number of Divisions

Details of "Edge Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Edge
Definition	
Suppressed	No
Type	Number of Divisions
Number of Divisions	10
Behavior	Soft
Curvature Normal Angle	Default
Growth Rate	Default
Bias Type	No Bias





Edge meshed with 10 elements

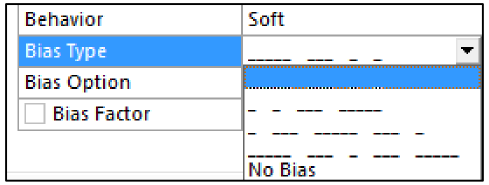
The Curvature Normal Angle and/or the Growth Rate maybe not displayed depending on the ASF used

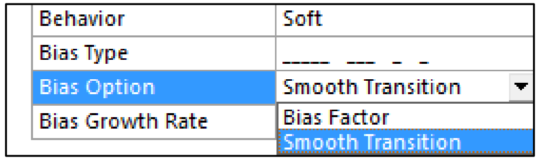
Sizing : Edges

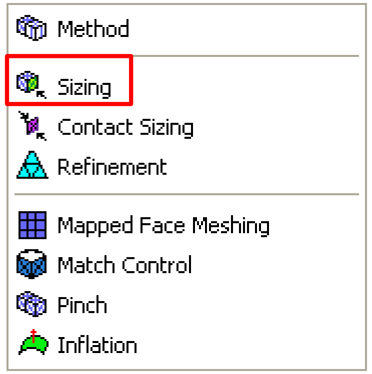
Bias Type and Bias Factor

Specify the grading scheme and factor

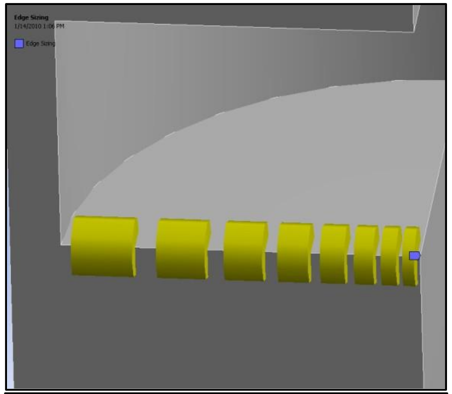
- **Bias Type: grading of elements towards one end, both ends, or the center**



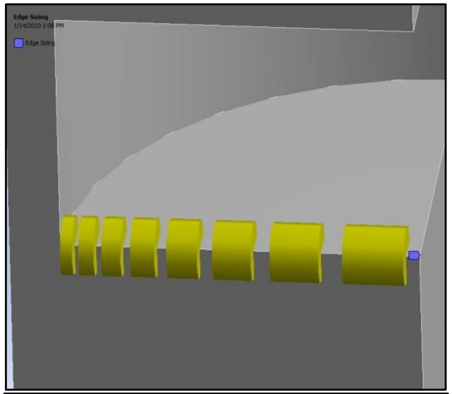




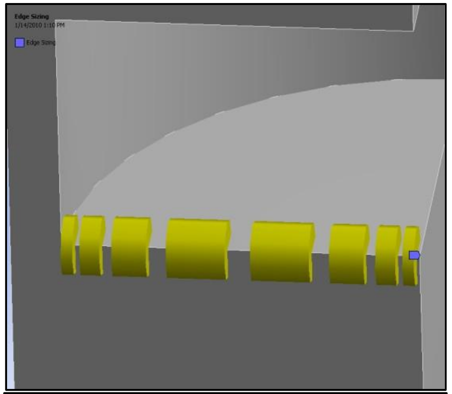
- **Bias Option:**
  - **Bias Factor: is the ratio of the largest element to the smallest element**
  - **Smooth Transition: defined by Growth Rate which is ratio of size of an element with size of previous element. (Growth Rate = Bias Factor^(1(n-1))**



Definition	
Suppressed	No
Type	Number of Divisions
Number of Divisions	8
Behavior	Soft
Bias Type	_____ ___ _ _
Bias Option	Bias Factor
Bias Factor	5.



Definition	
Suppressed	No
Type	Number of Divisions
Number of Divisions	8
Behavior	Soft
Bias Type	_ _ ___ _____
Bias Option	Bias Factor
Bias Factor	5.



Definition	
Suppressed	No
Type	Number of Divisions
Number of Divisions	8
Behavior	Soft
Bias Type	_ ___ _____ ___ _
Bias Option	Bias Factor
Bias Factor	5.

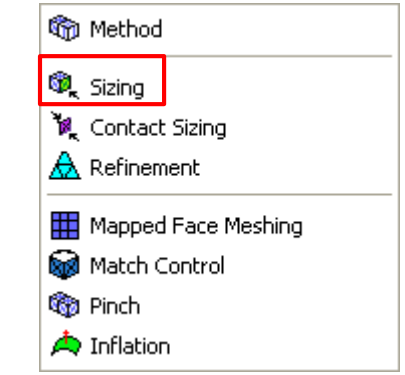
Sizing : Edges

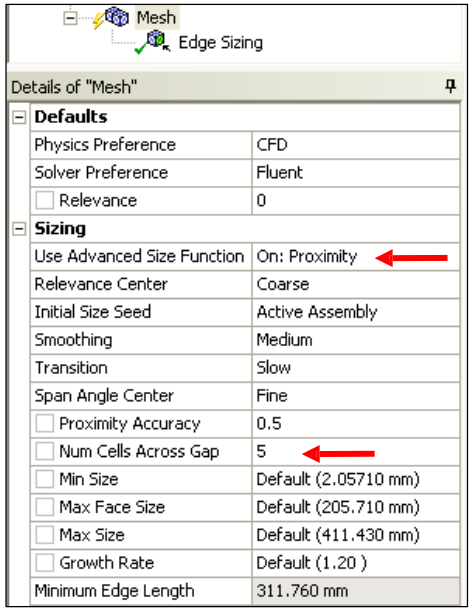
Behavior

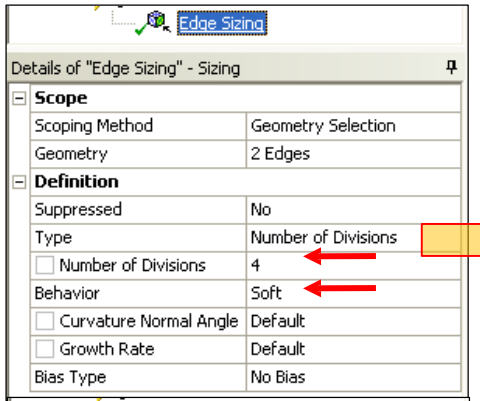
Soft: Sizing will be influenced by global sizing functions such as those based on proximity and/or curvature as well as local mesh controls

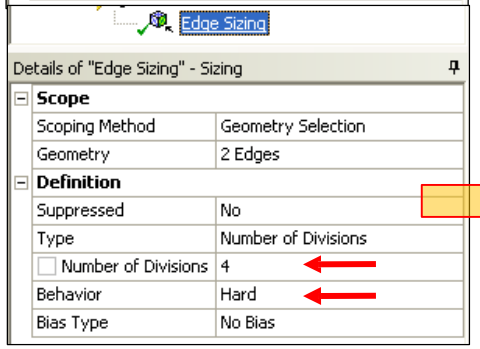
Hard: Size control is strictly adhered to

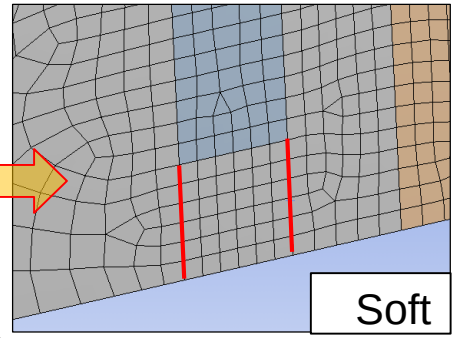
- *Transition between hard edges (or any edge with bias) and adjacent edge and face meshes may be abrupt*
- *Hard edges or edges with bias will override Max Face Size and Max Size properties*

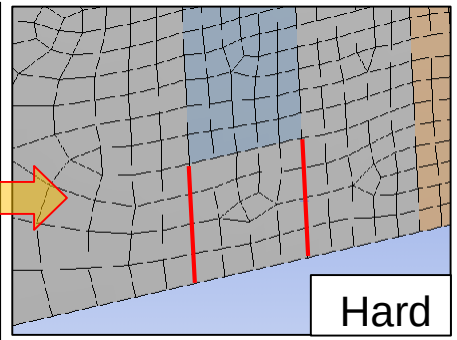












Influenced by global Proximity advanced size function.

No influence from other global settings

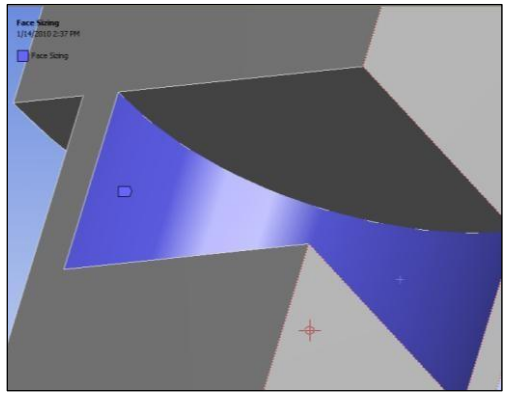
Sizing : Faces

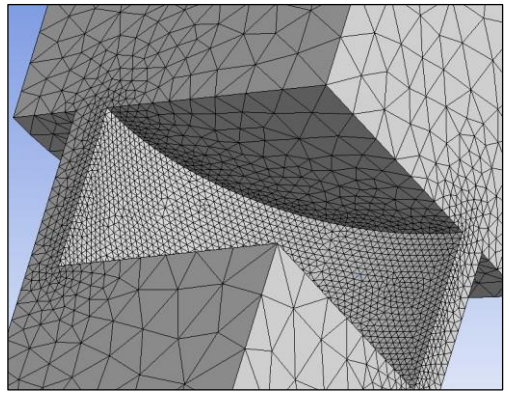
Element Size

Defines the maximum element size on the face

Face Sizing

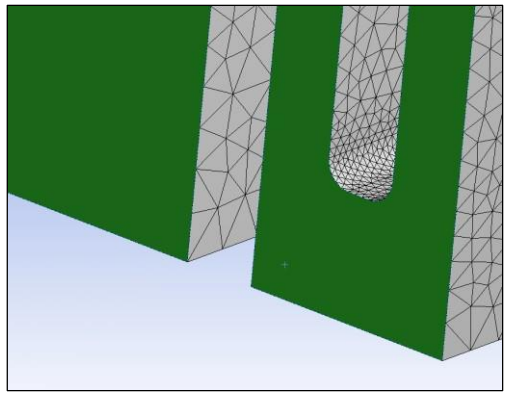
Details of "Face Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Suppressed	No
Type	Element Size
Element Size	0.2 mm
Behavior	Soft
Curvature Normal Angle	Default
Growth Rate	Default

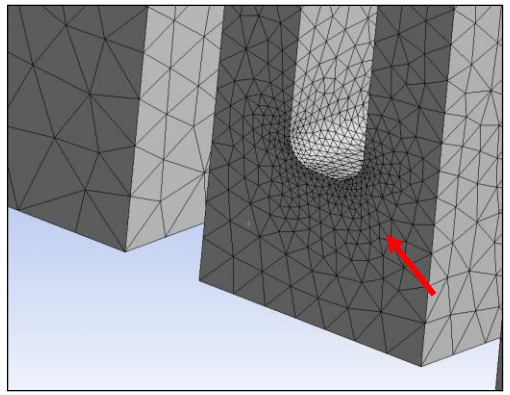


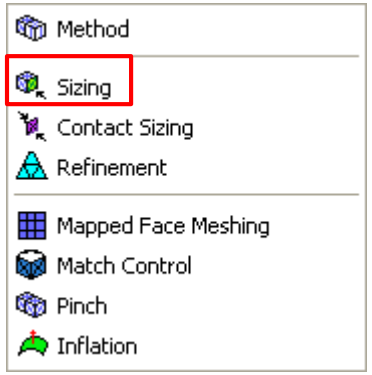


Face Sizing

Details of "Face Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Suppressed	No
Type	Element Size
Element Size	Default
Behavior	Soft
Curvature Normal Angle	10.0 °
Growth Rate	1.20







Face meshed with constant element size

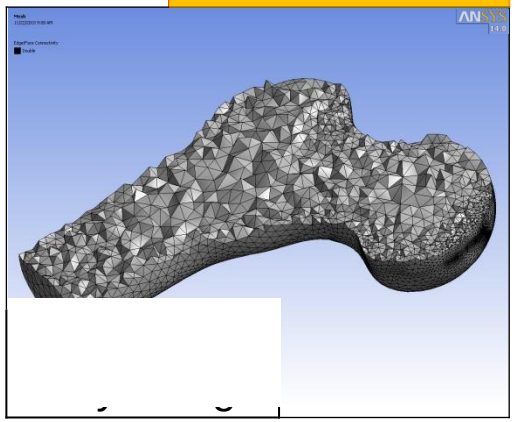
Edge curvature is resolved

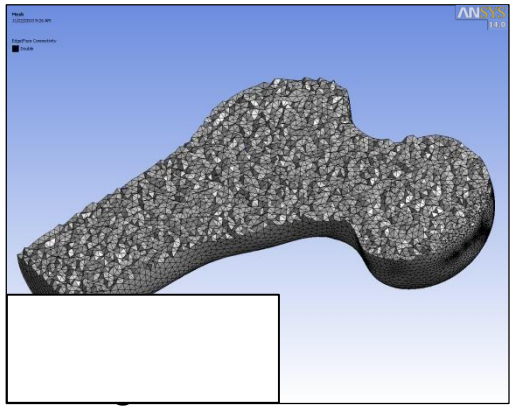
Sizing : Body (volume)

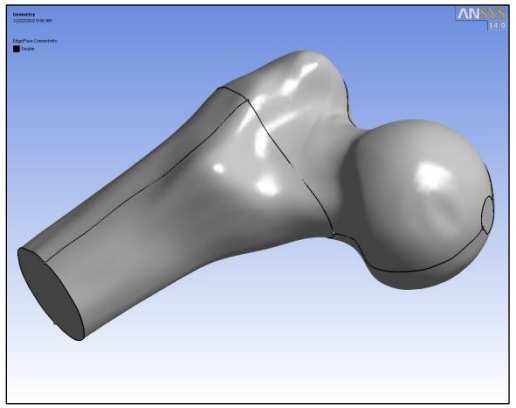
Element Size

Defines the maximum cell size on the Body

Tetrahedron patch conforming mesh





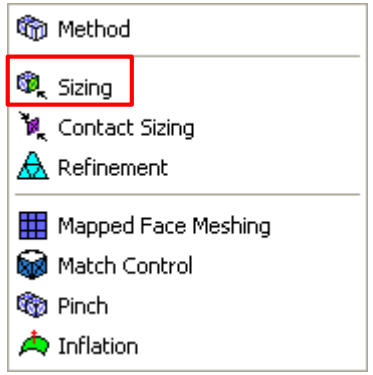


Body Sizing

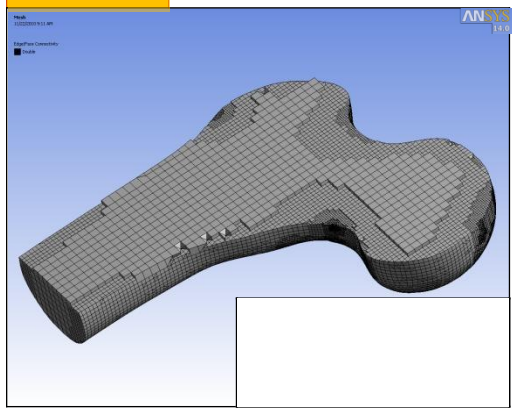
Details of "Body Sizing" - Sizing

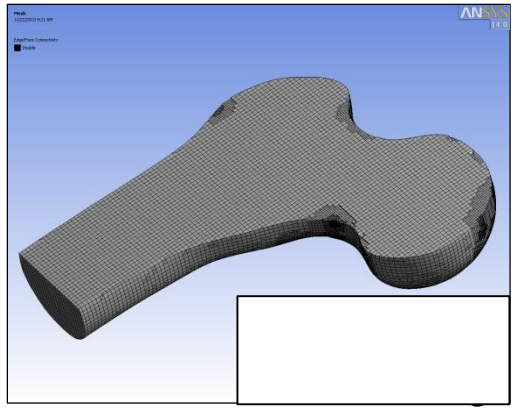
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	2. mm
Behavior	Soft
Curvature Normal Angle	Default
Growth Rate	Default

Body meshed with max cell size defined

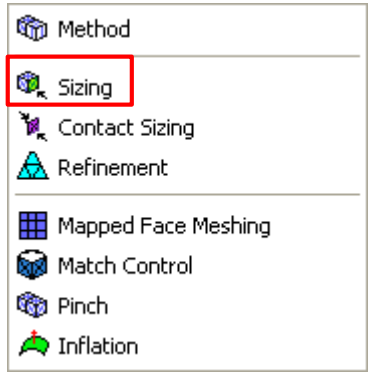


CutCell mesh



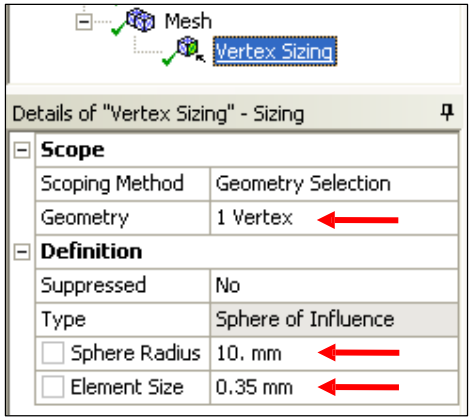


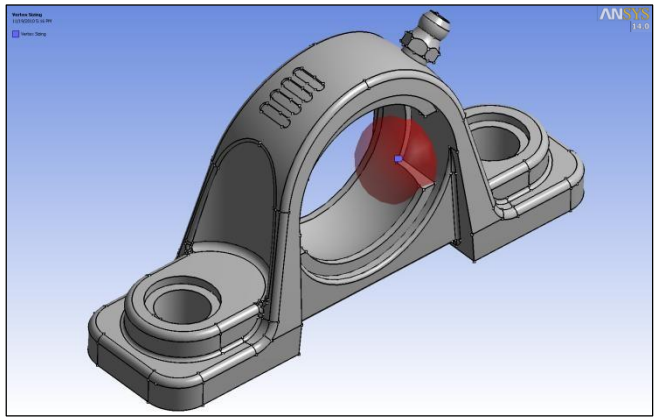
Sizing : Sphere of Influence

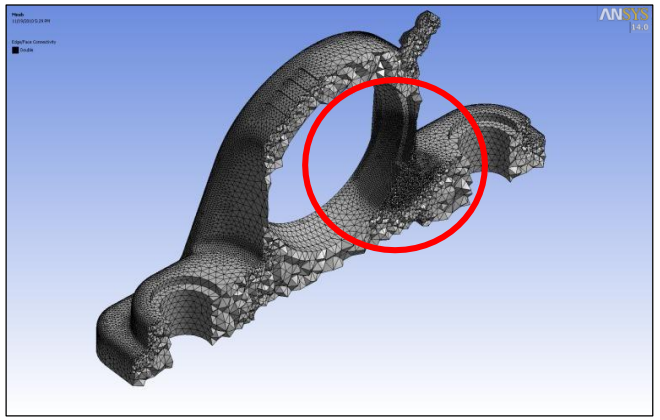


Sphere of Influence : on Vertex

- Available with or without Advanced Size Functions
- Sets the average element size around the selected vertex
- Inputs:
  - Sphere radius and Element size
  - Center of the sphere is defined by a model vertex

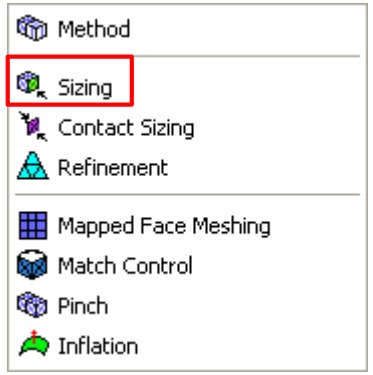






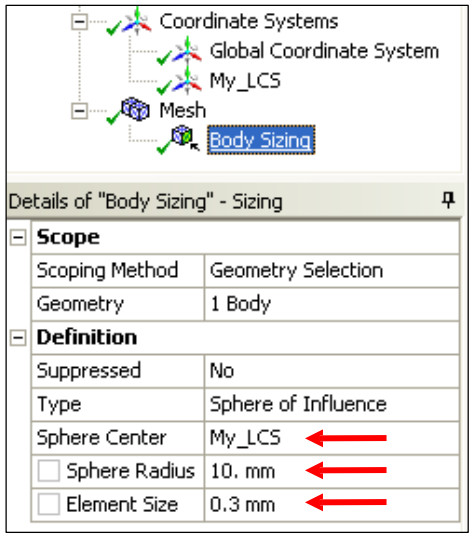
- Good resolution at the vertex
- The element size will be applied to all entities connected to the selected vertex

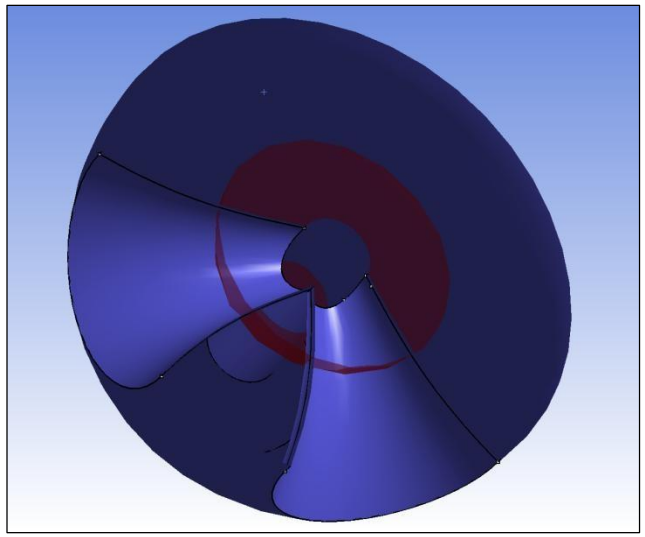
Sizing : Sphere of Influence

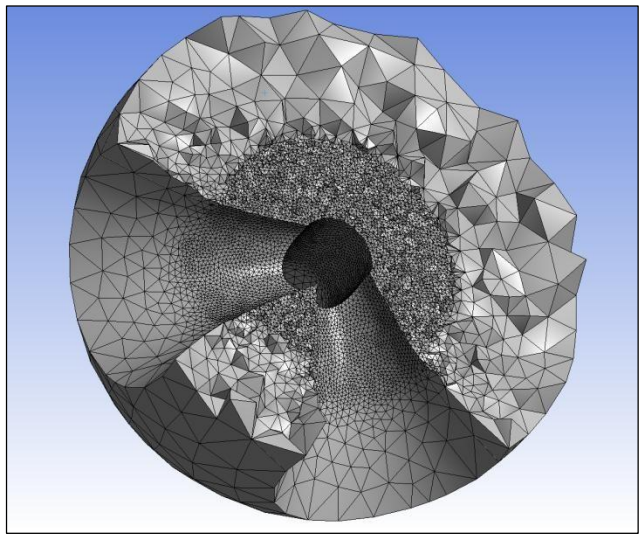


Sphere of Influence : on Bodies

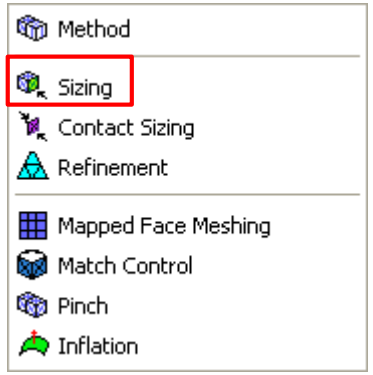
- Available with or without Advanced Size Functions
- Constant element size is applied within the confines of a sphere
- Use coordinate system to define the center of the Sphere





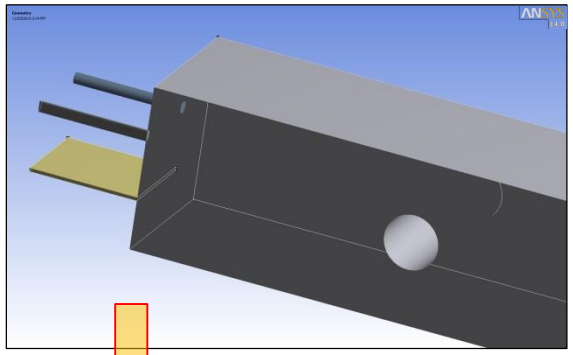


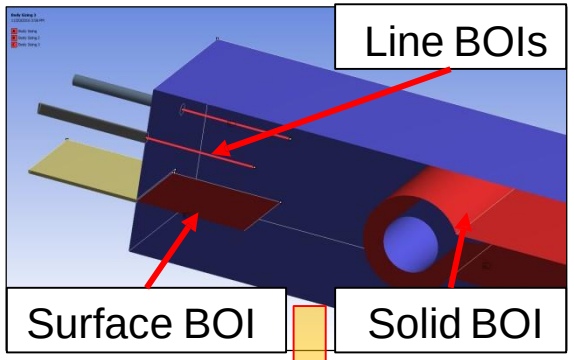
Sizing : Bodies of Influence

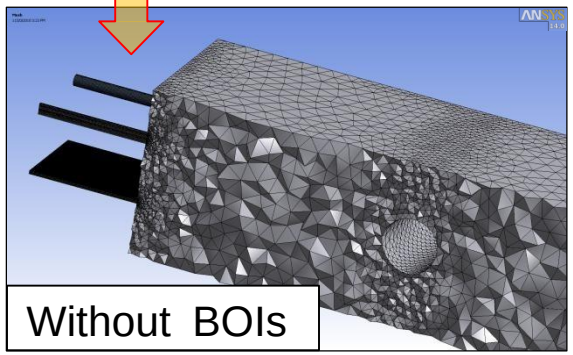


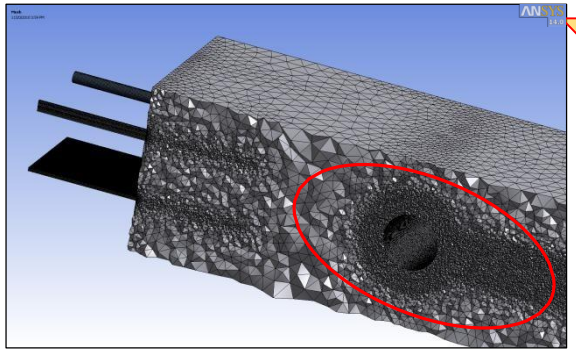
Bodies of influence (BOI)

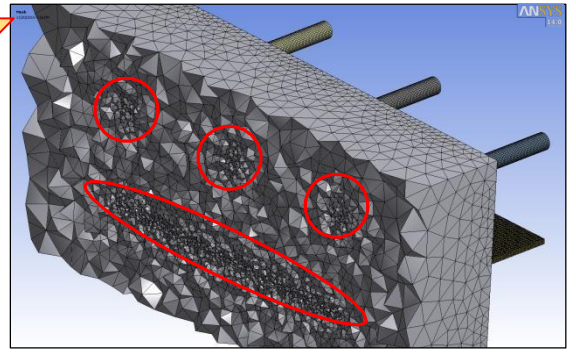
- **Lines, surfaces and solid bodies can be used to refine the mesh**
- **Accessible when ASF is On**





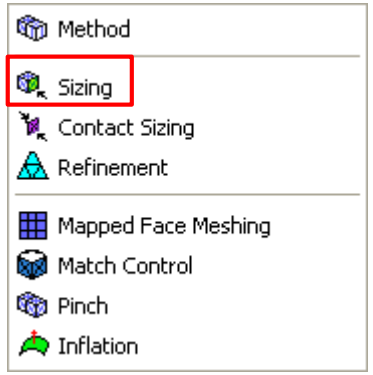




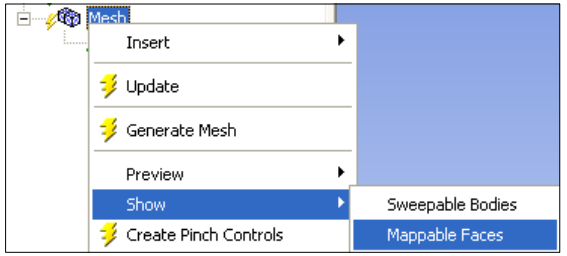


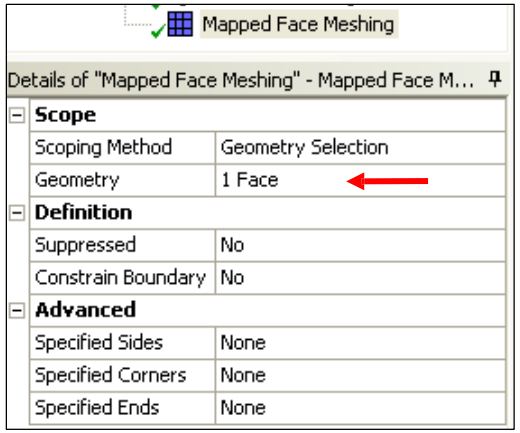
The 'Body of Influence' itself will not be meshed

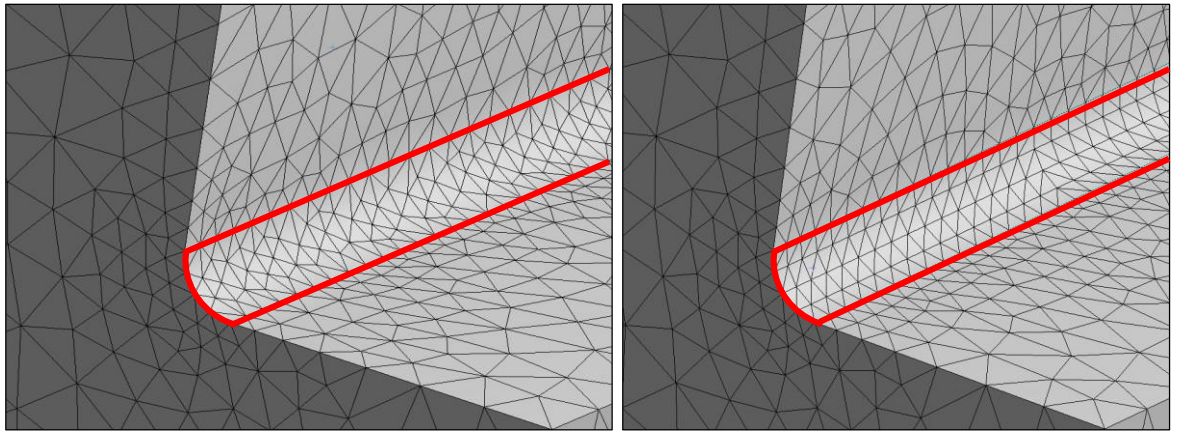
Mapped Face Meshing



- Creates structured meshes on selected mappable surfaces
  - Mapped Face Meshing with advanced control is supported for
    - Sweep, Patch Conforming, Hexa Dominant
    - Quad Dominant and Triangles
  - Mapped Face Meshing with basic control is supported for
    - MultiZone
    - Uniform Quad/Tri and Uniform Quad
  - RMB on Mesh and Show/Mappable Faces to display all mappable faces





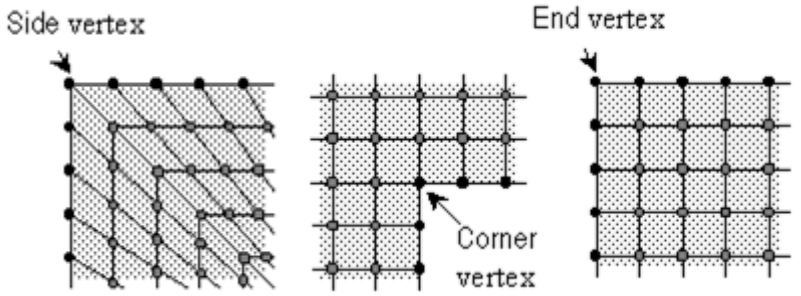


If Mapped Face Meshing fails, ( ) icon appears adjacent to corresponding object in the Tree outline. The mesh will still be created but will ignore this control.

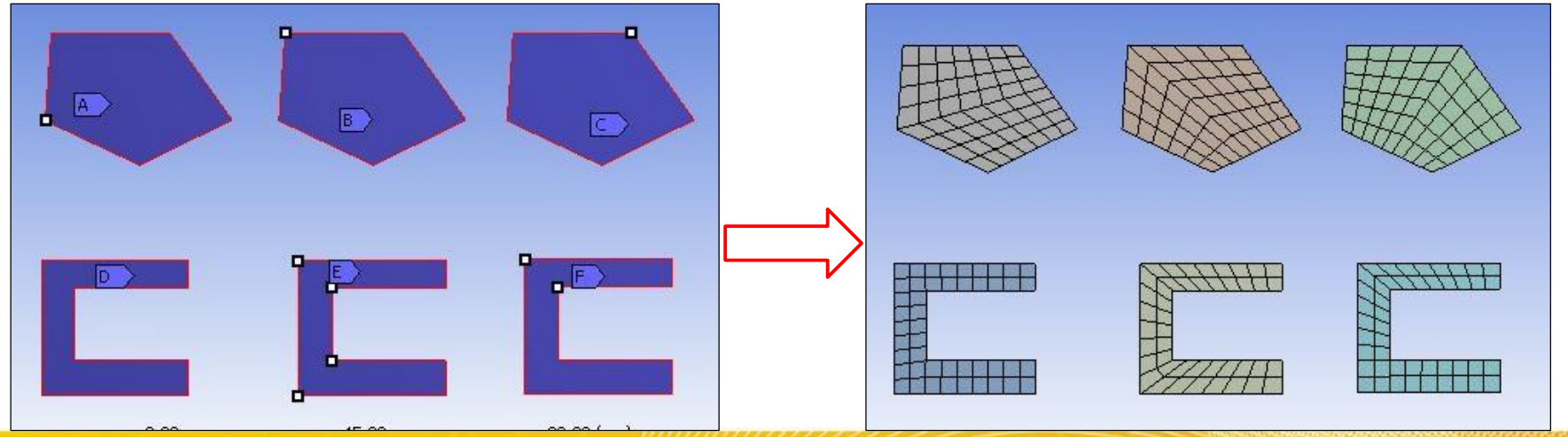
Mapped Face Meshing: Vertex Type

- **'Side', 'Corner' and 'End' controls for vertices, to define strategy for Mapping**

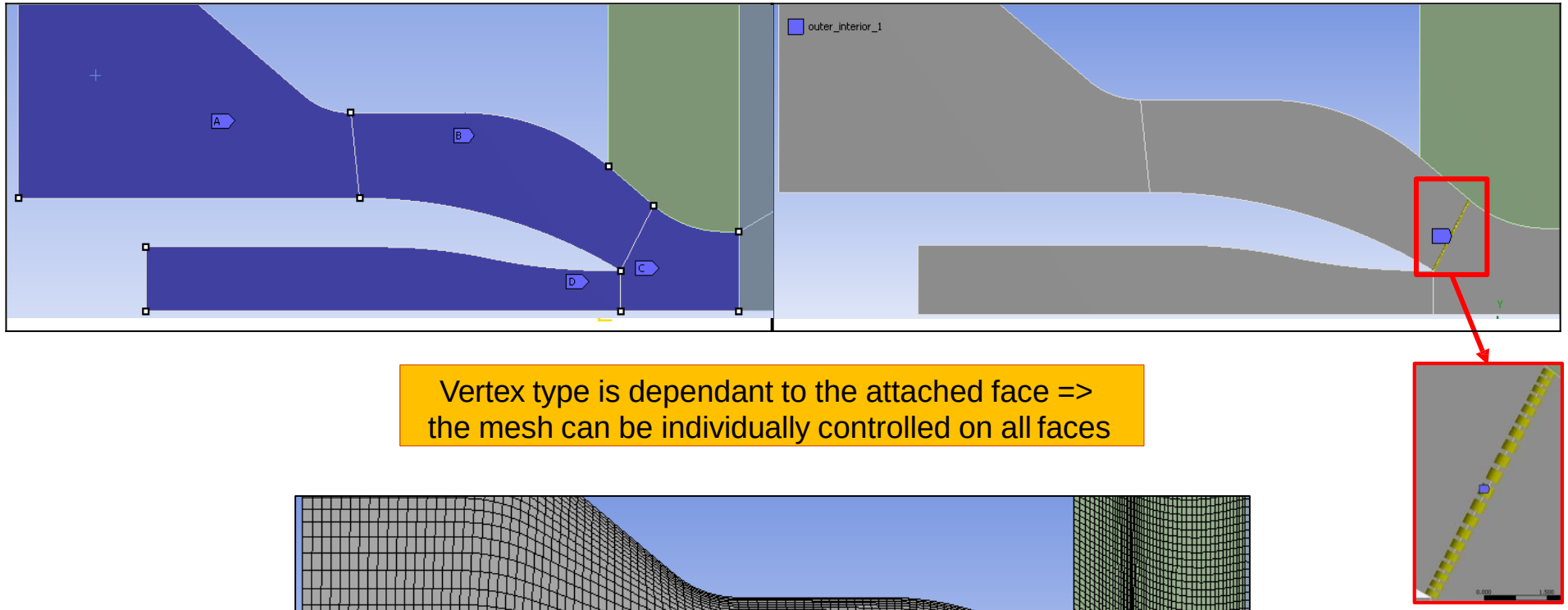
Details of "Mapped Face Meshing" - Mapped Face ...	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Suppressed	No
Method	Quadrilaterals
Constrain Boundary	No
Advanced	
Specified Sides	1 Vertex
Specified Corners	None
Specified Ends	None



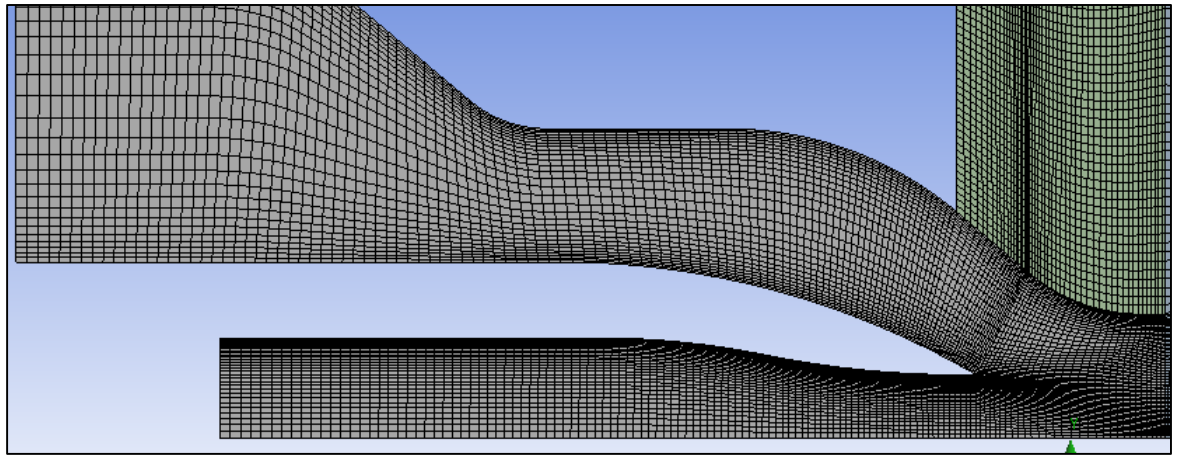
Vertex Type	Intersecting Grid Lines	Angle Between Edges
End	0	0° — 135°
Side	1	136° — 224°
Corner	2	225° — 314°



Mapped Face Meshing: Example

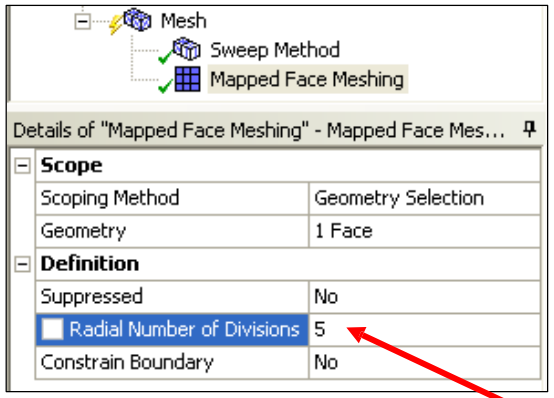


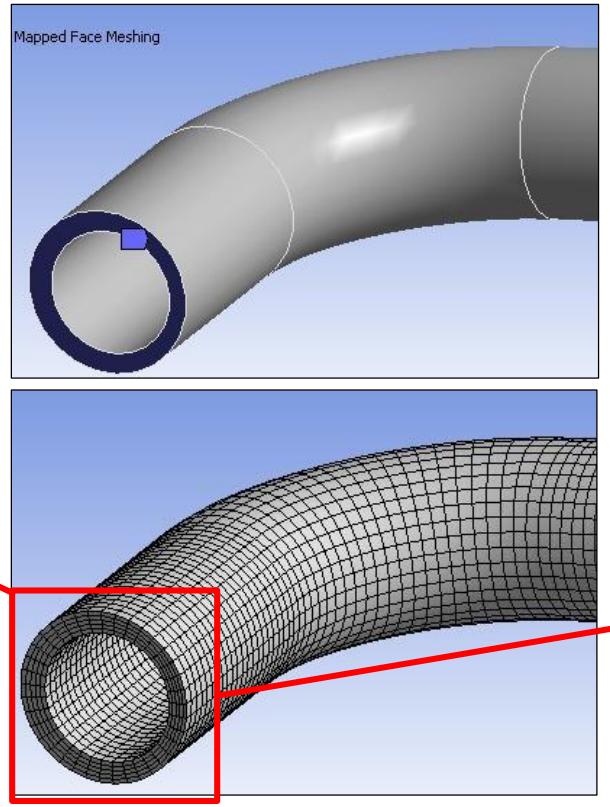
Vertex type is dependant to the attached face =>
the mesh can be individually controlled on all faces



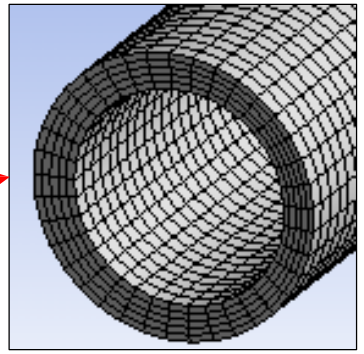
Mapped Face Meshing: Radial No. of Divisions

- If face is defined by two loops, then the “Radial Number of Divisions” field is activated
  - Specify the number of divisions across the annular region
  - Useful for creating number of layers across an annulus



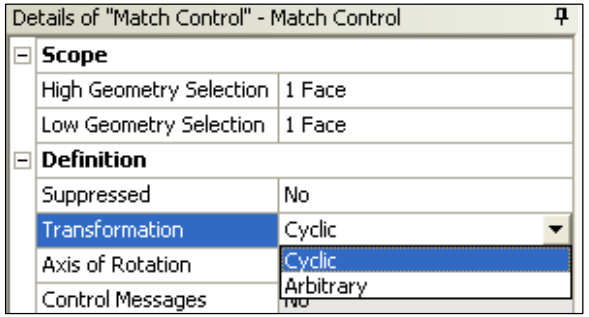


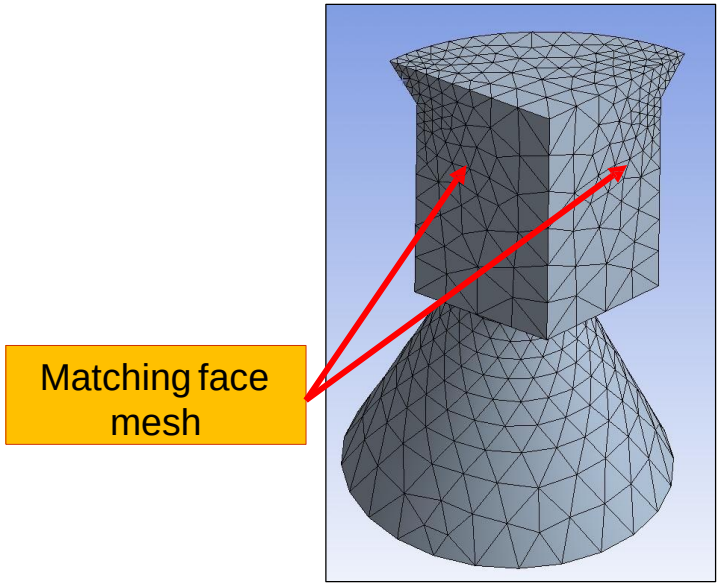
Mapped face is swept to create pure hex mesh



Match Control

- **Define periodicity on faces (3D) or edges (2D)**
  - **The two faces or edges should be topologically and geometrically the same**
  - **A match control can only be assigned to one unique face/edge pair**
  - **Match controls are not supported with Post Inflation Algorithm**
  - **Match Control with Patch Independent tetrahedrons not supported yet**
- **Two types of match controls available:**
  - **Cyclic and**
  - **Arbitrary**
- **Not available for CutCell meshing**

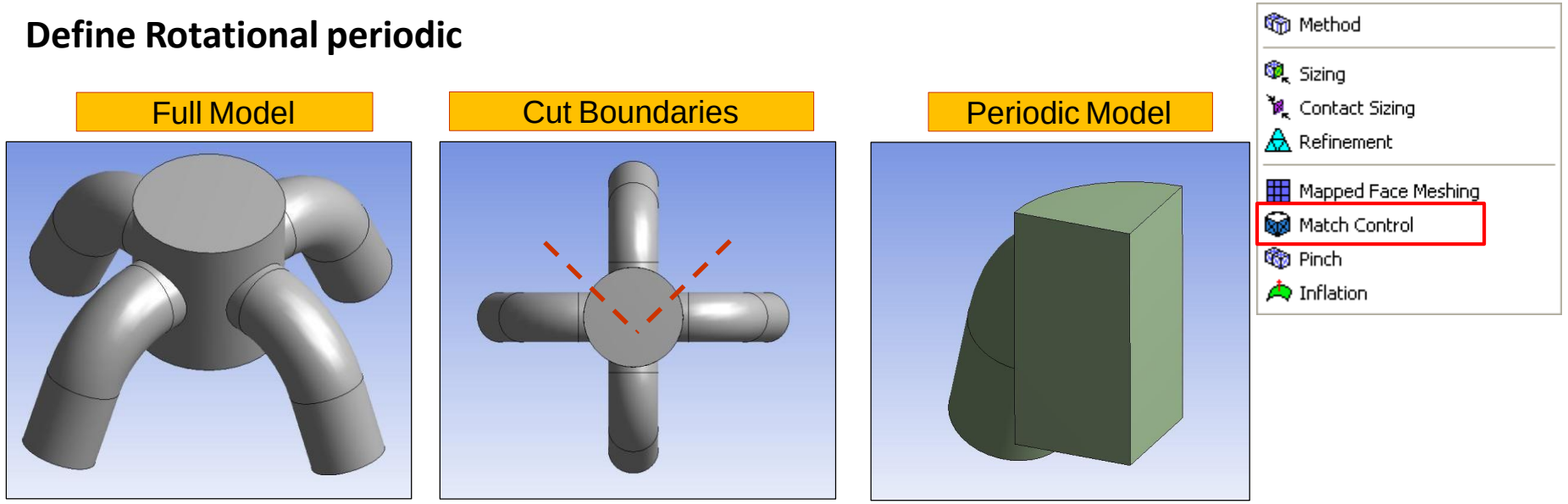




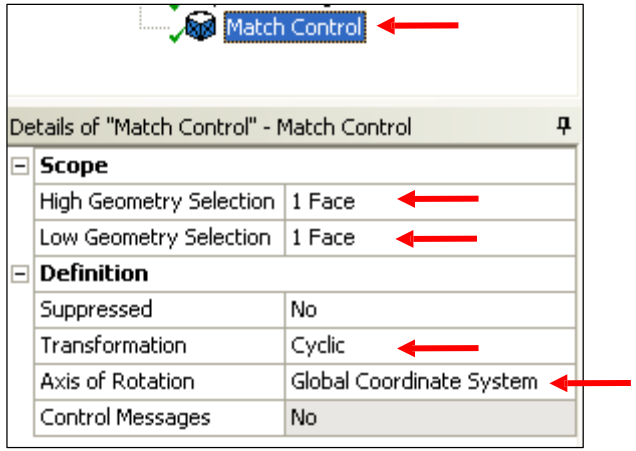
If 'Match Control' fails, ( ) icon appears adjacent to corresponding object in the outline Tree, however the mesh is created ignoring it

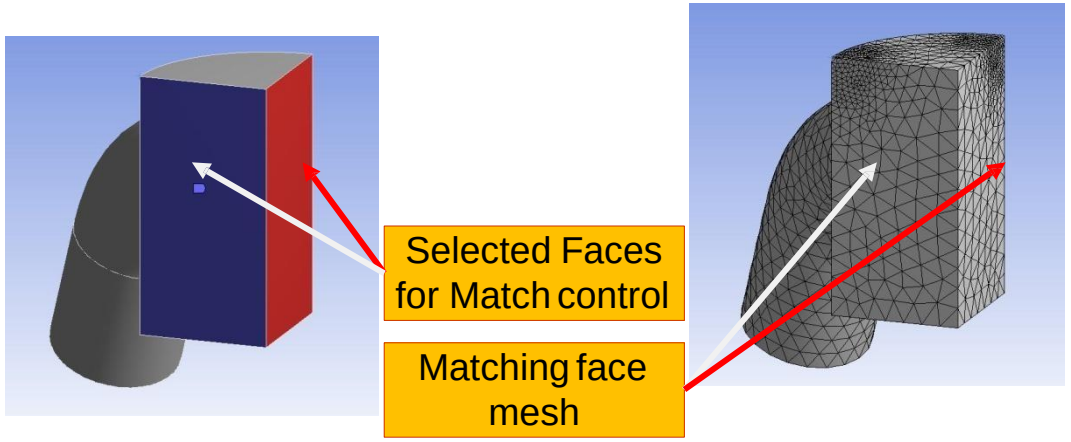
Match Control: Cyclic

- **Define Rotational periodic**



Model is symmetrical at 90° so slice the body along dotted lines in DesignModeler

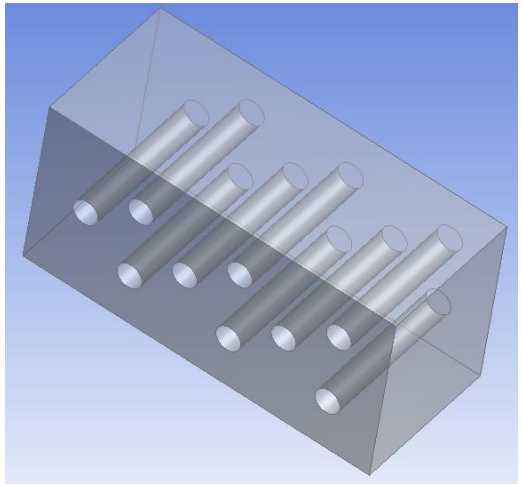




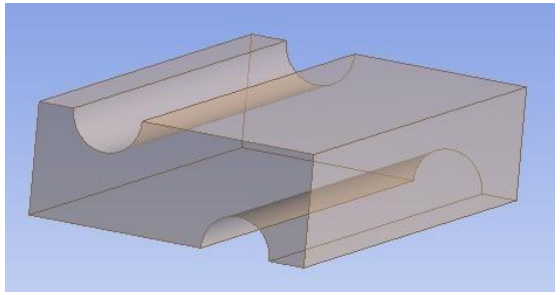
Match Control: Arbitrary

- **Two faces or edges to be matched, can be arbitrarily located**

Full Model : Tube Banks

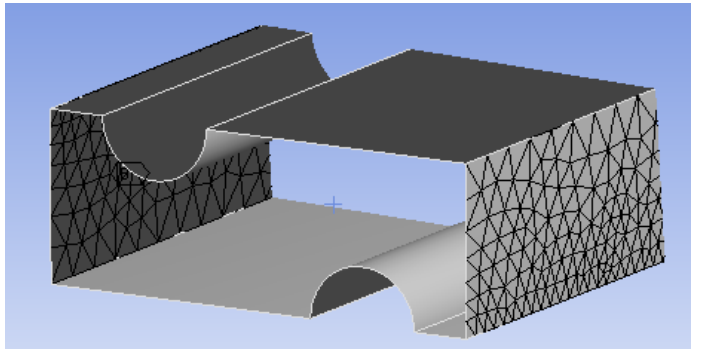


Symmetric + Periodic Model

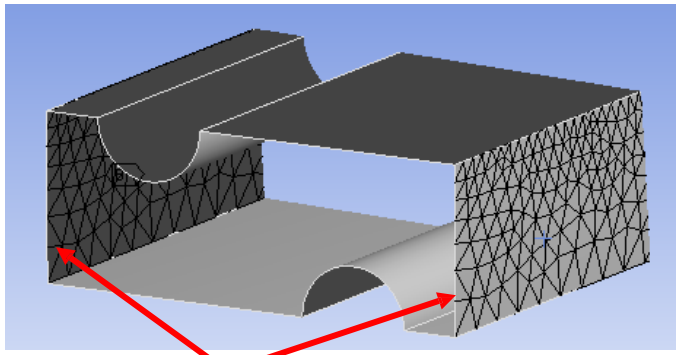


Model extracted through 'Slice' operation in DM

Face Mesh before 'Match Control'

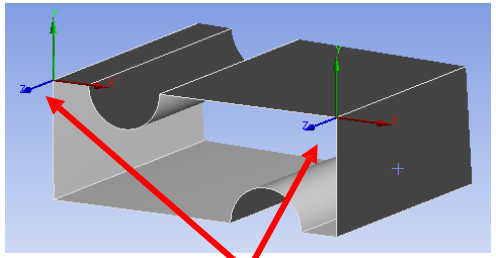


Face Mesh after 'Match Control'



Matching face mesh

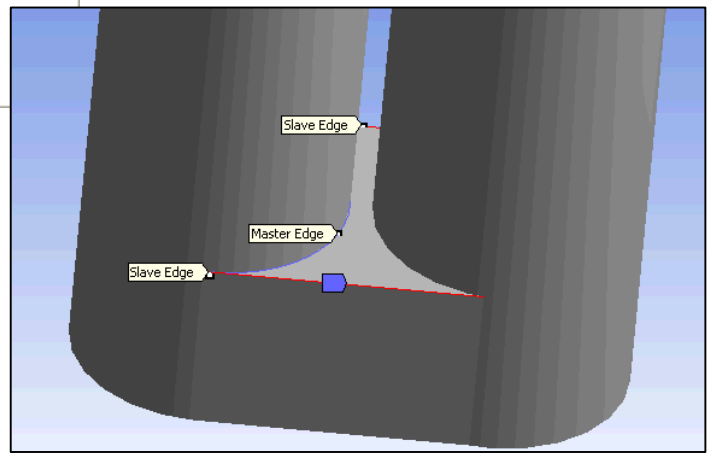
Details of "Match Control" - Match Control	
Scope	
High Geometry Selection	1 Face
Low Geometry Selection	1 Face
Definition	
Suppressed	No
Transformation	Arbitrary
High Coordinate System	Global Coordinate System
Low Coordinate System	Coordinate System
Control Messages	No

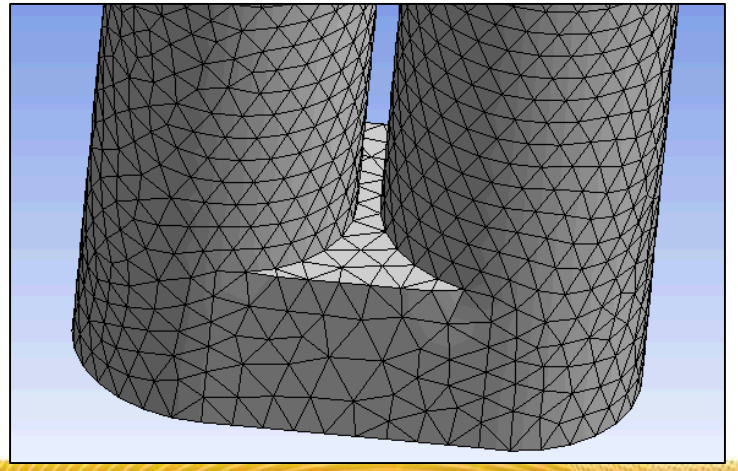


Coordinate systems need to be suitably defined at the faces to be matched

Pinch

- To improve quality Pinch control removes small features (edges or narrow regions) at the mesh level
- The Pinch feature is supported for the following mesh methods:
  - Patch Conforming Tetrahedrons
  - Thin Solid Sweeps
  - Hex Dominant meshing
  - Quad Dominant Surface Meshing
  - Triangles Surface meshing
- Not supported for CutCell meshing
- More details in lecture 5 “Mesh Quality”

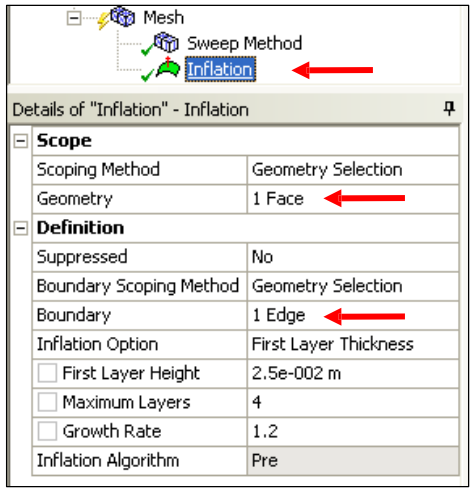




Inflation

Used to generate prism layers (as explained in Global settings chapter)

Inflation layer can be applied to faces or bodies using respectively edges or faces as the boundary



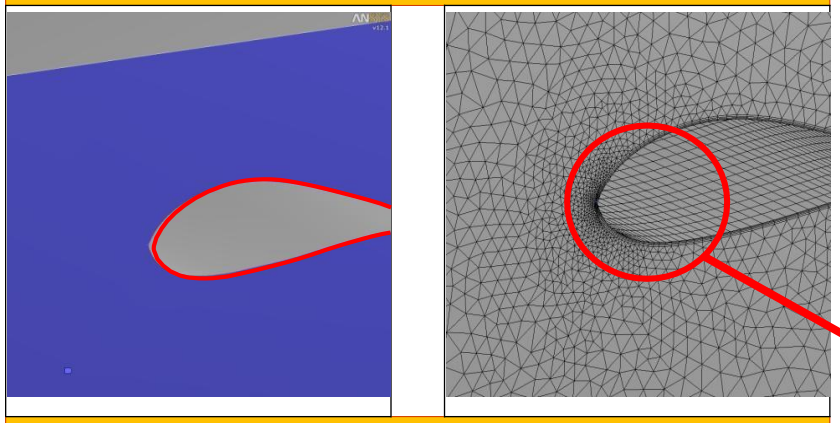
Details of "Inflation" - Inflation

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Suppressed	No
Boundary Scoping Method	Geometry Selection
Boundary	1 Edge
Inflation Option	First Layer Thickness
First Layer Height	2.5e-002 m
Maximum Layers	4
Growth Rate	1.2
Inflation Algorithm	Pre

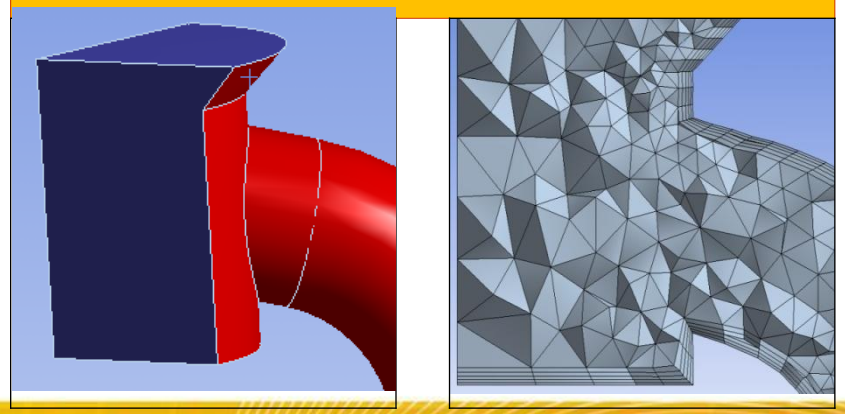
Details of "Inflation" - Inflation

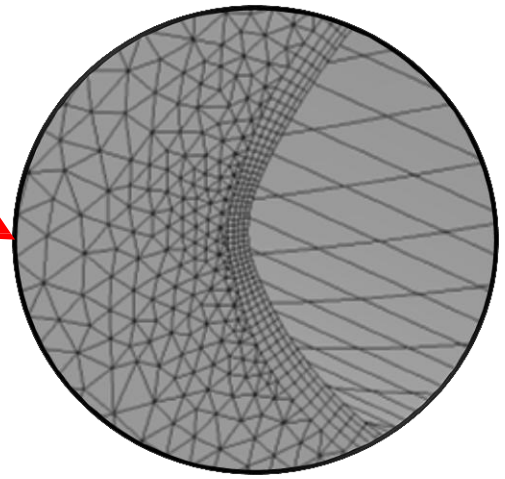
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Boundary Scoping Method	Geometry Selection
Boundary	9 Faces
Inflation Option	First Layer Thickness
First Layer Height	2.5e-002 m
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre

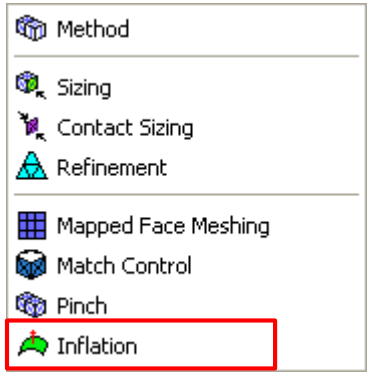
Inflation layer grown on edge boundary (red)



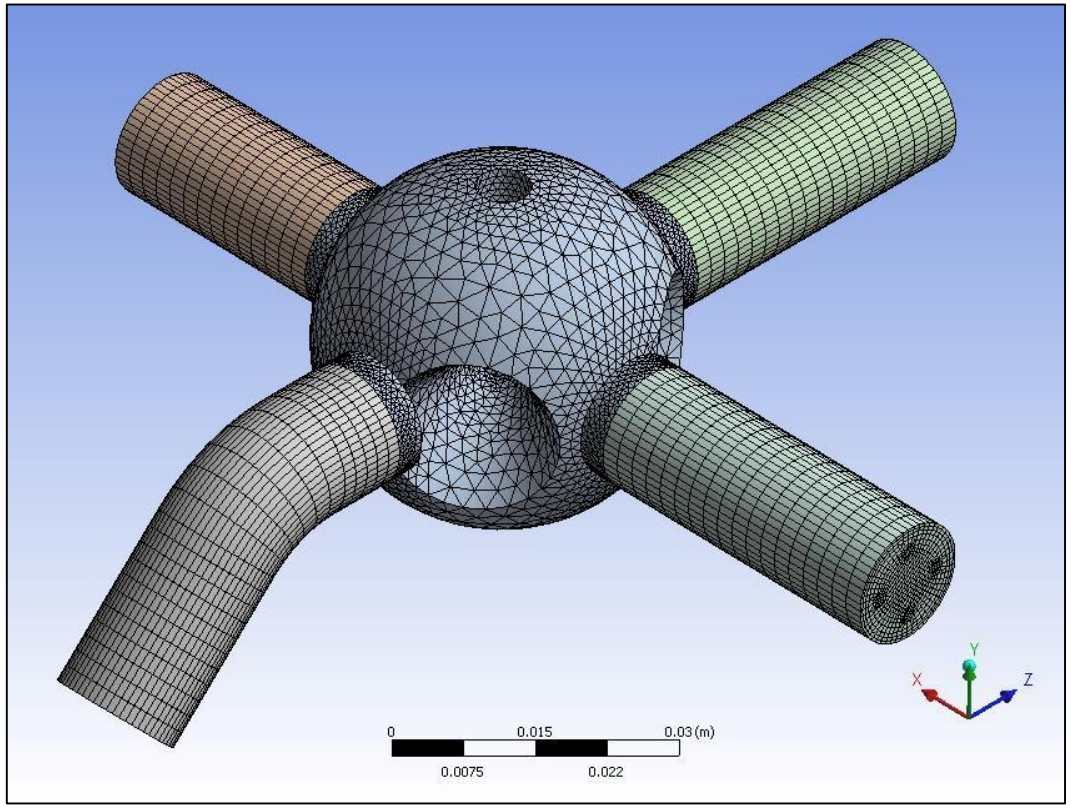
Inflation layer grown on face boundary (red)







Workshop 4 – Local Mesh Controls



Appendix

Contents

- Edge, Face & Body Sizing Options
- Sizing: Sphere of Influence
- Contact Sizing
- Refinement
- Inflation
- Object generator for copying mesh settings to like bodies

Edge, Face and Body Sizing Options

Curvature Normal Angle

Maximum allowable angle that one element edge is allowed to span

Available only when Use Advanced Size Function is set to either On: Proximity and Curvature or On: Curvature

You can specify a value from 0 to 180 degrees or accept the default. (A value of 0 resets the option to its default.)

The default is calculated based on the values of the Relevance and Span Angle Center options

Growth Rate

Represents the increase in element edge length with each succeeding layer of elements. (For example, a growth rate of 1.2 results in a 20% increase in element edge length with each succeeding layer of elements.)

Available when Use Advanced Size Function is on

Specify a value from 1 to 5 or accept the default

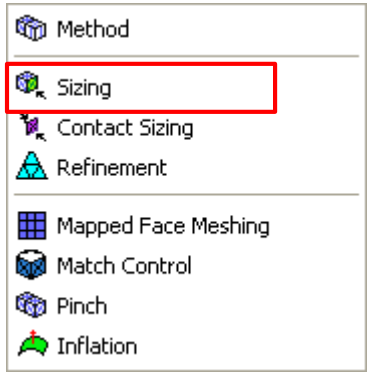
The default is calculated based on the values of the Relevance and Transition options

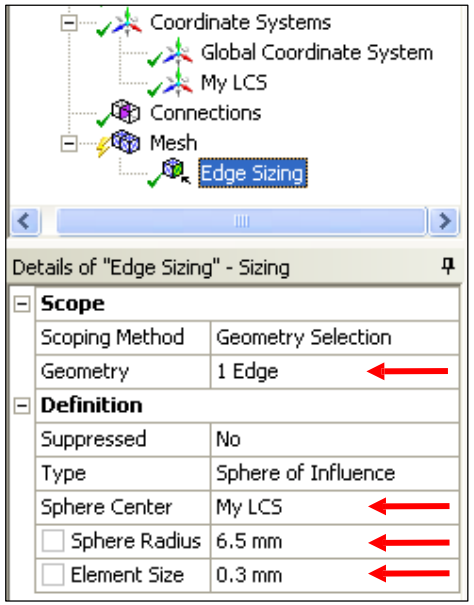
Must be always lower or equal the global growth rate

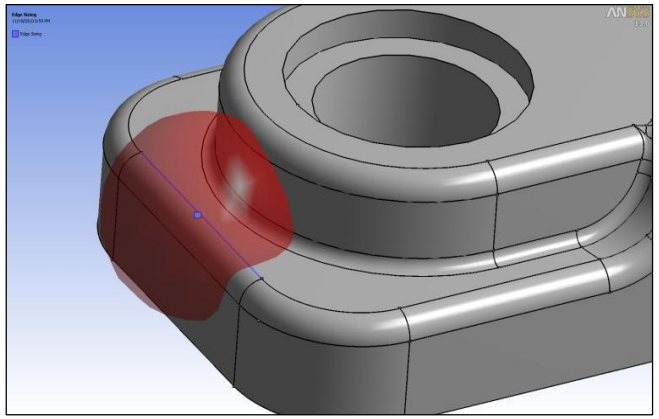
Sizing : Sphere of Influence

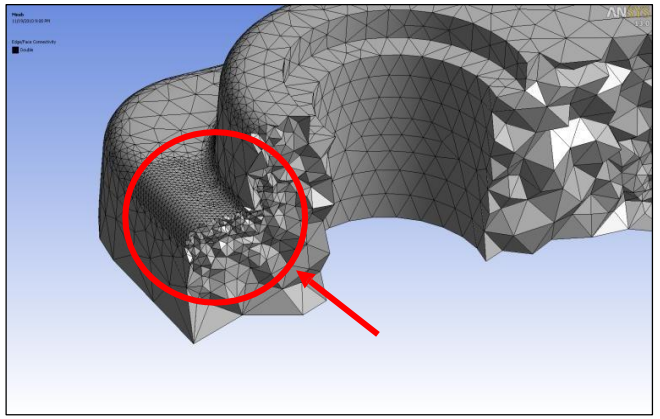
Sphere of Influence : on Edges

- Available only if Advanced Size Function is OFF
- Use coordinate system to define the center of the Sphere







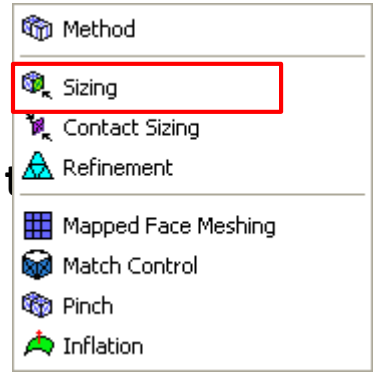


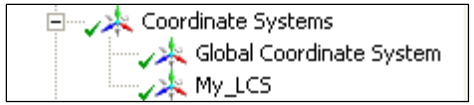
Mesh on the entity and other proximity entities that lies within the sphere of influence is affected

Sizing : Sphere of Influence

Sphere of Influence : on Faces

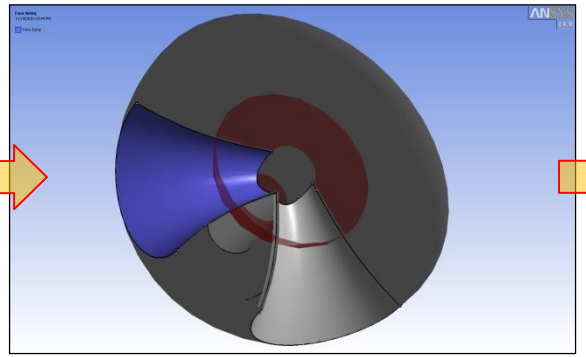
- Available only if Advanced Size Function is OFF
- Elements within the sphere will have given average elemen
- Use coordinate system to define the center of the sphere

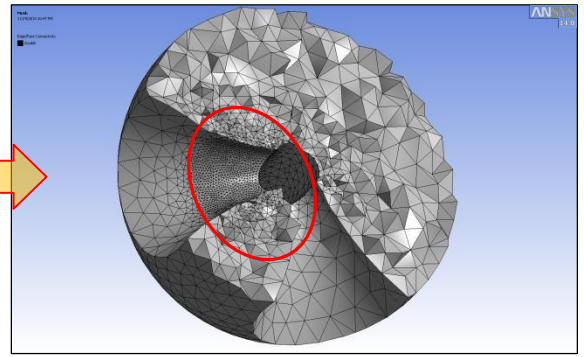




Details of "Face Sizing" - Sizing

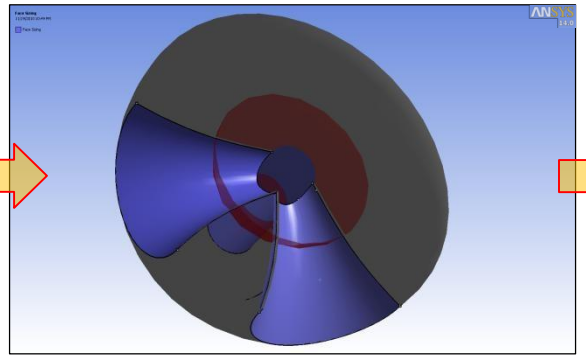
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Suppressed	No
Type	Sphere of Influence
Sphere Center	My_LCS
Sphere Radius	10. mm
Element Size	0.3 mm

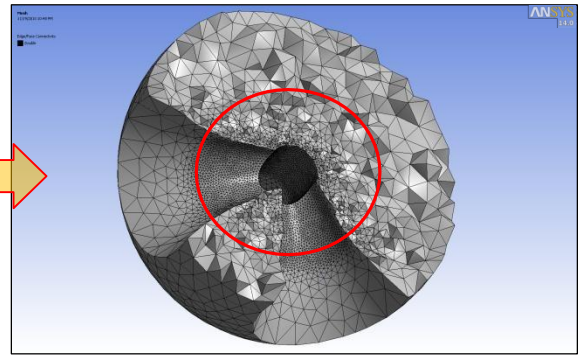




Details of "Face Sizing" - Sizing

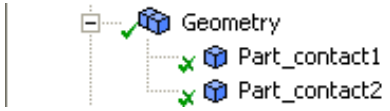
Scope	
Scoping Method	Geometry Selection
Geometry	3 Faces
Definition	
Suppressed	No
Type	Sphere of Influence
Sphere Center	My_LCS
Sphere Radius	10. mm
Element Size	0.3 mm

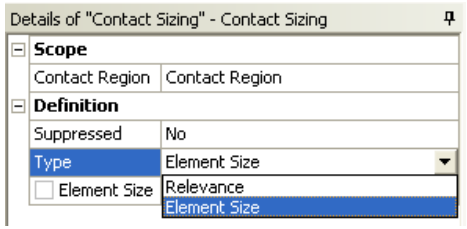


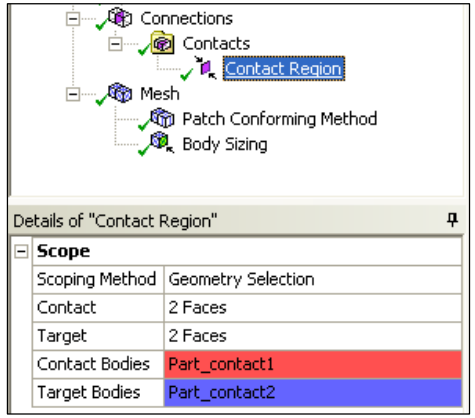


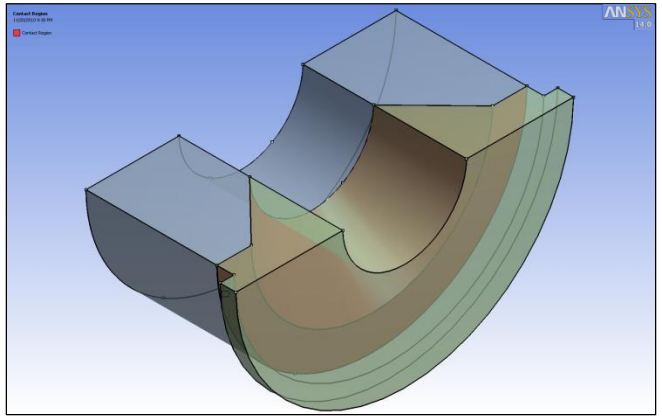
Contact Sizing

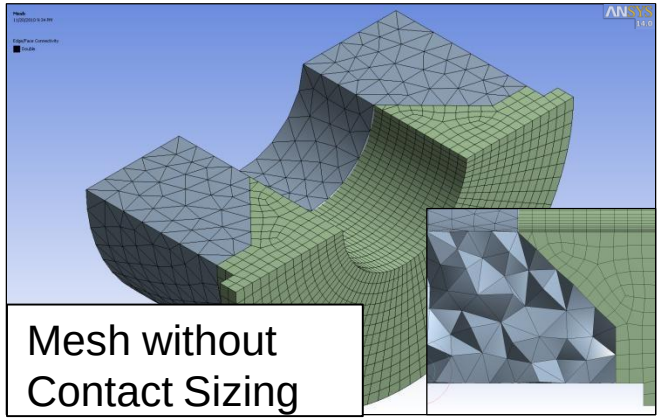
- Generates similar-sized elements on contact faces between parts
  - Two options
    - Element Size. The size of the elements on contact faces respects the value of Element Size specified
    - Relevance. The size of the elements on contact faces are determined internally by spheres of influence with automatic determination of radius and size depending on the value of specified Relevance
  - Not available for CutCell Meshing





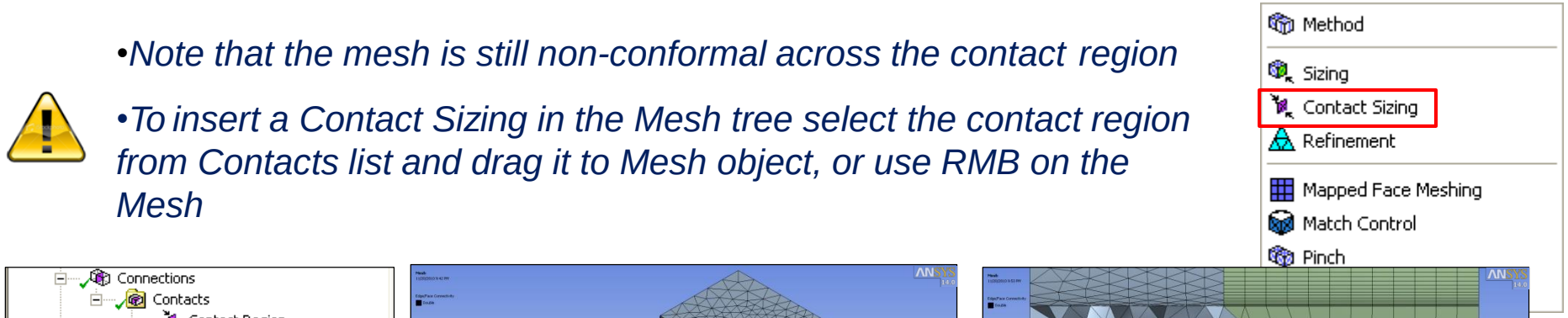


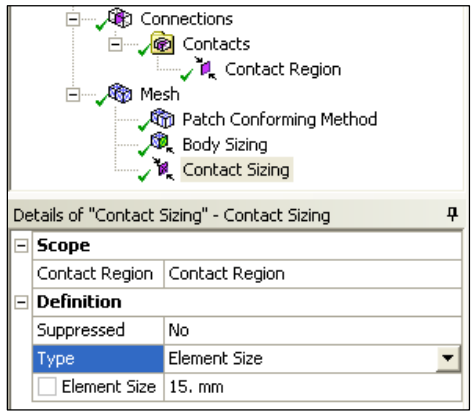


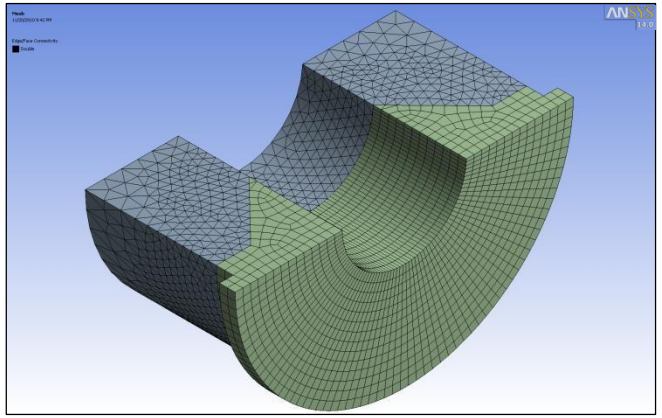


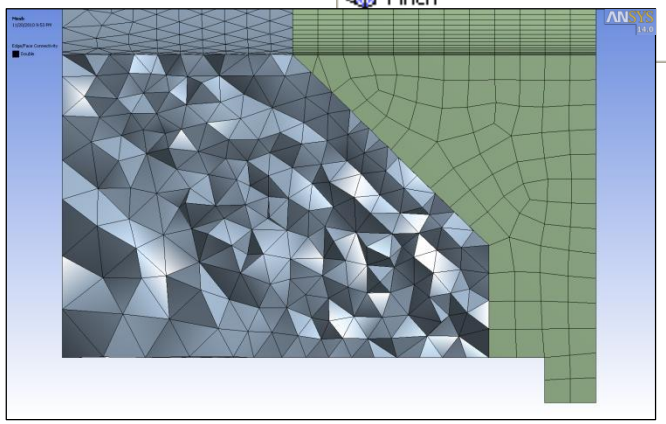
Contact Sizing

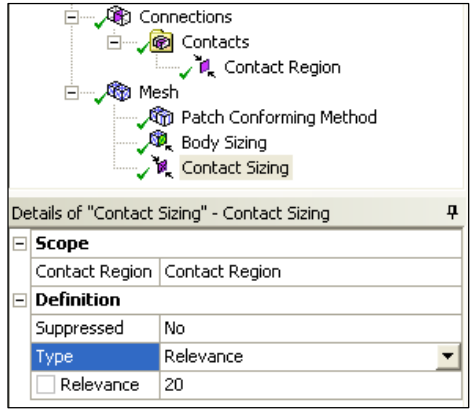
- *Note that the mesh is still non-conformal across the contact region*
- *To insert a Contact Sizing in the Mesh tree select the contact region from Contacts list and drag it to Mesh object, or use RMB on the Mesh*

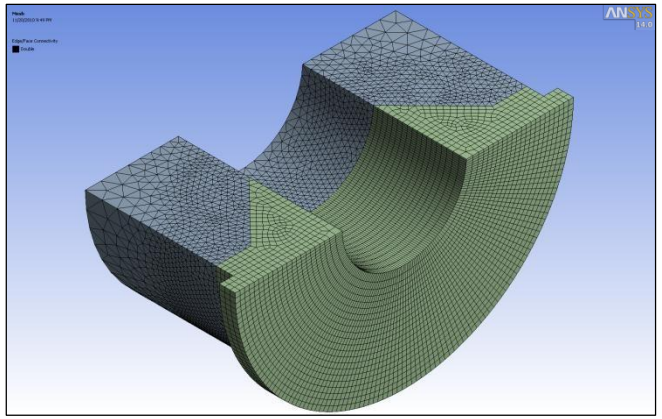


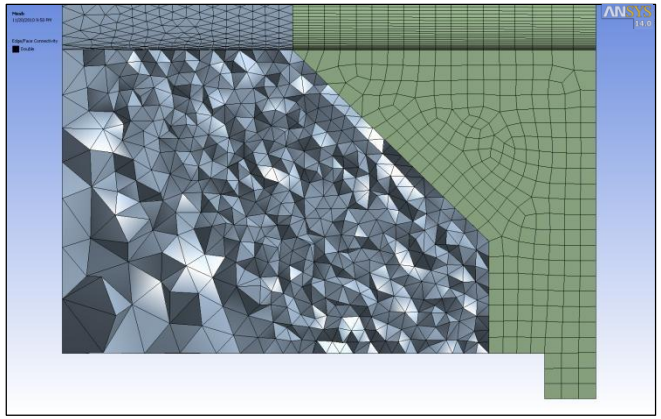








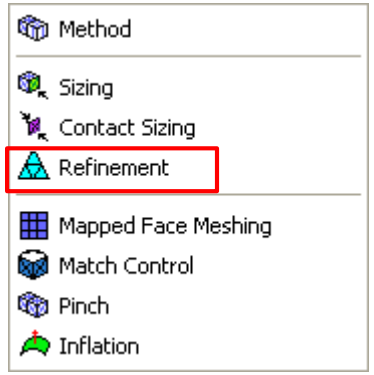




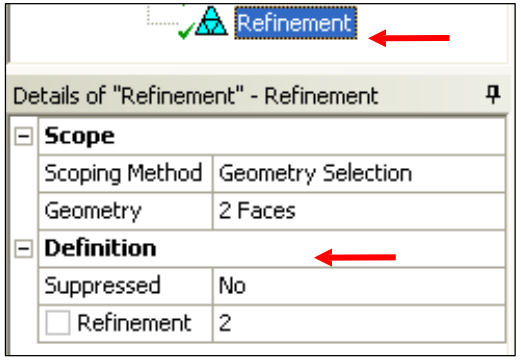
Refinement

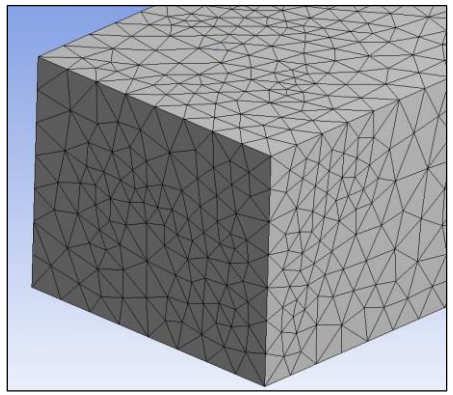
- Valid for only for faces or edges
  - Not available for Patch Independent Tetrahedrons, CutCell, Uniform Uniform Quad meshing methods
- Refinement is applied after the creation of mesh with rest of the settings
- Refinement level can vary from 1 (minimal) to 3 (maximum)
  - A refinement level of “1” breaks up the edges of the elements into half

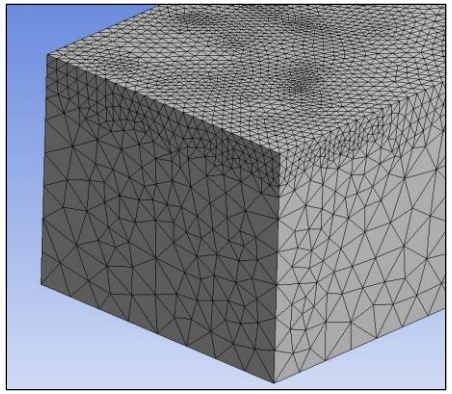
– The Refinement control may be automatically suppressed when use inflation depending on how the inflation/refinement is used. See the user’s Guide for details



Resultant mesh may be of poor quality







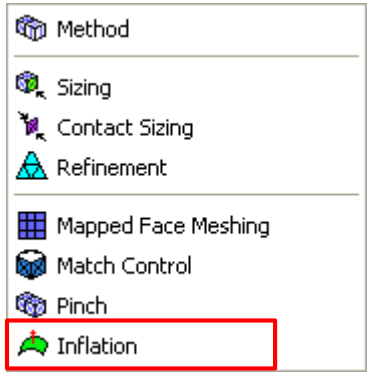
Only the selected face is affected and rest is almost unchanged

Inflation

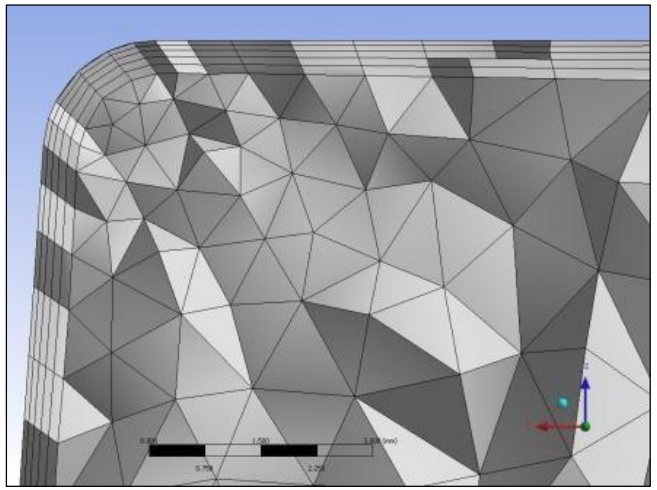
Details of "Inflation" - Inflation	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Boundary Scoping Method	Geometry Selection
Boundary	5 Faces
Inflation Option	Smooth Transition
Transition Ratio	Default (0.272)
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre

Transition Ratio: Attempts to match the size of last prism layer with that of next Tet cell

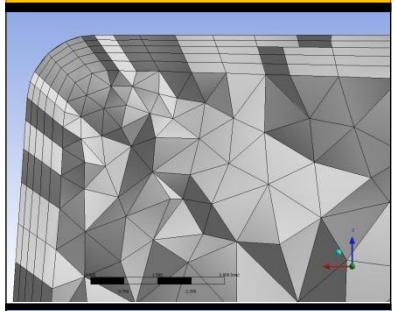
Growth Rate: It determines the relative thickness of adjacent inflation layers



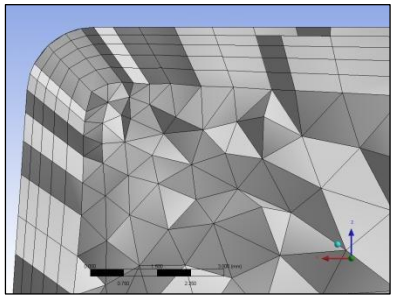
Defaults: Transition Ratio: 0.272
Growth Rate: 1.2

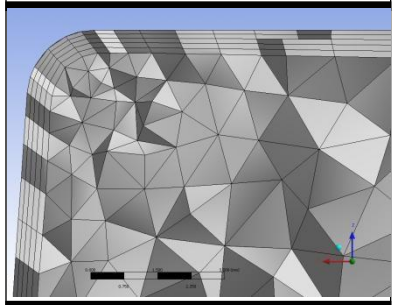


Transition Ratio: 0.5
Growth Rate: 1.2

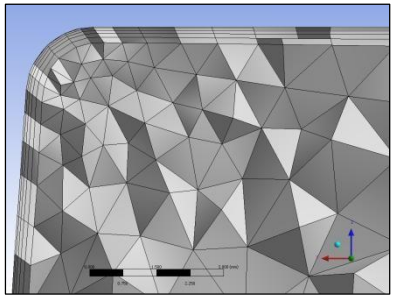


Transition Ratio: 0.8
Growth Rate: 1.2





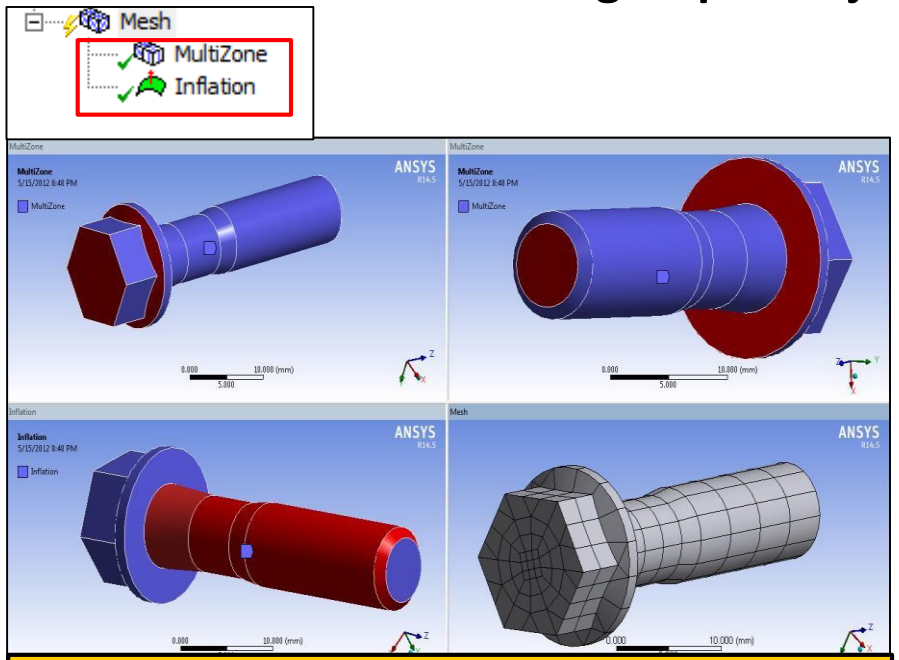
Transition Ratio: 0.27
Growth Rate: 1.1



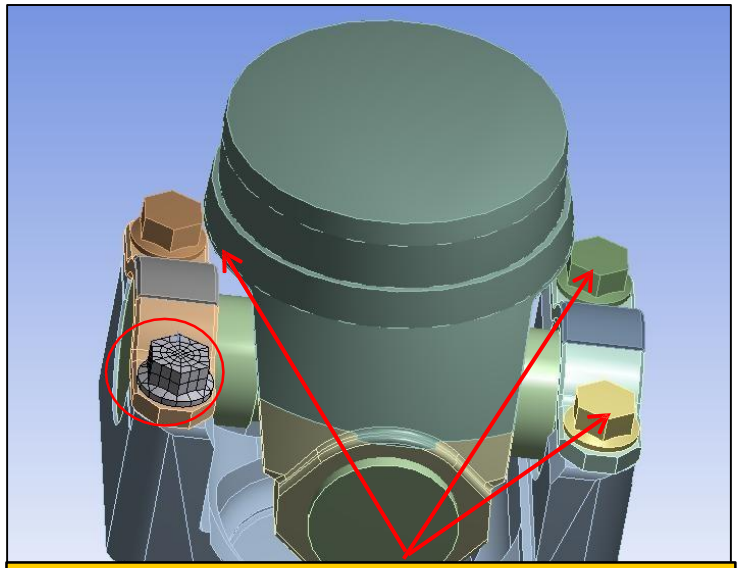
Transition Ratio: 0.27
Growth Rate: 1.4

Object Generator

- Object generator allows user to copy tree objects attached to an entity to several entities.
- Entities may or may not be similar. However, this works best for copying mesh settings on similar entities.
- With mesh controls, it provides an easy way to assign similar controls to a group of objects.



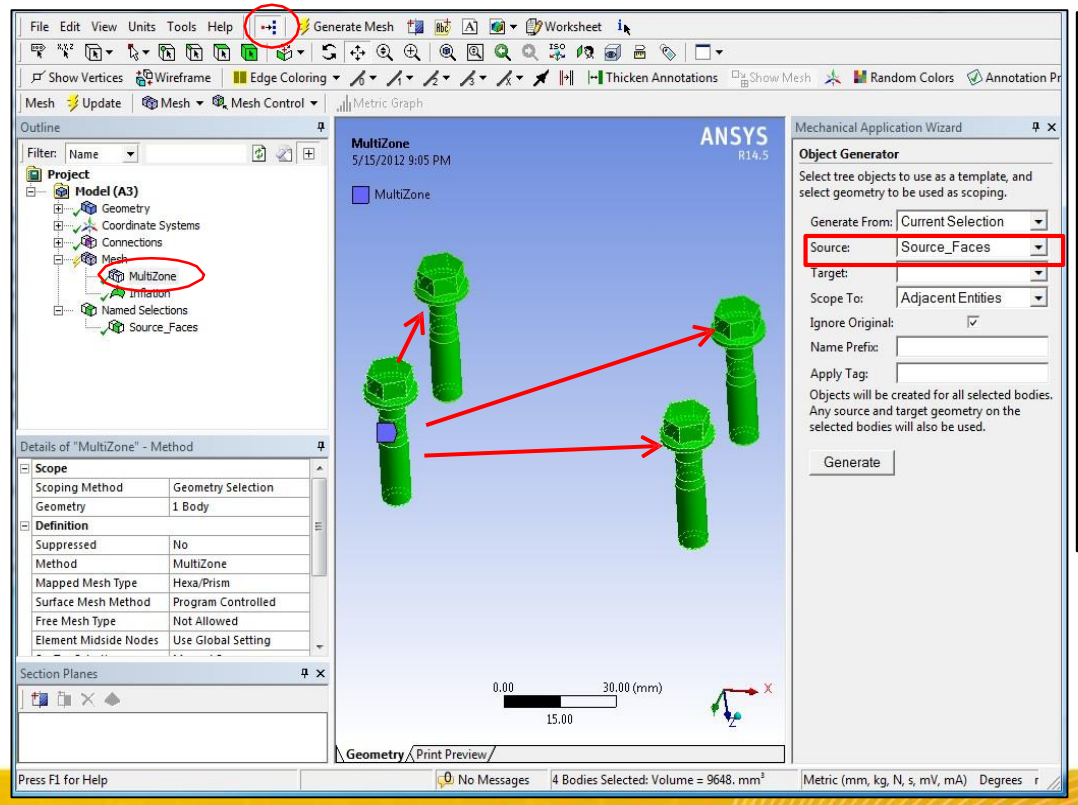
In this example, multiple mesh controls are used to define mesh for a bolt body



There are 4 similar bolt bodies on which these mesh settings can be copied easily using Object Generator

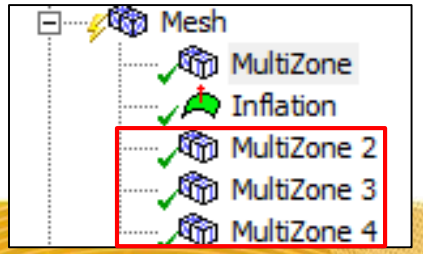
Object Generator

- **To use the Object Generator:**
  - **In the standard toolbar, click the View Object Generator button to view the Object Generator window.**
  - **In the Tree Outline, select the mesh control to be copied.**
  - **In the Geometry window, select the geometry to which the mesh control should be copied in the Object Generator window.**
  - **In the Object Generator window, select any required options and press Generate.**



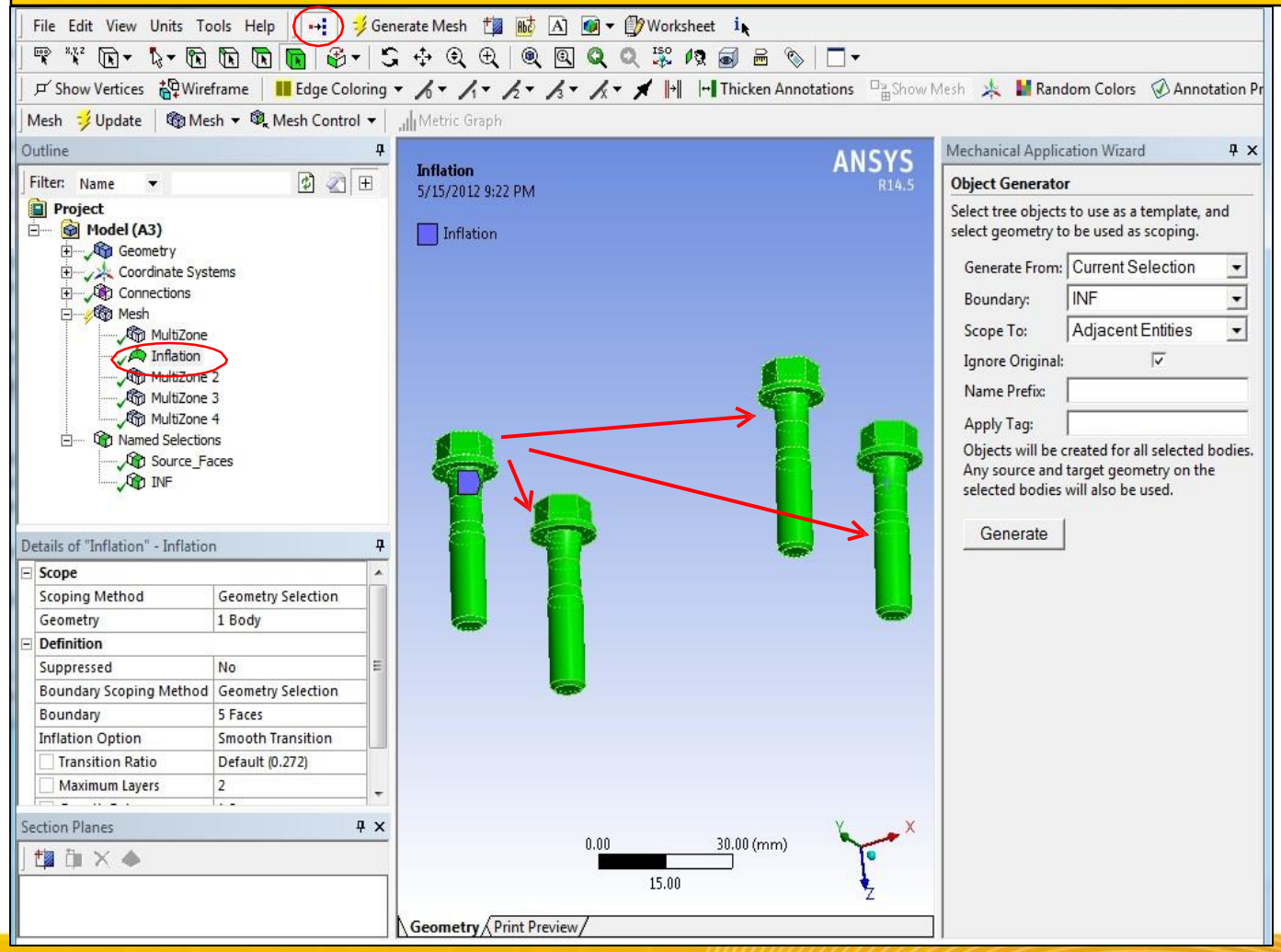
For mesh controls requiring multiple geometry, primary set of entities should be selected in "Generate From". The entities for rest of the inputs can be grouped in Named Selections.

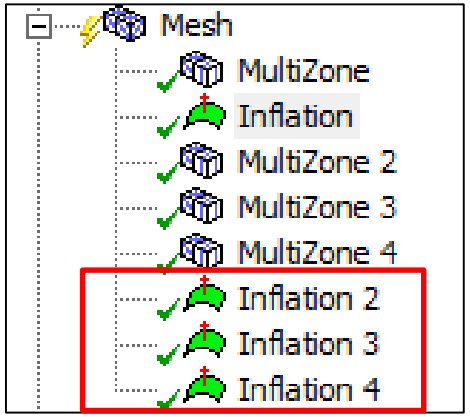
For example, in this case input for "Source" comes from set of source faces grouped in "Source_Faces" Named Selection. This can be created based on instance information if it exists, or similar sized faces, etc. See slides on Named Selection Worksheet. Similarly, Named Selection can be provided for "Target".



Object Generator

For copying inflation settings, two sets of entities will be required, first one for "Geometry" on which inflation needs to be applied and second one for "Boundary". Here, set of faces for "Boundary" is grouped in "INF" Named Selection.





Introduction to ANSYS Meshing

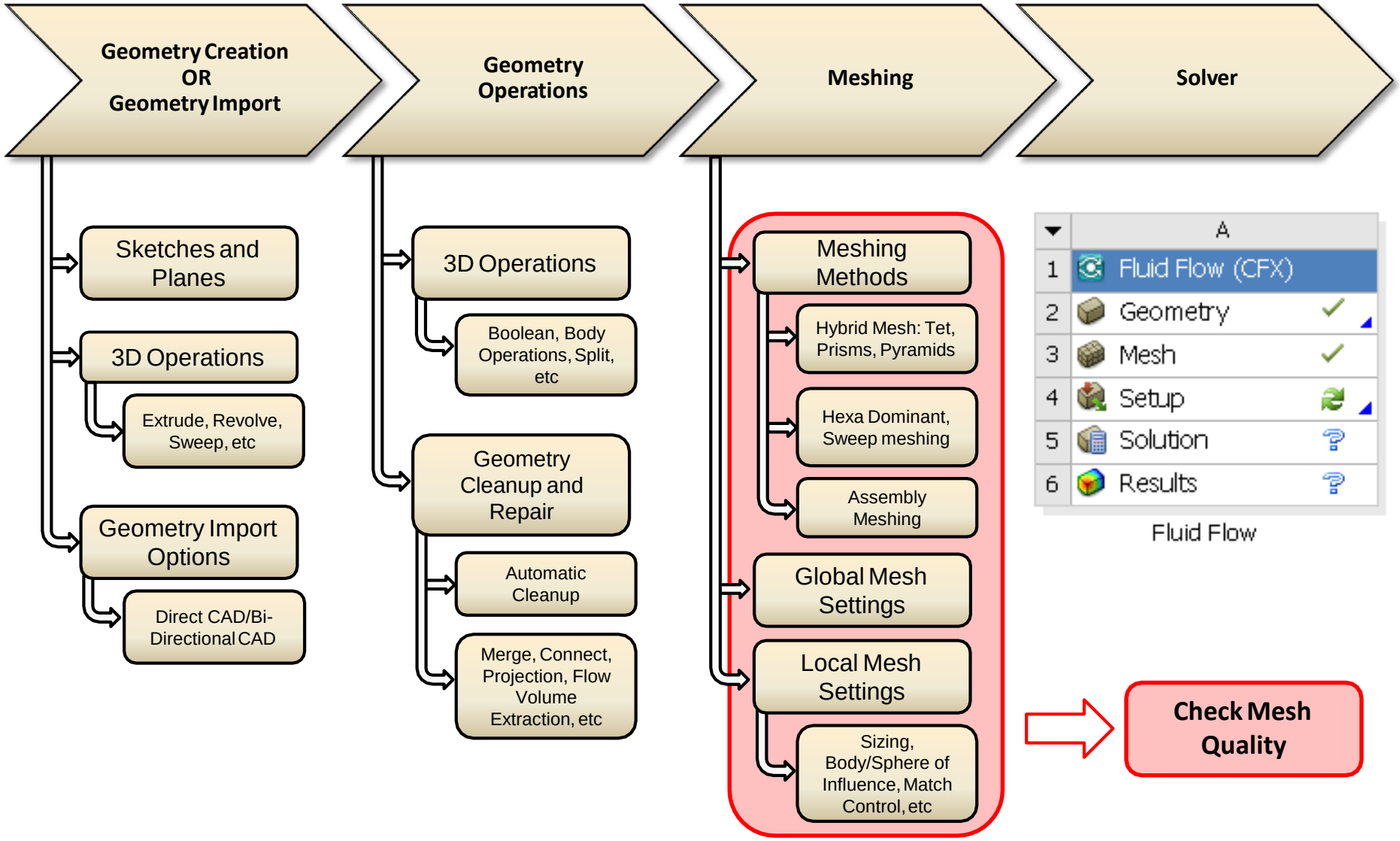
Module 5: Mesh Quality

Mesh Quality

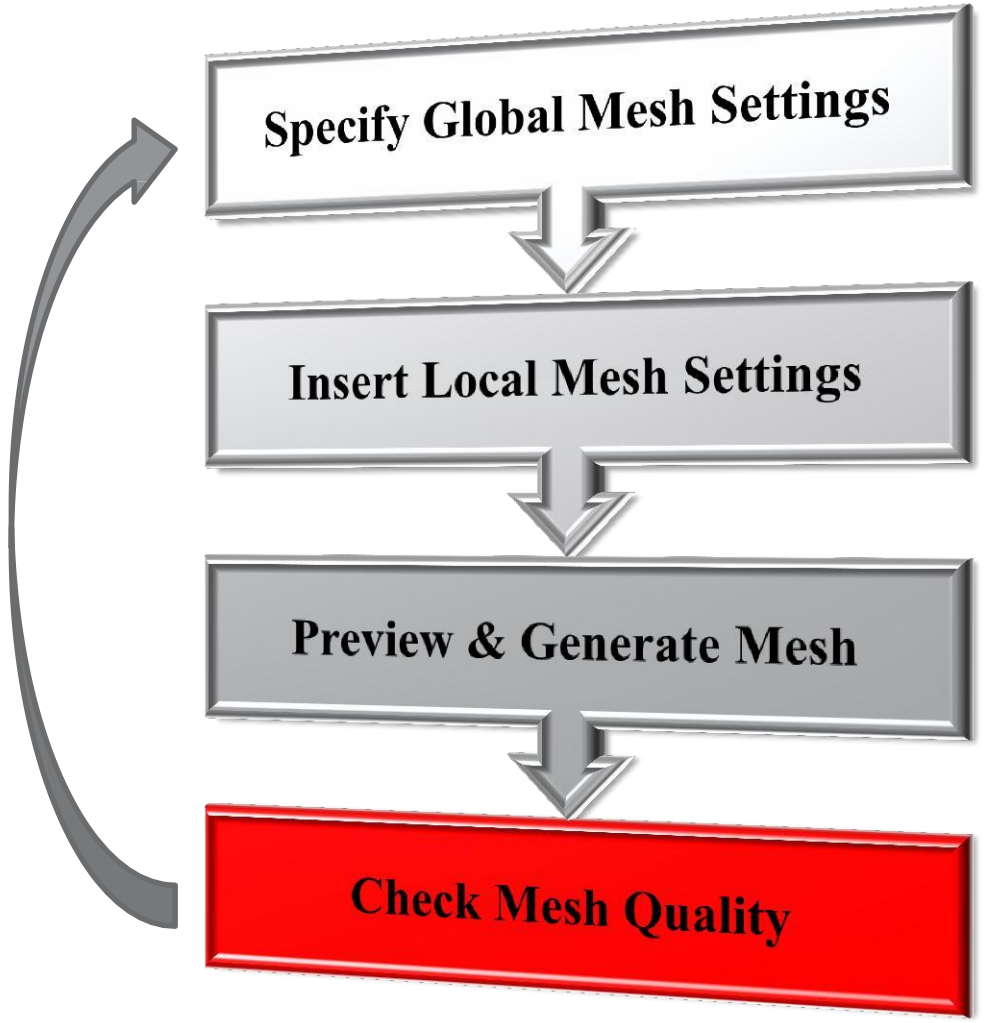
What you will learn from this presentation

- Impact of the Mesh Quality on the Solution
- Quality criteria
- Methods for checking the mesh quality
- Tools to improve quality in Meshing
- Pinch
- Virtual topology

Preprocessing Workflow



Meshing Process in ANSYS Meshing



Impact of the Mesh Quality

Good quality mesh means that…

- **Mesh quality criteria are within correct range**
  - **Orthogonal quality …**
- **Mesh is valid for studied physics**
  - **Boundary layer …**
- **Solution is grid independent**
- **Important geometric details are well captured**

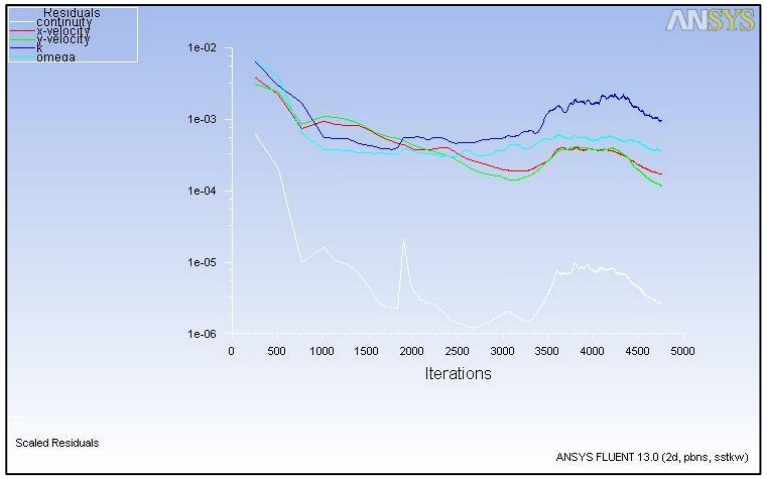


Table of Design Points

	A	B	C	D	E	F
1	Name	P1 - Sweep Method 3 Sweep Element Size	P2 - Sweep Method 2 Sweep Element Size	P3 - Sweep Method Sweep Element Size	P4 - Face Sizing Element Size	P6 - Dp
2		m	m	m	m	Pa
3	Current	0.04	0.04	0.04	0.02	747.88
4	DP 1	0.02	0.02	0.02	0.01	500.44
5	DP 2	0.01	0.01	0.01	0.005	361.4
6	DP 3	0.005	0.005	0.005	0.0025	307.6
7	DP 4	0.0025	0.0025	0.0025	0.00125	299.86
*						

Bad quality mesh can cause;

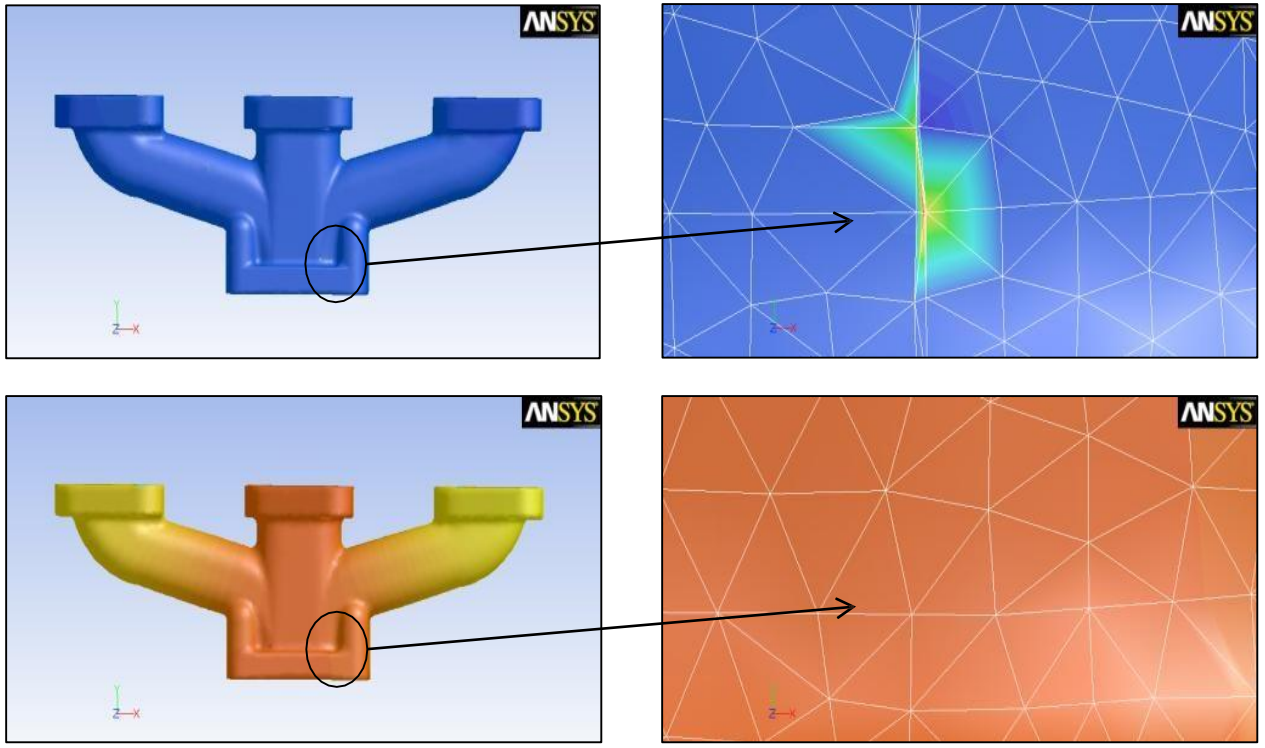
- **Convergence difficulties**
- **Bad physic description**
- **Diffuse solution**

User must…

- **Check quality criteria and improve grid if needed**
- **Think about model and solver settings before generating the grid**
- **Perform mesh parametric study, mesh adaption …**

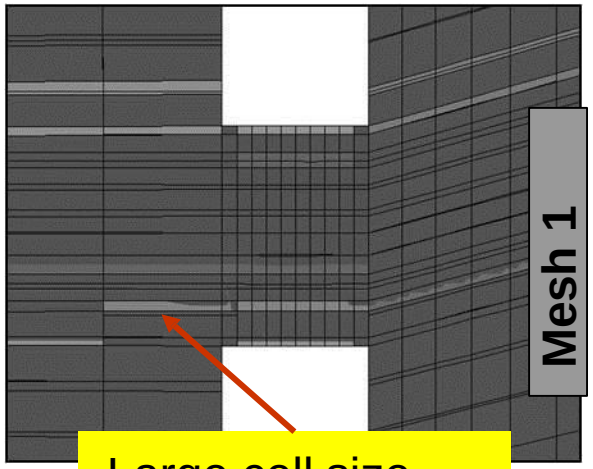
Impact of the Mesh Quality on the Solution

- Example showing difference between a mesh with cells failing the quality criteria and a good mesh
- Unphysical values in vicinity of poor quality cells

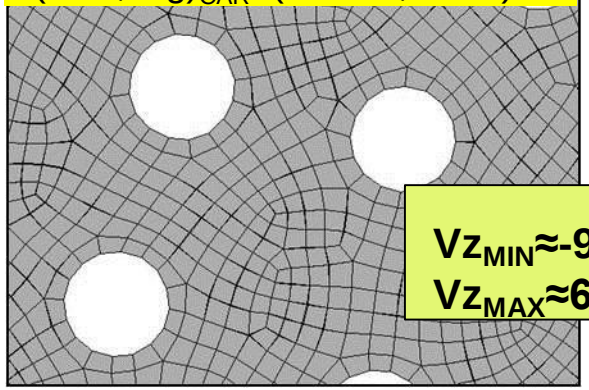


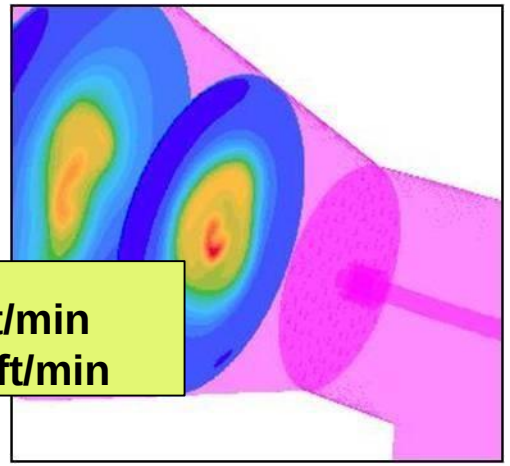
Impact of the Mesh Quality on the Solution

- Diffusion example

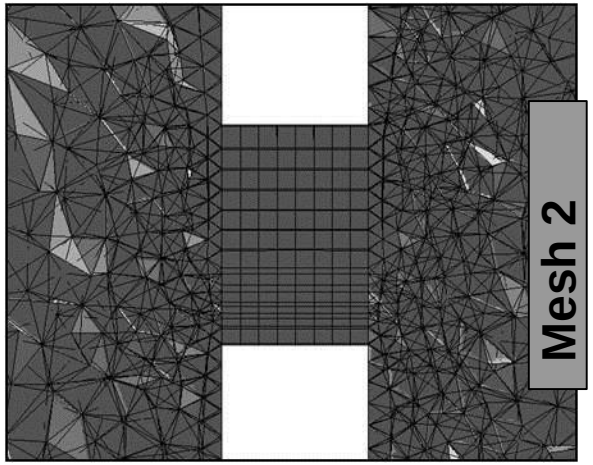


$(max,avg)_{CSKEW}=(0.912,0.291)$
$(max,avg)_{CAR}=(62.731,7.402)$

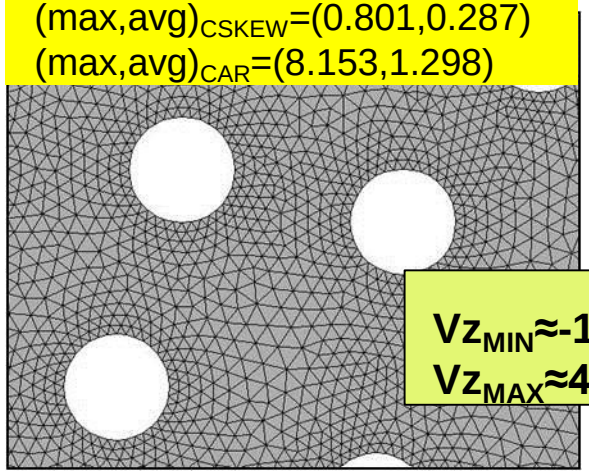


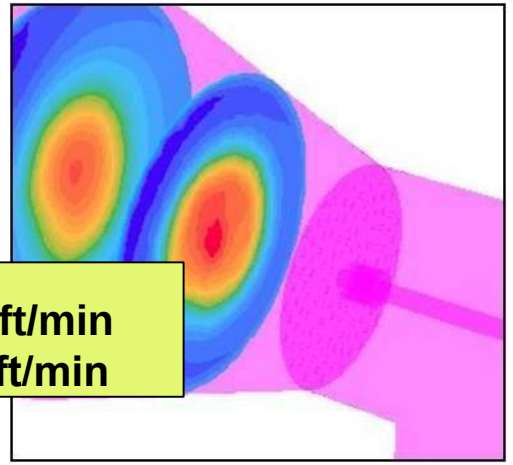


Vz_{MIN}≈-90ft/min
Vz_{MAX}≈600ft/min



$(max,avg)_{CSKEW}=(0.801,0.287)$
$(max,avg)_{CAR}=(8.153,1.298)$





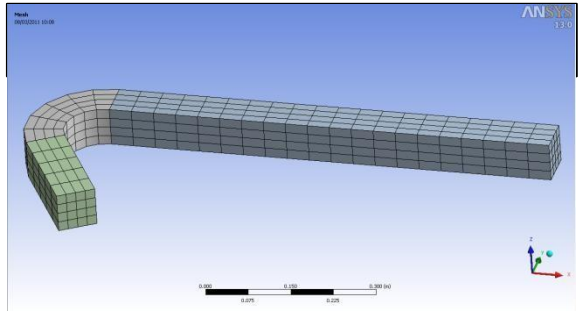
Vz_{MIN}≈-100ft/min
Vz_{MAX}≈400ft/min

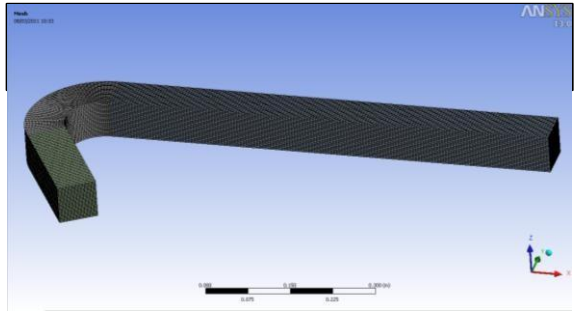
ANSYS

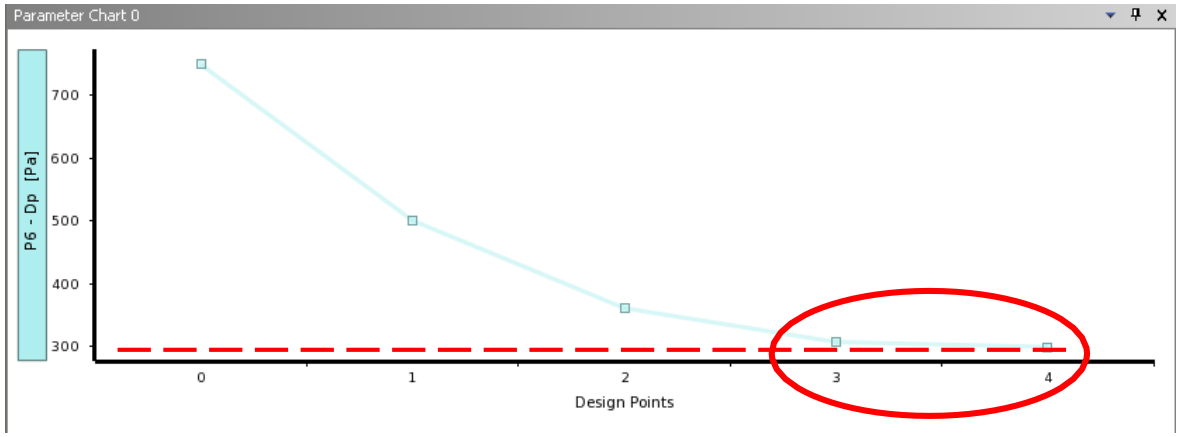
Grid Dependency

- Solution run with multiple meshes
- Note : For all runs the computed Y+ is valid for wall function (first cell not in laminar zone)

	DP 0	DP 1	DP 2	DP 3	DP 4
Nb Cells	500	3 000	24 000	190 000	1.5 M x8

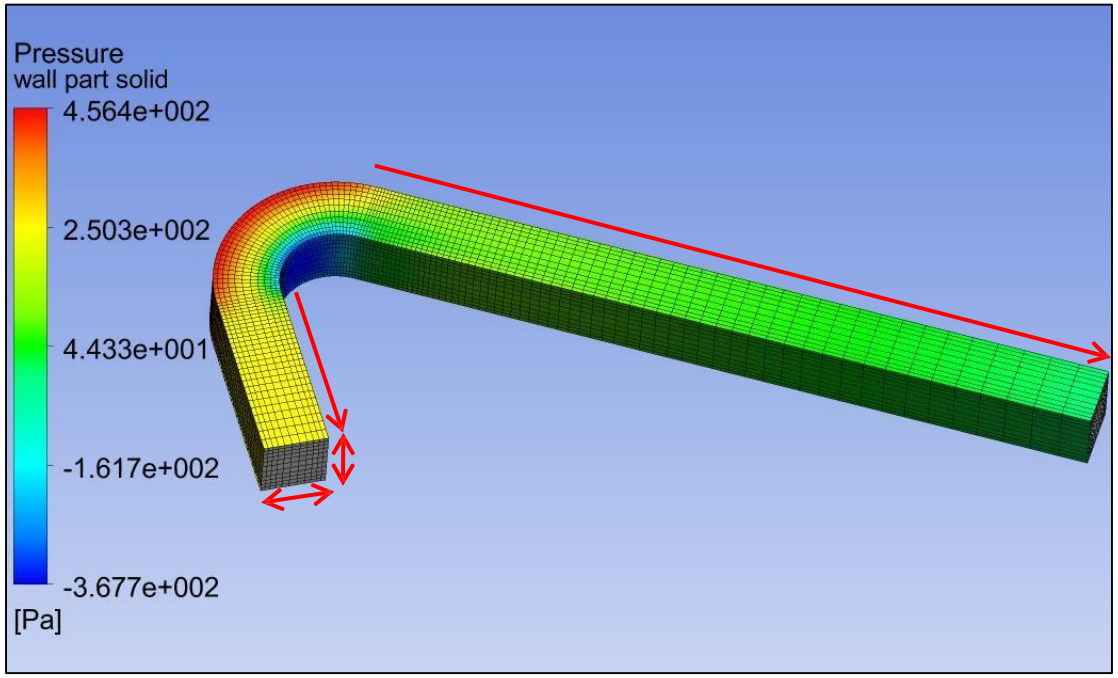






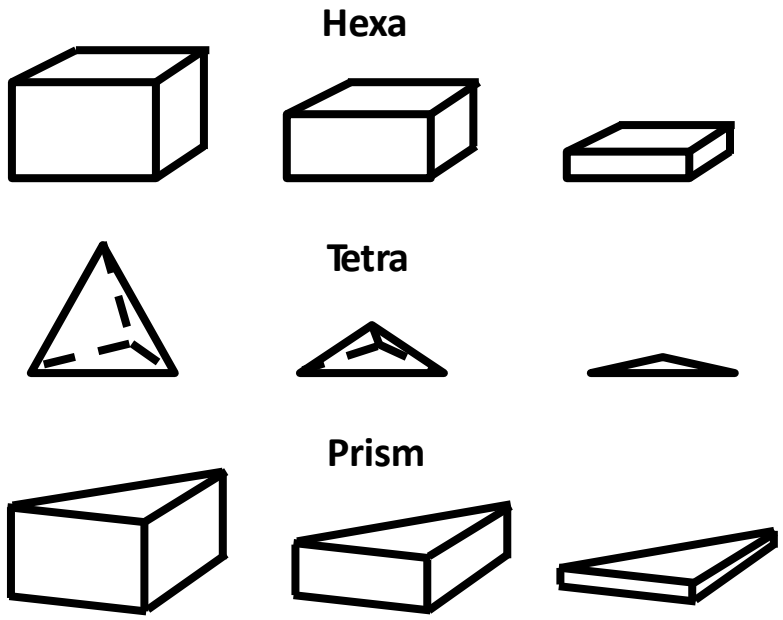
Grid Dependency

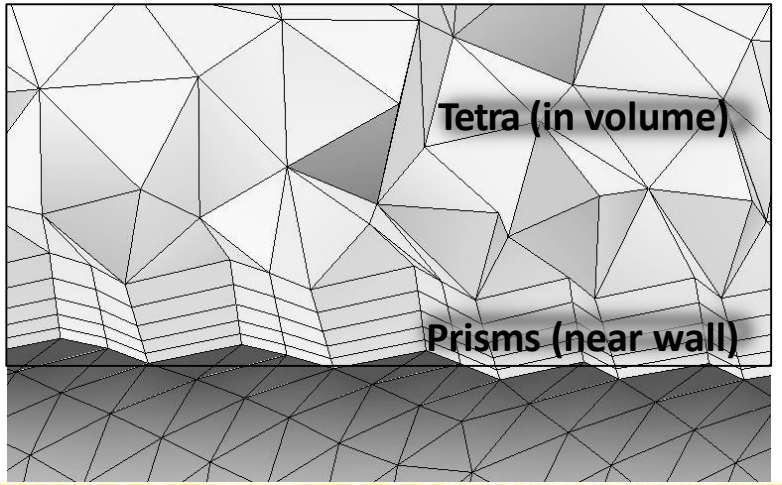
- Hexa cells can be stretched in stream direction to reduce number of cells
- Bias defined on inlet and outlet walls
- Bias defined on inlet edges
  - 16 000 cells (~DP2)
  - Delta P = 310 Pa (~DP3)



Hexa vs. Tetra

- **Hexa: Concentration in one direction**
  - Angles unchanged
- **Tetra: Concentration in one direction**
  - Angles change
- **Prism: Concentration in one direction**
  - Angles unchanged
- **Solution for boundary layer resolution**
  - Hybrid prism/tetra meshes
  - Prism in near-wall region, tetra in volume
  - Automated
  - Reduced CPU-time for good boundary layer resolution





Mesh Statistics and Mesh Metrics

Displays mesh information for Nodes and Elements

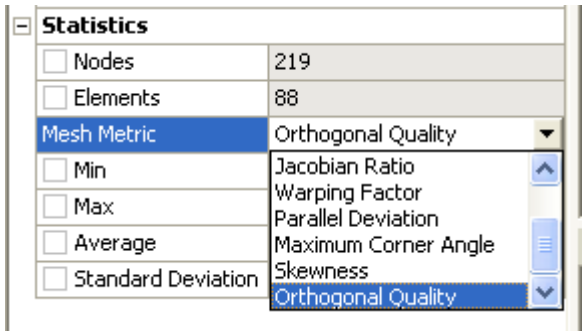
List of quality criteria for the Mesh Metric

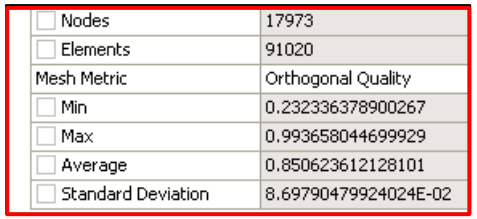
- **Select the required criteria to get details for quality**
- **It shows minimum, maximum, average and standard deviation**

Different physics and different solvers have different requirements for mesh quality

Mesh metrics available in ANSYS Meshing include:

- **Element Quality**
- **Aspect Ratio**
- **Jacobean Ration**
- **Warping Factor**
- **Parallel Deviation**
- **Maximum Corner Angle**
- **Skewness**
- **Orthogonal Quality**





For Multi-Body Parts, go to corresponding body in Tree Outline to get its separate mesh statistics per part/body

Mesh Quality Metrics

Orthogonal Quality (OQ)

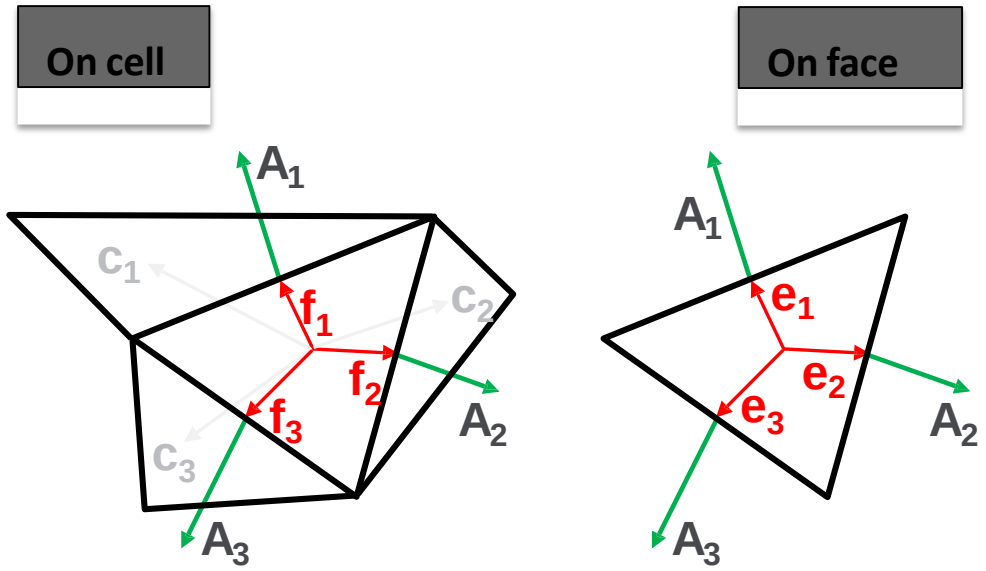
Derived directly from

Fluent solver discretization

- ***For a cell*** **it is the minimum of:**

$$\frac{A_i \cdot f_i}{|\vec{A_i}||\vec{f}_i|} \qquad \frac{A_i \cdot c_i}{|\vec{A_i}||\vec{c_i}|}$$

computed for each face *i*



For the face **it is computed as the minimum of** $\frac{A_i \cdot e_i}{|\vec{A_i}||\vec{e_i}|}$ **computed for each edge *I***

Where A_i is the face normal vector and f_i is a vector from the centroid of the cell to the centroid of that face, and c_i is a vector from the centroid of the cell to the centroid of the adjacent cell, where e_i is the vector from the centroid of the face to the centroid of the edge

At boundaries and internal walls

c_i is ignored in the computations of OQ

Mesh Quality Metrics

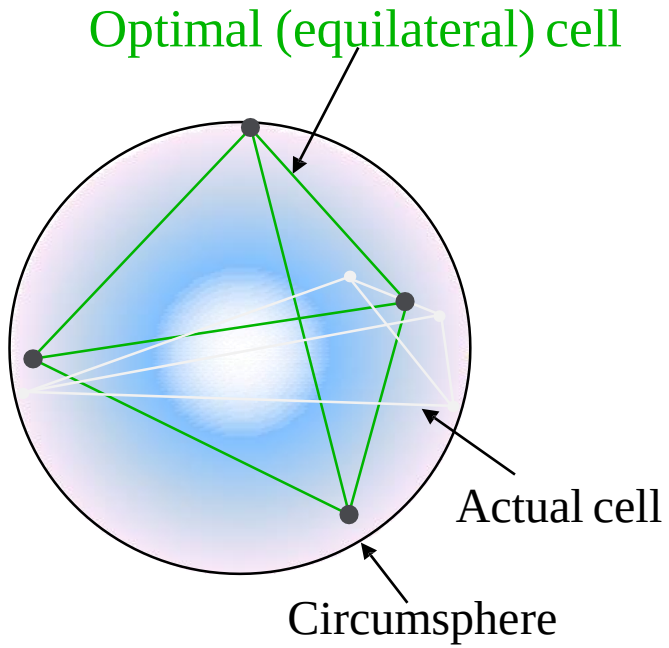
Skewness

Two methods for determining skewness:

1. Equilateral Volume deviation:

$$\text{Skewness} = \frac{\text{optimal cell size} - \text{cell size}}{\text{optimal cell size}}$$

Applies only for triangles and tetrahedrons



2. Normalized Angle deviation:

$$\text{Skewness} = \max\left[\frac{\theta_{max} - \theta_e}{180 - \theta_e}, \frac{\theta_e - \theta_{min}}{\theta_e}\right]$$

Where θ_e is the equiangular face/cell (60 for tets and tris, and 90 for quads and hexas)

- Applies to all cell and face shapes
- Used for hexa, prisms and pyramids

Mesh Quality

Mesh quality recommendations

Low Orthogonal Quality or high skewness values are not recommended

Generally try to keep minimum orthogonal quality > 0.1, or maximum skewness < 0.95. However these values may be different depending on the physics and the location of the cell

Fluent reports negative cell volumes **if the mesh contains degenerate cells**

Skewness mesh metrics spectrum

Excellent	Very good	Good	Acceptable	Bad	Unacceptable
0-0.25	0.25-0.50	0.50-0.80	0.80-0.94	0.95-0.97	0.98-1.00

Orthogonal Quality mesh metrics spectrum

Unacceptable	Bad	Acceptable	Good	Very good	Excellent
0-0.001	0.001-0.14	0.15-0.20	0.20-0.69	0.70-0.95	0.95-1.00

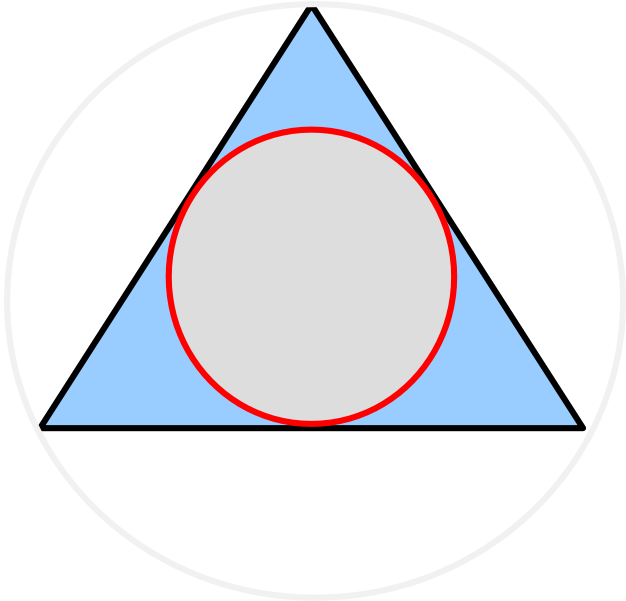
Aspect Ratio

2-D:

- Length / height ratio: $\delta x/\delta y$

3-D

- Area ratio
- Radius ratio of circumscribed / inscribed circle



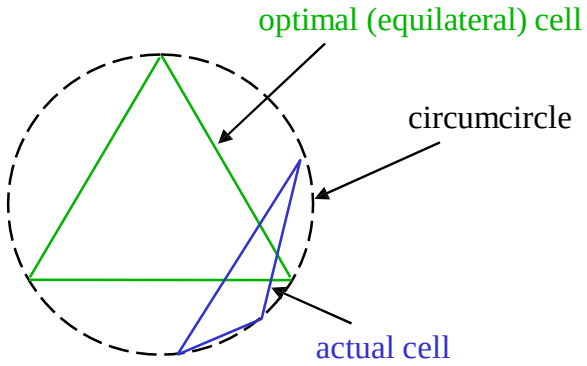
Limitation for some iterative solvers

- A < 10 … 100
- (CFX: < 1000)

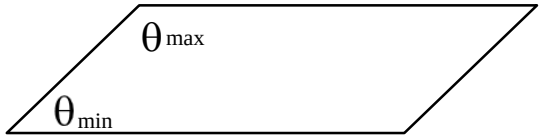
Large aspect ratio are accepted where there is no strong transverse gradient (boundary layer ...)

Mesh quality: skewness

- Two methods for determining skewness:
  1. Based on the equilateral volume:
     - Skewness = $\dfrac{\text{optimal cell size} - \text{cell size}}{\text{optimal cell size}}$
     - Applies only to triangles and tetrahedra.
     - Default method for tris and tets.



  2. Based on the deviation from a normalized equilateral angle:
     - Skewness (for a quad) = $\max\left[\dfrac{\theta_{\max}-90}{90}, \dfrac{90-\theta_{\min}}{90}\right]$
     - Applies to all cell and face shapes.
     - Always used for prisms and pyramids.



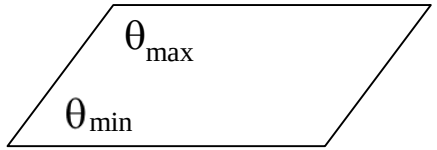
Equiangle skewness

- Common measure of quality is based on equiangle skew.
- Definition of equiangle skew:

$$\max\left[\frac{\theta_{\max}-\theta_e}{180-\theta_e}, \frac{\theta_e-\theta_{\min}}{\theta_e}\right]$$

where:

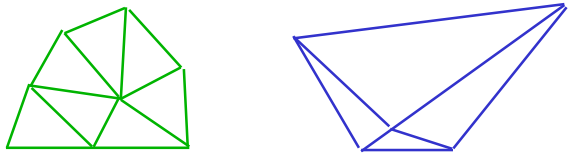
- θ_{max} = largest angle in face or cell.
- θ_{min} = smallest angle in face or cell.
- θ_e = angle for equiangular face or cell.
  - e.g., 60 for triangle, 90 for square.



- Range of skewness:

Mesh quality: smoothness and aspect ratio

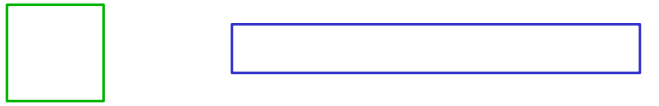
- Change in size should be gradual (smooth).



smooth change in cell size

large jump in cell size

- Aspect ratio is ratio of longest edge length to shortest edge length. Equal to 1 (ideal) for an equilateral triangle or a square.



aspect ratio = 1

high-aspect-ratio quad

aspect ratio = 1

high-aspect-ratio triangle

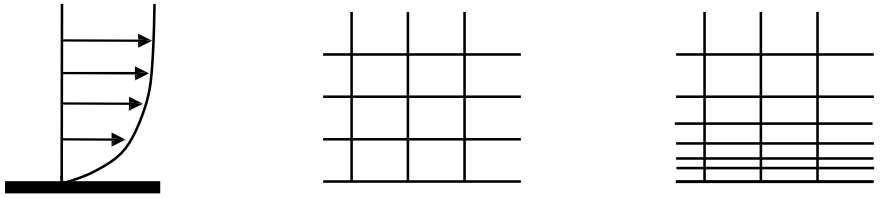
Striving for quality

- A poor quality grid will cause inaccurate solutions and/or slow convergence.
- Minimize equiangle skew:
  - Hex and quad cells: skewness should not exceed 0.85.
  - Tri's: skewness should not exceed 0.85.
  - Tets: skewness should not exceed 0.9.
- Minimize local variations in cell size:
  - E.g. adjacent cells should not have 'size ratio' greater than 20%.
- If such violations exist: delete mesh, perform necessary decomposition and/or pre-mesh edges and faces, and remesh.

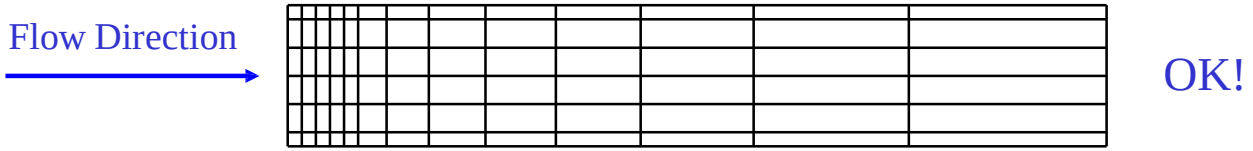
Value of Skewness	0-0.25	0.25-0.50	0.50-0.80	0.80-0.95	0.95-0.99	0.99-1.00
Cell Quality	excellent	good	acceptable	poor	sliver	degenerate

Grid design guidelines: resolution

- Pertinent flow features should be adequately resolved.

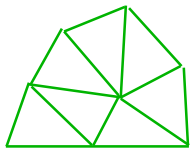


- Cell aspect ratio (width/height) should be near one where flow is multi-dimensional.
- Quad/hex cells can be stretched where flow is fully-developed and essentially one-dimensional.

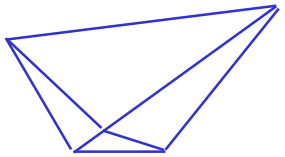


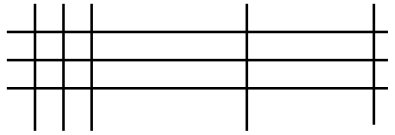
Grid design guidelines: smoothness

- Change in cell/element size should be gradual (smooth).



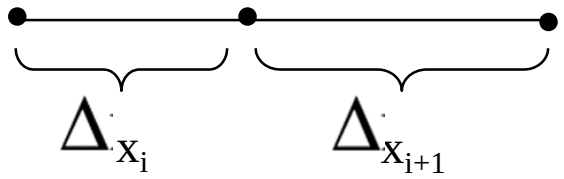
smooth change
in cell size





sudden change
in cell size — AVOID!

- Ideally, the maximum change in grid spacing should be <20%:



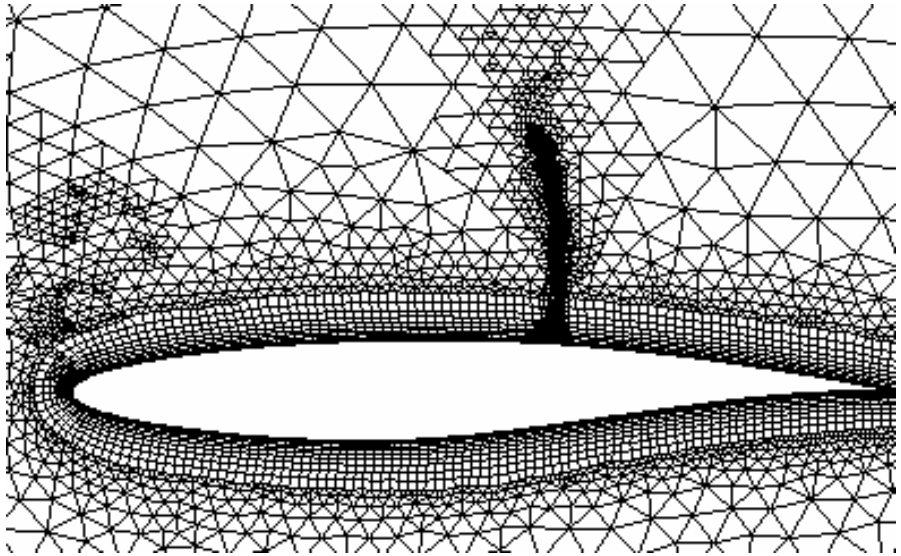
$$\frac{\Delta x_{i+1}}{\Delta x_i} \leq 1.2$$

Grid design guidelines: total cell count

- More cells *can* give higher accuracy. The downside is increased memory and CPU time.
- To keep cell count down:
  - Use a non-uniform grid to cluster cells only where they are needed.
  - Use solution adaption to further refine only selected areas.
- Cell counts of the order:
  - 1E4 are relatively small problems.
  - 1E5 are intermediate size problems.
  - 1E6 are large. Such problems can be efficiently run using multiple CPUs, but mesh generation and post-processing may become slow.
  - 1E7 are huge and should be avoided if possible. However, they are common in aerospace and automotive applications.

Solution adaption

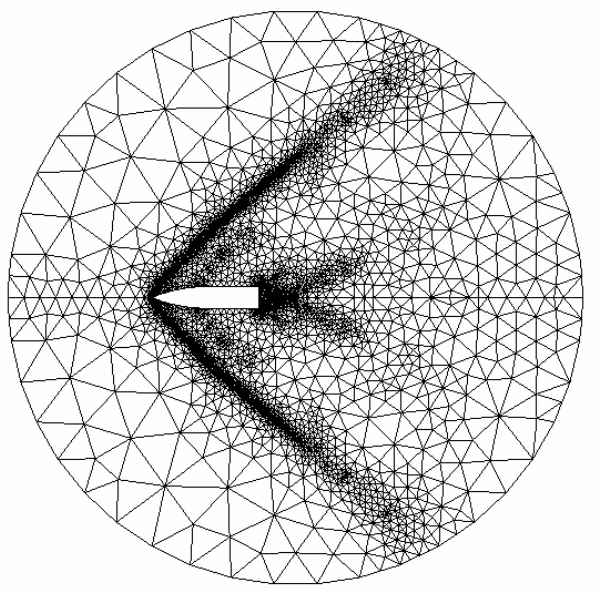
- How do you ensure adequate grid resolution, when you don't necessarily know the flow features? Solution-based grid adaption!
- The grid can be refined or coarsened by the solver based on the developing flow:
  - Solution values.
  - Gradients.
  - Along a boundary.
  - Inside a certain region.



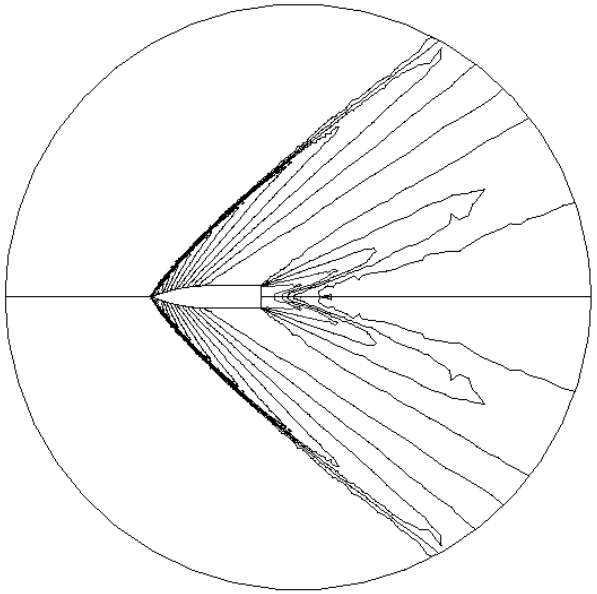
Grid adaption

- Grid adaption adds more cells where needed to resolve the flow field.
- Fluent adapts on cells listed in register. Registers can be defined based on:
  - Gradients of flow or user-defined variables.
  - Isovalues of flow or user-defined variables.
  - All cells on a boundary.
  - All cells in a region.
  - Cell volumes or volume changes.
  - y^+ in cells adjacent to walls.
- To assist adaption process, you can:
  - Combine adaption registers.
  - Draw contours of adaption function.
  - Display cells marked for adaption.
  - Limit adaption based on cell size and number of cells.

Adaption example: final grid and solution



2D planar shell - final grid



2D planar shell - contours of pressure
final grid

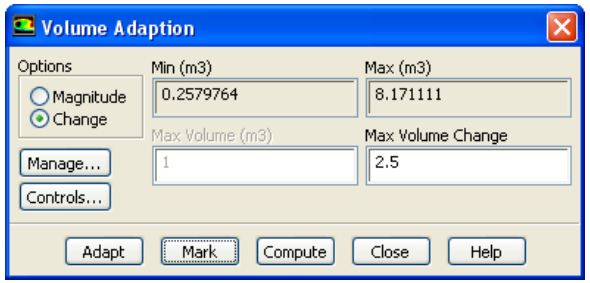
Main sources of errors

- Mesh too coarse.
- High skewness.
- Large jumps in volume between adjacent cells.
- Large aspect ratios.
- Interpolation errors at non-conformal interfaces.
- Inappropriate boundary layer mesh.

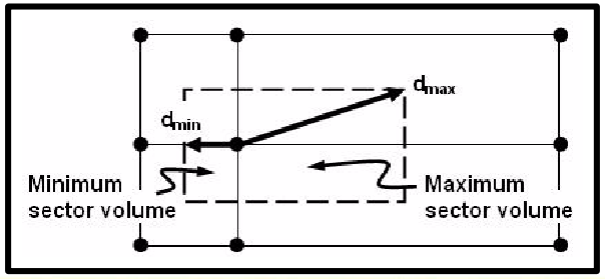
Smoothness

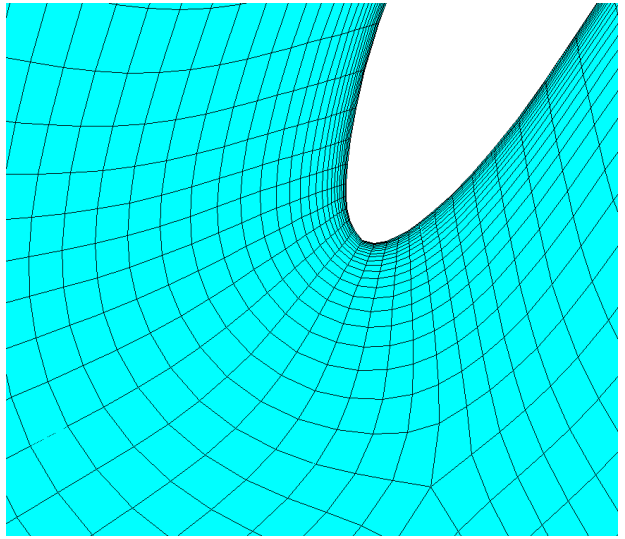
Checked in solver

- **Volume Change in Fluent**
  - **Available in Adapt/Volume**
  - ***3D :*** $\sigma_i = V_i / V_{nb}$



- **Expansion Factor in CFX**
  - **Checked during mesh import**
  - **Ratio of largest to smallest element volumes surrounding a node**



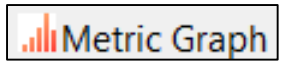


Recommendation:

Good: 1.0 < σ < 1.5
Fair: 1.5 < σ < 2.5
Poor: σ > 5 … 20

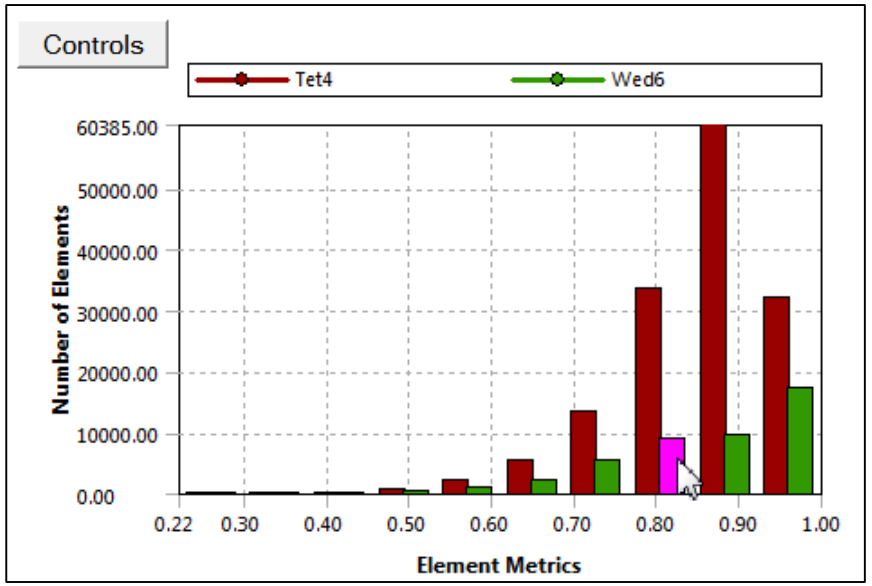
Mesh Metric Graph

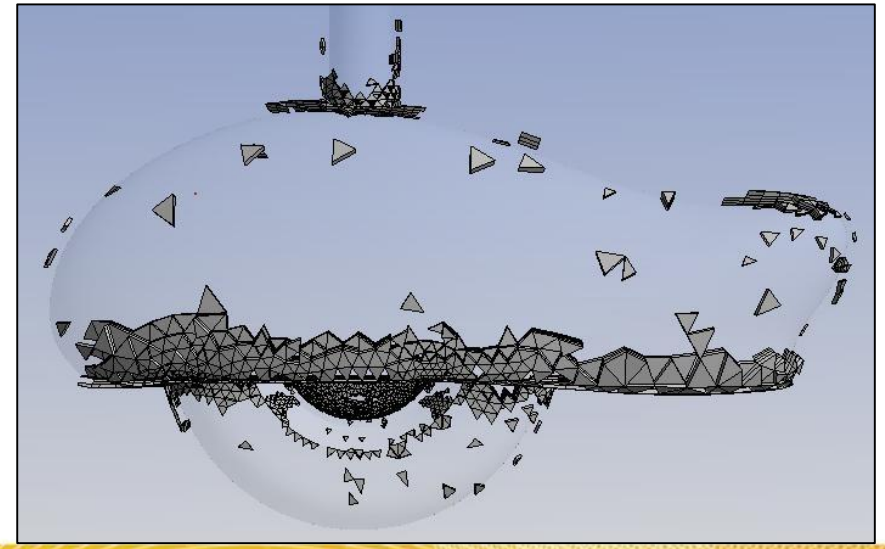
- **Displays Mesh Metrics graph for the element quality distribution**
- **Different element types are plotted with different color bars**
- **Can be accessed through menu bar using Metric Graph button**



- **Axis range can be adjusted using controls button (details next slide)**

- **Click on bars to view corresponding elements in the graphics window**
  - Use to help locate poor quality elements

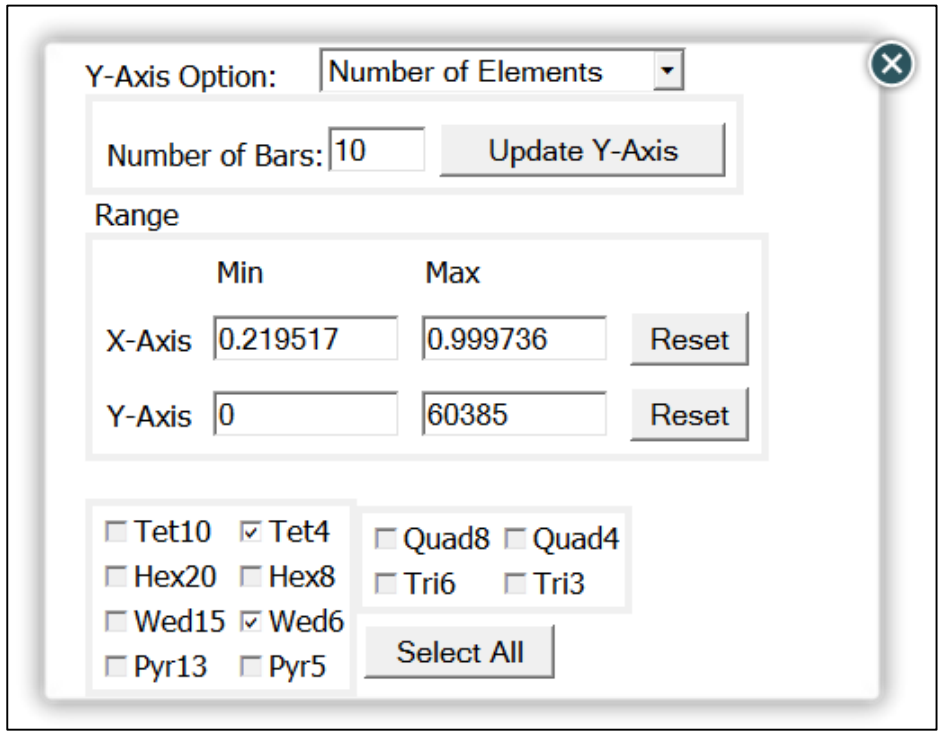




Mesh Metric Graph Controls

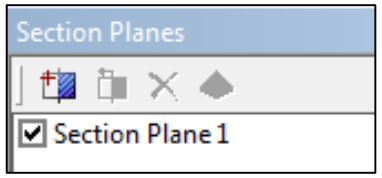
Controls

- **Elements on Y-Axis can be plotted with two methods;**
  - Number of Elements
  - Percentage of Volume/Area
- **Options to change the range on either axis**
- **Specify which element types to include in graph**
  - Tet4 = 4 Node Linear Tetrahedron
  - Hex8 = 8 Node Linear Hexahedron
  - Wed6 = 6 Node Linear Wedge (Prism)
  - Pyr5 = 5 Node Linear Pyramid
  - Quad4 = 4 Node Linear Quadrilateral
  - Tri3 = 3 Node Linear Triangle
    - Te10, Hex20, Wed15, Pyr13, Quad8 & Tri6 non-linear elements



Section Planes

Displays internal elements of the mesh 

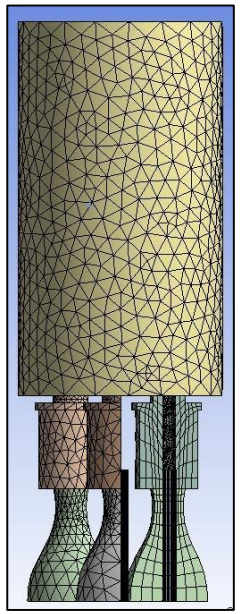


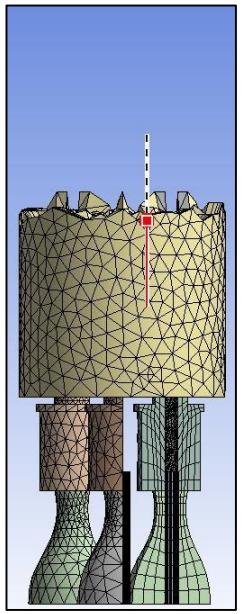
- **Elements on either side of plane can be displayed**
- **Toggle between cut or whole elements display**
- **Elements on the plane**

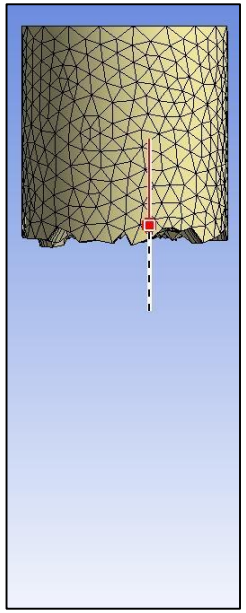
Edit Section Plane button  **can be used to drag section plane to new location**

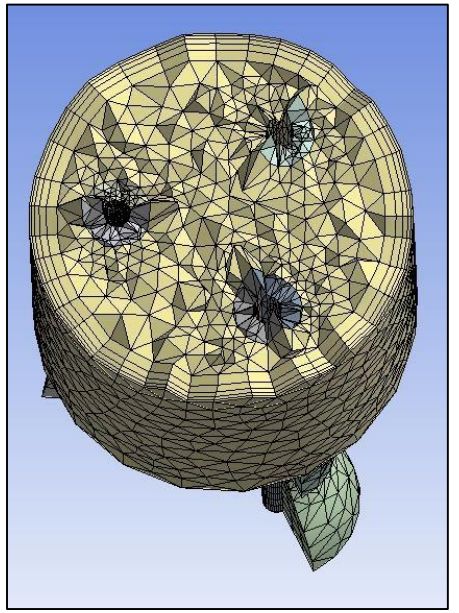
- **Clicking on "Edit Section Plane" button will make section plane's anchor to appear**

Multiple section planes are allowed









For large meshes, it is advisable to switch to geometry mode (click on geometry in the Tree Outline), create the section plane and then go back to mesh model

Mesh Quality Check for CFX

- The CFX solver calculates 3 important measures of mesh quality at the start of a run and updates them each time the mesh is deformed
- Mesh Orthogonality
- Aspect Ratio
- Expansion Factor

```
+--------------------------------------------------------------------+
|                          Mesh Statistics                           |
+--------------------------------------------------------------------+
Domain Name: Air Duct
    Minimum Orthogonality Angle [degrees]          =     20.4 ok
    Maximum Aspect Ratio                           =     13.5 OK
    Maximum Mesh Expansion Factor                  =    700.4  !
Domain Name: Water Pipe
    Minimum Orthogonality Angle [degrees]          =     32.8 ok
    Maximum Aspect Ratio                           =      6.4 OK
    Maximum Mesh Expansion Factor                  =     73.5  !
Global Mesh Quality Statistics :
    Minimum Orthogonality Angle [degrees]          =     20.4 ok
    Maximum Aspect Ratio                           =     13.5 OK
    Maximum Mesh Expansion Factor                  =    700.4  !
```

Good
(OK)

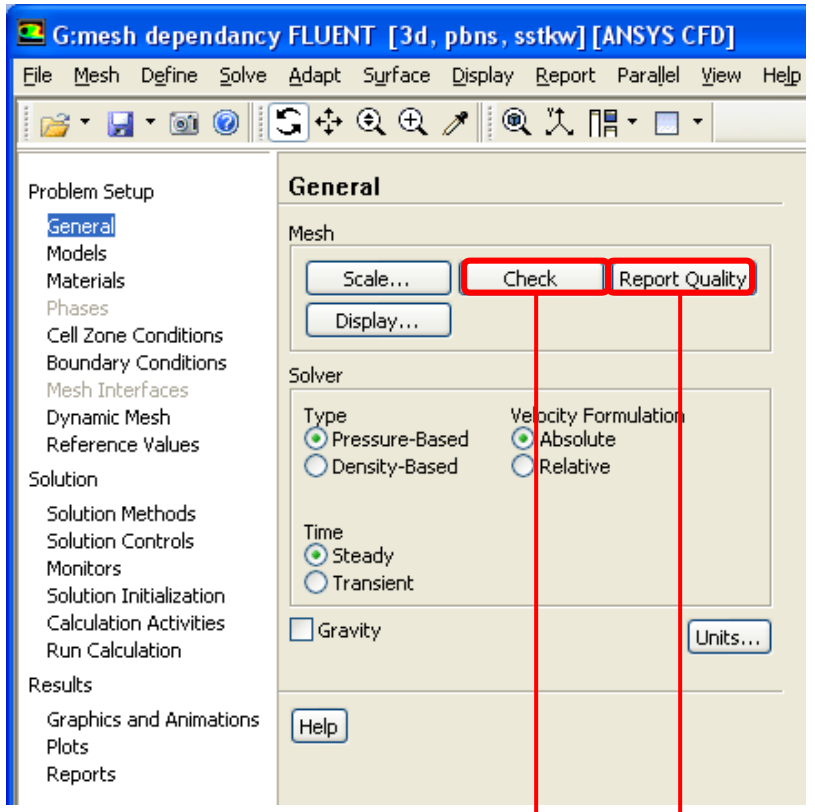
Acceptable
(ok)

Questionable
(!)

Mesh Quality Check for Fluent

Grid check tools available

- *Check* : Perform various mesh consistency checks
- *Report Quality* : lists worse values of orthogonal quality and aspect ratio
- TUI command *mesh/check-verbosity* sets the level of details in the report




```
 Domain Extents:
   x-coordinate: min (m) = -1.349580e-01, max (m) = 8.000000e-01
   y-coordinate: min (m) = -2.407051e-01, max (m) = 1.350000e-01
   z-coordinate: min (m) = -3.500000e-02, max (m) = 3.500000e-02
 Volume statistics:
   minimum volume (m3): 2.067421e-08
   maximum volume (m3): 3.187442e-07
     total volume (m3): 5.925829e-03
 Face area statistics:
   minimum face area (m2): 6.187846e-06
   maximum face area (m2): 1.274684e-04
 Checking mesh.......................
Done.

Mesh Quality:
 Orthogonal Quality ranges from 0 to 1, where values close to 0 correspond to low quality.
Minimum Orthogonal Quality =  9.99641e-01
Maximum Aspect Ratio =  2.03929e+01
```

Factors Affecting Quality

Geometry problems

- Small edge
- Gaps
- Sharp angle

Geometry cleanup in Design Modeler
or
Virtual topology & pinch in Meshing

Meshing parameters

- Sizing Function On / Off
- Min size too large
- Inflation parameters
  - Total height
  - Maximum angle
- Hard sizing

Mesh setting change

Meshing methods

- Patch conformal or patch independent tetra
- Sweep or Multizone
- Cutcell

Mesh setting change

Workshops 5

Automotive Aero