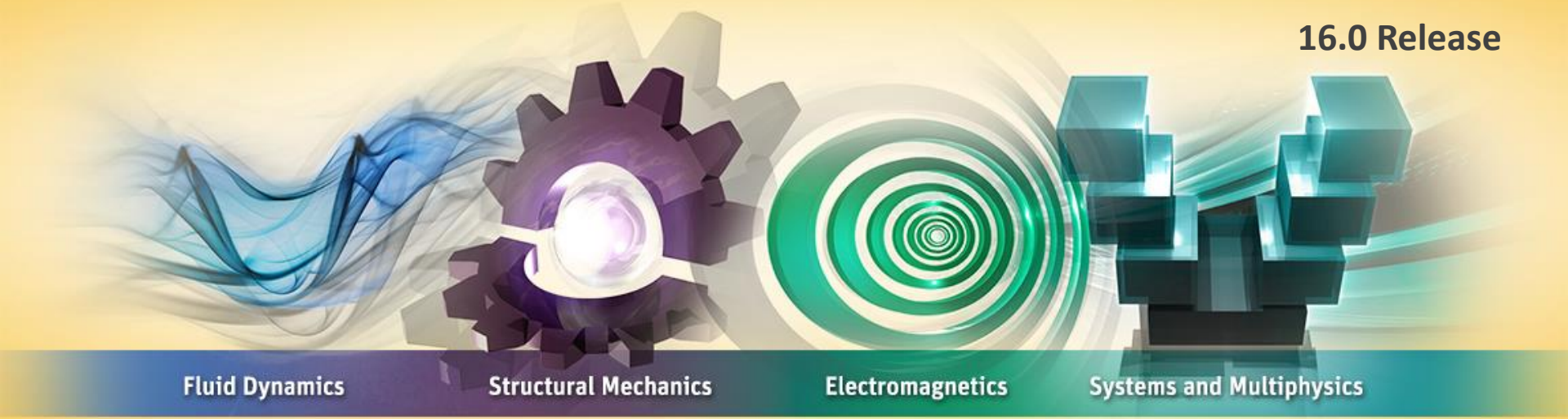
Lecture 4:
Meshing Methods

16.0 Release



Introduction to ANSYS Meshing

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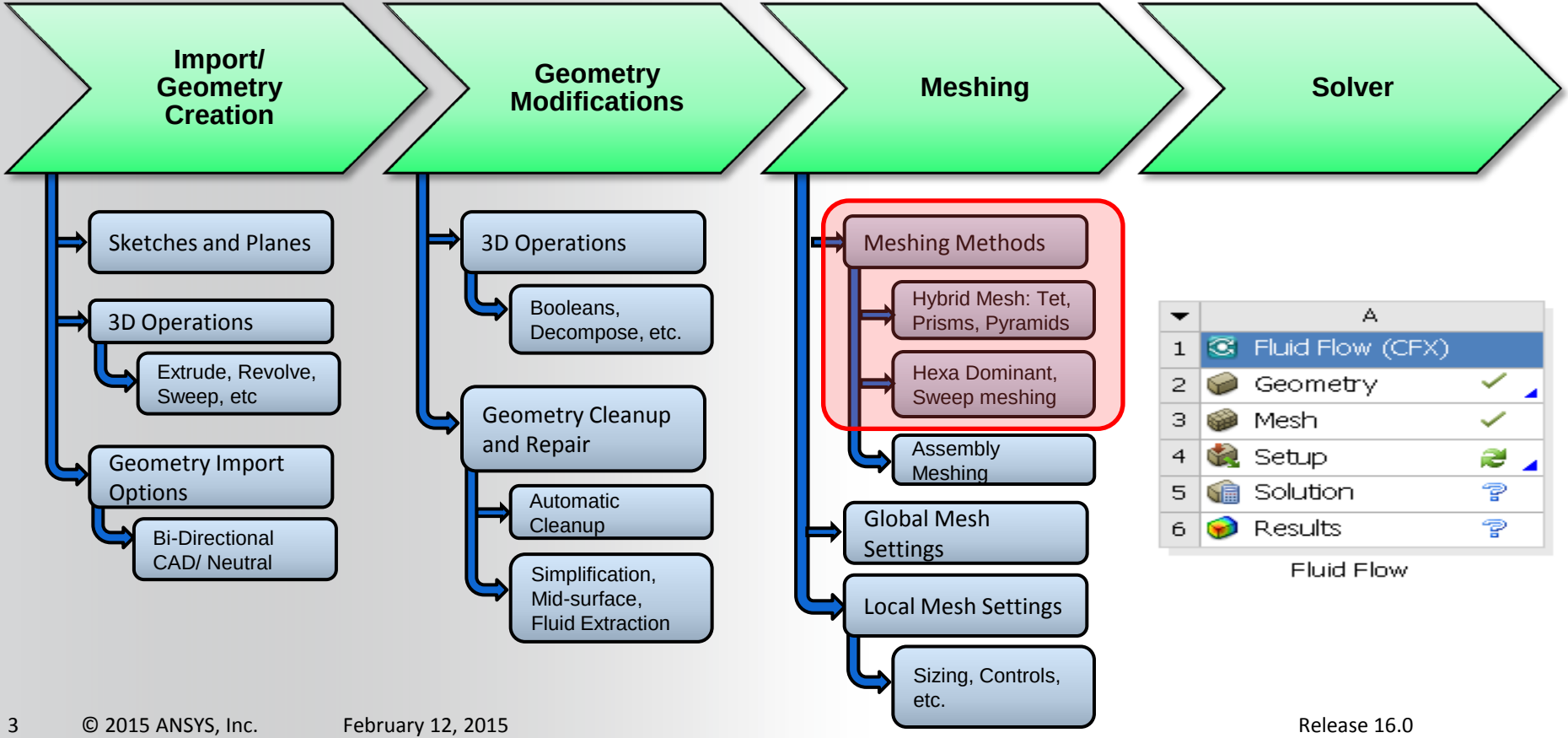
Introduction to ANSYS Meshing

In this lecture we will learn:

- **Meshing Methods for Part/Body Meshing**
  - **Assembly Meshing covered separately**
- **Methods & Algorithms for;**
  - **Tetrahedral Meshing**
  - **Hex Meshing**
  - **2D Meshing**
- **Meshing Multiple Bodies**
  - **Selective Meshing**
  - **Recording Meshing Order**

Preprocessing Workflow

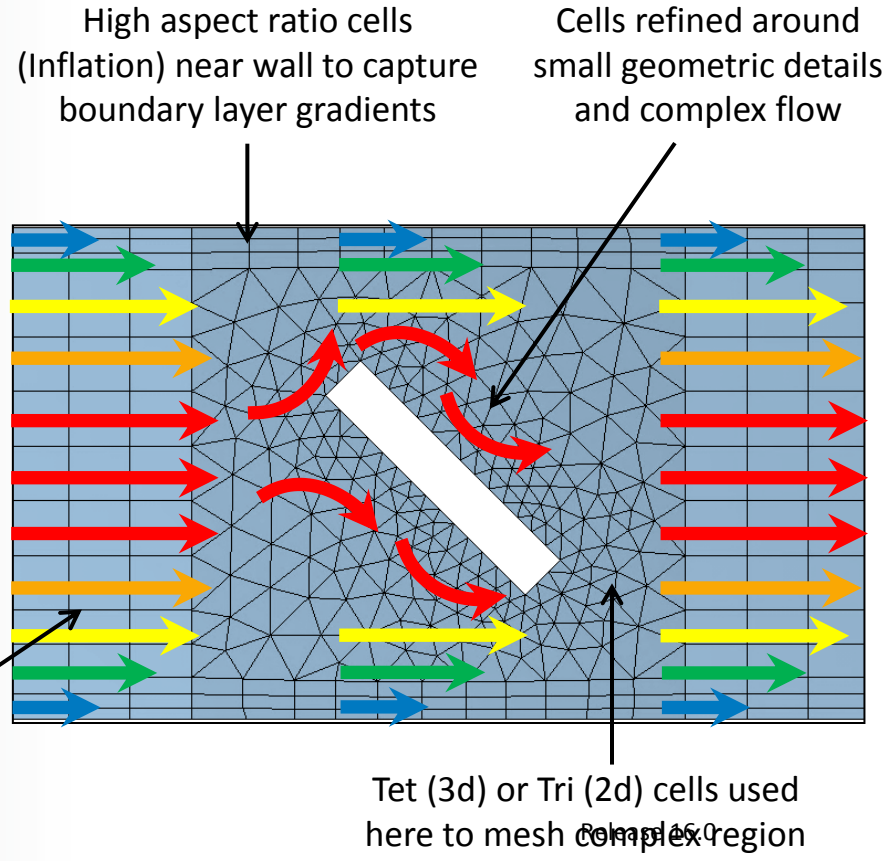


Which method to choose?

Why Multiple Methods?

- Choice depends on :
  - Physics
  - Geometry
  - Resources

- Mesh could require just one or a combination of methods.

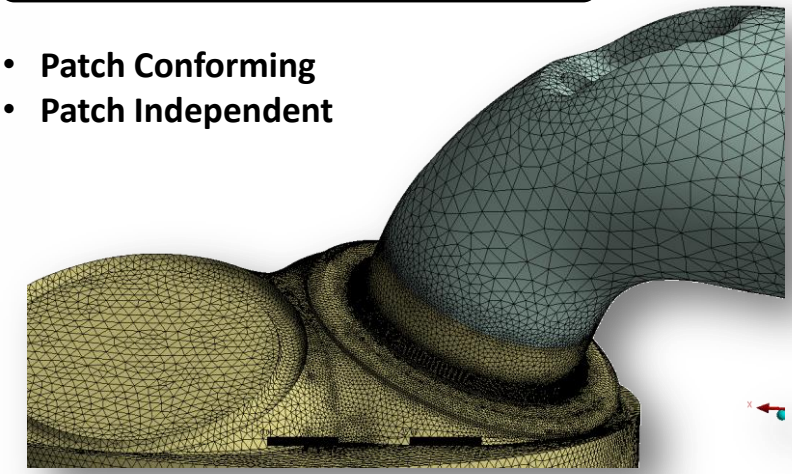


Agenda

- Meshing Methods for Part/Body Meshing
  - Assembly Meshing covered separately
- **Methods & Algorithms for**
  - **Tetrahedral Meshing**
  - Hex Meshing
  - 2D Meshing
- Meshing Multiple Bodies
  - Selective Meshing
  - Recording Meshing Order

2 algorithms available

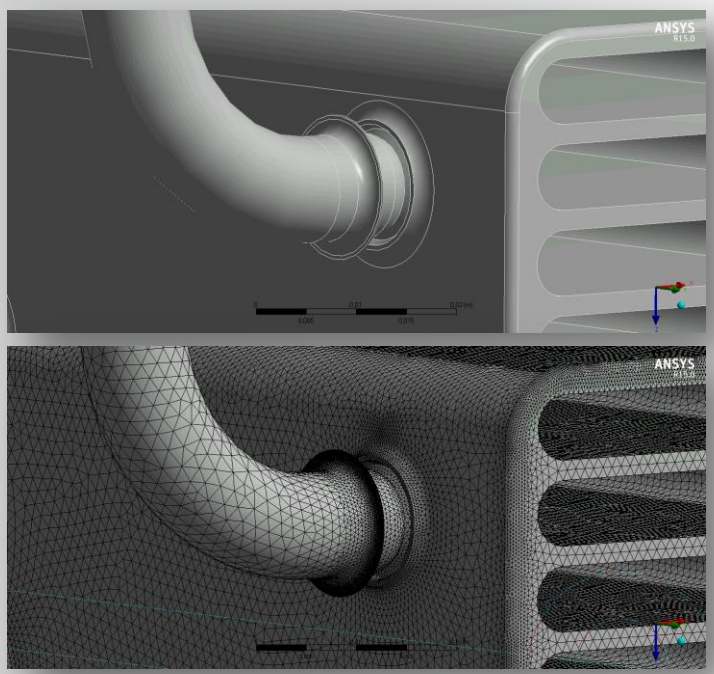
- **Patch Conforming**
- **Patch Independent**

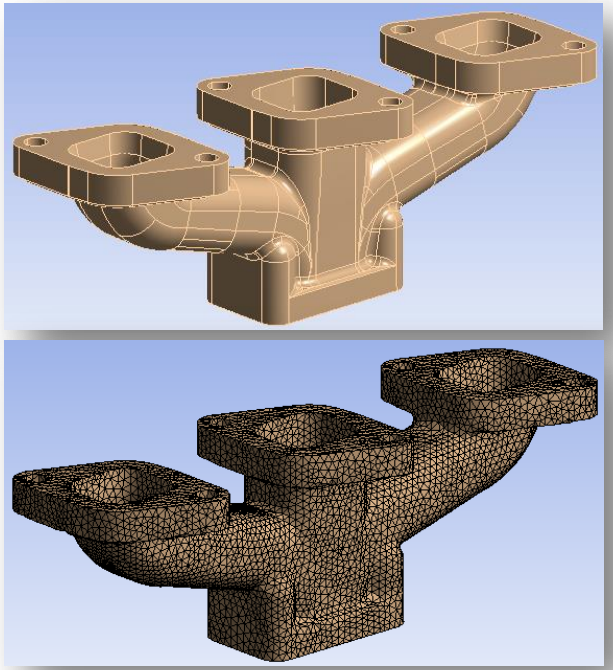


Patch Conforming versus Independent

Patch Conforming
- Clean CAD, Accurate surface mesh

Patch Independent
- Dirty Geometry, defeatured surface mesh





Tetrahedrons Methods

Patch Conforming

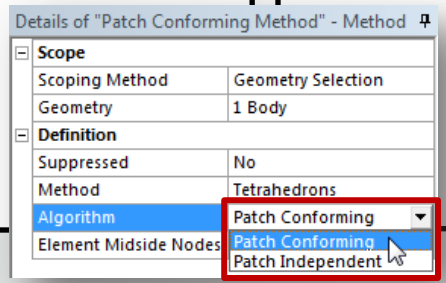
- Bottom up approach: Meshing process
  - Edges ➔ Faces ➔ volume
- All faces and their boundaries are respected (conformed to) and meshed (except with defeaturing tolerance)
- Good for high quality (clean) CAD geometries
  - CAD cleanup required for dirty geometry
- Sizing is defined by global and/or local controls
- Compatible with inflation

To access it
- Insert Method
  - Set to Tetrahedrons
  - Set to Patch Conforming

Patch Independent

- Top down approach: Meshing process
  - Volume meshed first ➔ projected on to faces & edges
- Faces, edges & vertices not necessarily conformed
  - Controlled by tolerance and scoping of Named Selection, load or other object
- Good for gross de-featuring of poor quality (dirty) CAD geometries
- Method Details contain sizing controls
- Compatible with inflation

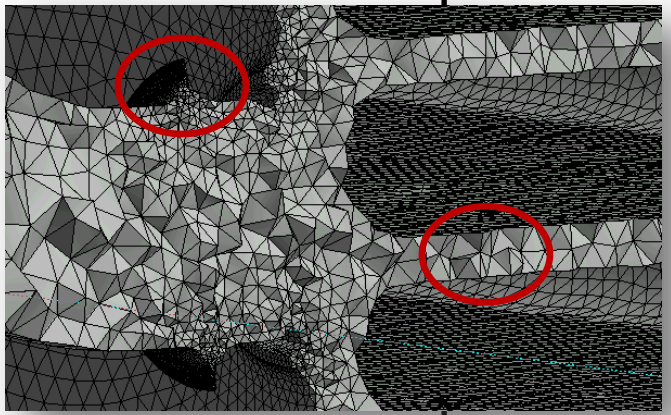
To access it
- Insert Method
  - Set to Tetrahedrons
  - Set to Patch Independent

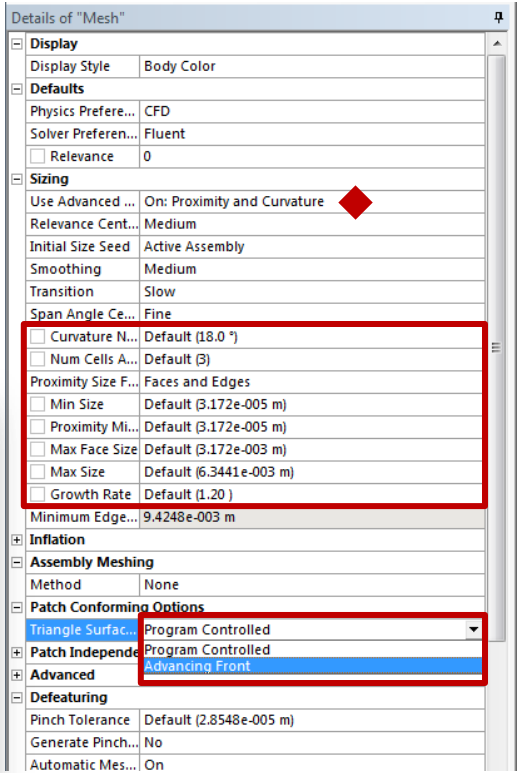


Tetrahedrons Method : Control

Patch Conforming - Sizing

- Mesh sizing for the Patch Conforming algorithm is defined by Global & Local Controls
- Automatic refinement based on curvature and/or proximity accessible in Global Controls
  - Details of Global & Local Controls covered in separate lectures
- Choice of surface mesher algorithm in global controls





Tetrahedrons Method : Control

Patch Independent - Sizing

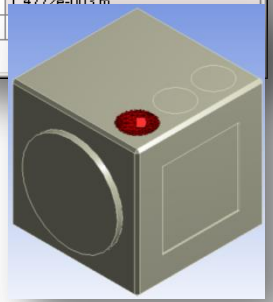
- Sizing for the Patch Independent algorithm defined in Patch Independent Details
- Automatic curvature & proximity refinement option

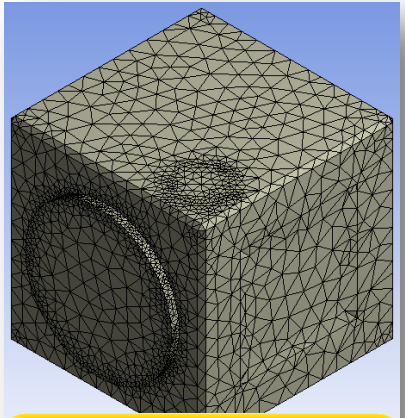
Defeaturing Control

- Set Mesh Based Defeaturing On
- Set Defeaturing Tolerance
- Assign Named Selections to selectively preserve geometry

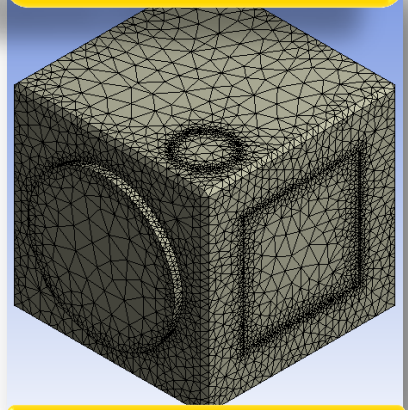
Details of "Patch Independent" - Method

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	Tetrahedrons
Algorithm	Patch Independent
Element Midside Nodes	Use Global Setting
Advanced	
Defined By	Max Element Size
Max Element Size	Default(2, m)
Feature Angle	30.0 °
Mesh Based Defeaturing	On
Defeaturing Tolerance	2,e-002 m
Refinement	Proximity and Curvature
Min Size Limit	Default
Num Cells Across Gap	Default
Curvature Normal Angle	Default
Smooth Transition	Off
Growth Rate	Default
Minimum Edge Length	1.4772e-003 m
Write ICEM CFD Files	



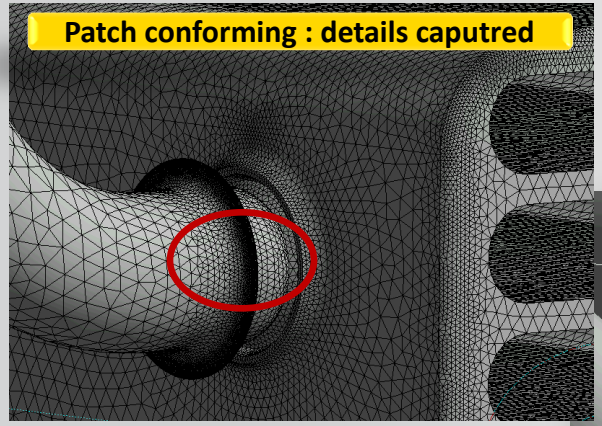


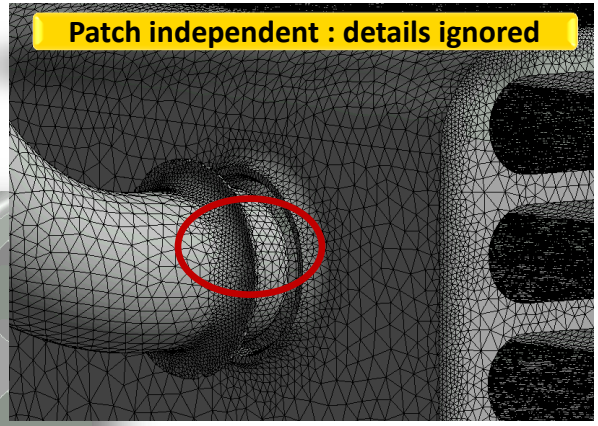
Name Selec. assigned & defeaturing Tol = 0.02
Features > 0.02m respected

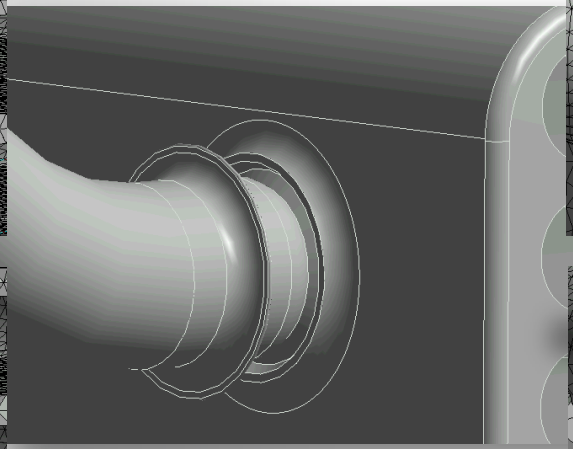


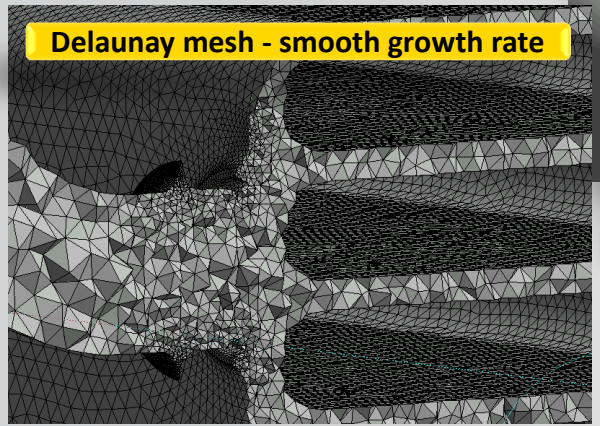
Defeaturing Tolerance off

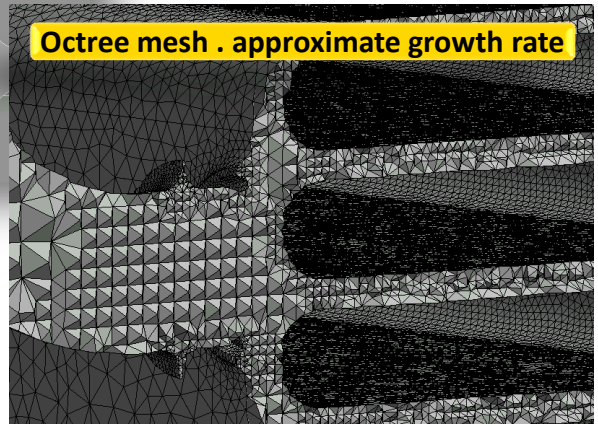
Tetrahedrons Method : Algorithm comparison









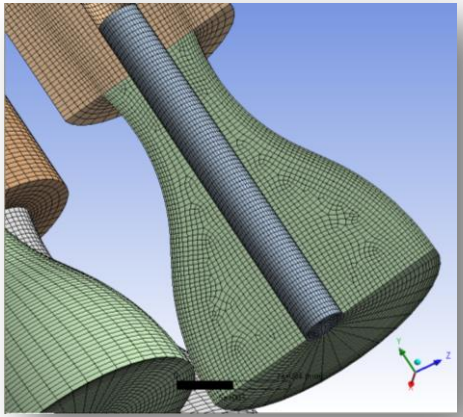


Agenda

- Meshing Methods for Part/Body Meshing
  - Assembly Meshing covered separately
- Methods & Algorithms for
  - Tetrahedral Meshing
  - **Hex Meshing**
  - 2D Meshing
- Meshing Multiple Bodies
  - Selective Meshing
  - Recording Meshing Order

3 methods available

- **Sweep**
- **Multizone**
- **Hex Dominant**
  - **(not recommended for CFD)**



Hexa Mesh - Introduction

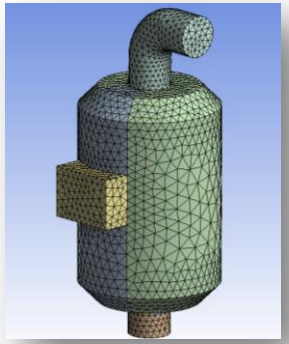
Hex Meshing

- Reduced element count
  - Reduced run time
- Elements aligned in direction of flow
  - Reduced numerical error

Initial Requirements

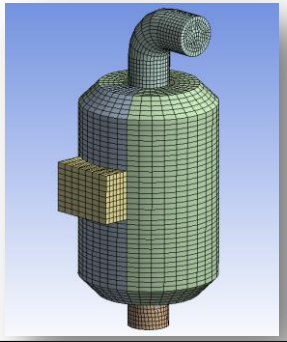
- Clean geometry
- May require geometric decomposition

Tetra mesh - 48 000 Cells



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

Hexa mesh - 19 000 Cells

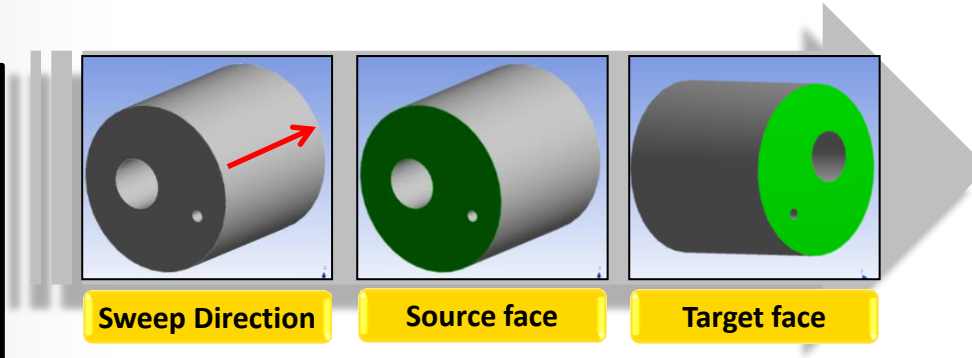


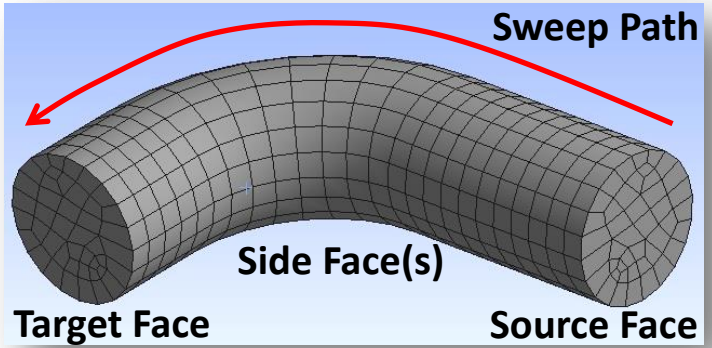
Statistics	
Nodes	21348
Elements	19614
Mesh Metric	Skewness
Min	1.79292772803879E-02
Max	0.606963936309246
Average	0.175918570374858
Standard Deviation	0.118321537967619

Sweep Meshing

Mesh Method & Behavior

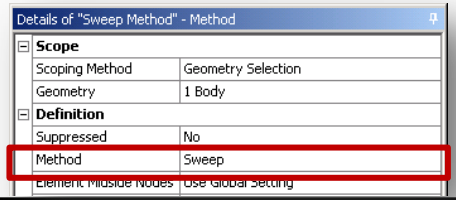
- Generates hex/wedge elements
- Meshes source surfaces ➔ Sweeps through to the target
  - Body must have topologically identical source and target faces
- Side faces must be mappable
  - A sweep path must be identified
- Only one source and one target face is allowed
  - Alternative 'thin' sweep algorithm can have multiple source & target faces





To access it

- Insert Method
  - Set to Sweep



Sweep Meshing

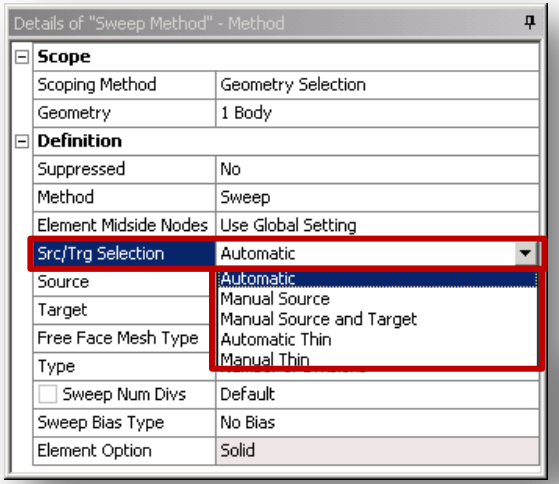
Source & Target selection

Automatic

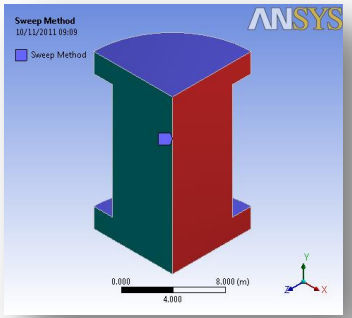
- **Source & Target faces identified automatically**
  - Requires that the mesher find the sweeping direction
- **Manual source & Manual source and target**
  - User selection
  - Source face colored in red
  - Target face colored in blue
  - ***Rotational** Sweeping*
    - ❖ **Sweep around an axis**
    - ❖ **Requires selection of both - Source & target**

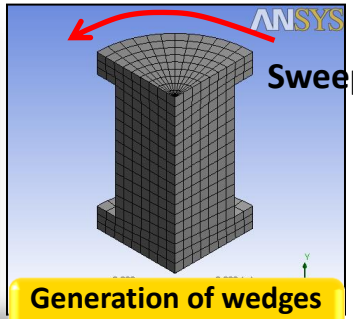
Note

- **Specifying both Source & Target accelerate meshing**



Define the nbr of intervals on the side face(s)





Sweep Path

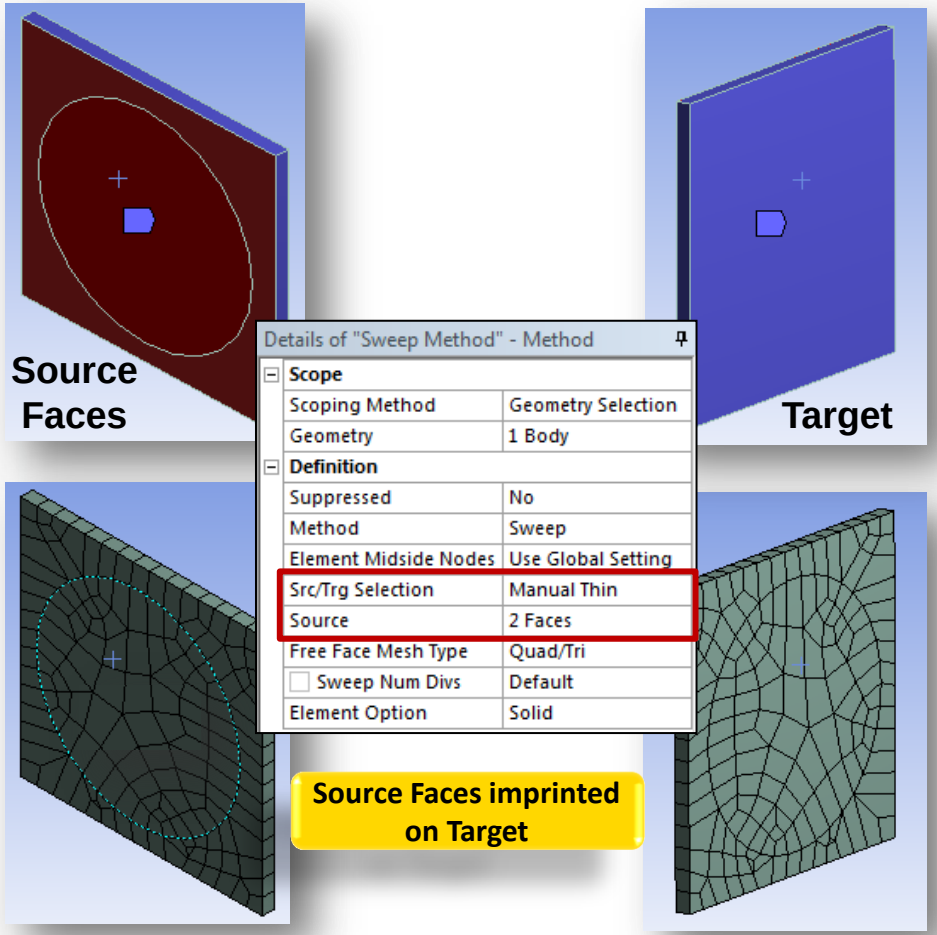
Generation of wedges & hex elements

Sweep Meshing

Source & Target selection

Automatic Thin & Manual Thin

- **Alternate sweep algorithm**
- **Advantages**
  - ✓ Sweep multiple Source & Target faces
  - ✓ Can perform some automatic defeaturing
- **Limitations**
  - X For multibody parts only one division allowed across the sweep
  - X Inflation not allowed
  - X Sweep bias not allowed



Sweep Meshing

Sweep and Inflation

Compatibility with Src/Trg Selection

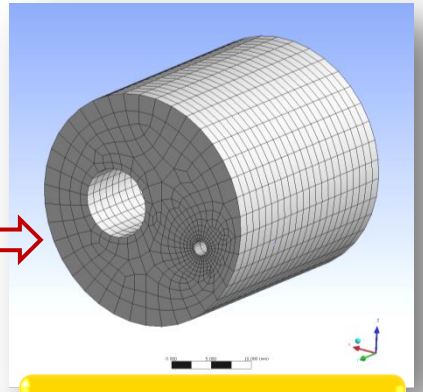
Automatic	X
Manual Source	✓
Manual Source and Target	✓
Automatic Thin	X
Manual Thin	X

Use of Inflation

- Defined on source face (NOT on target one)
- From boundary edges (2D)
- Swept through volume

Details of "Sweep Method" - Method

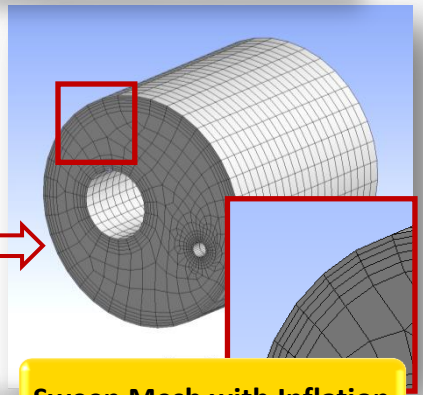
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	Sweep
Element Midside Nodes	Use Global Setting
Src/Trg Selection	Automatic
Source	Program Controlled
Target	Program Controlled
Free Face Mesh Type	Quad/Tri
Type	Number of Divisions
Sweep Num Divs	Default
Sweep Bias Type	No Bias
Element Option	Solid



Sweep Mesh - No Inflation

Details of "Sweep Method" - Method

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	Sweep
Element Midside Nodes	Use Global Setting
Src/Trg Selection	Manual Source
Source	1 Face
Target	Program Controlled
Free Face Mesh Type	Quad/Tri
Type	Number of Divisions
Sweep Num Divs	Default
Sweep Bias Type	No Bias
Element Option	Solid

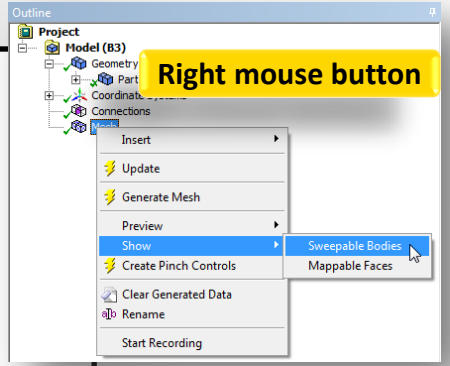


Sweep Mesh with Inflation

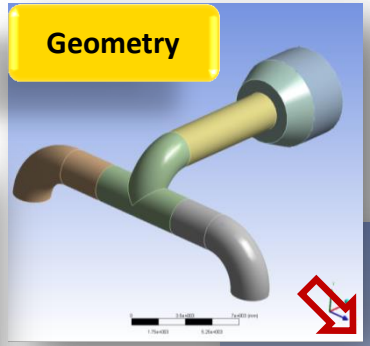
Sweep Meshing

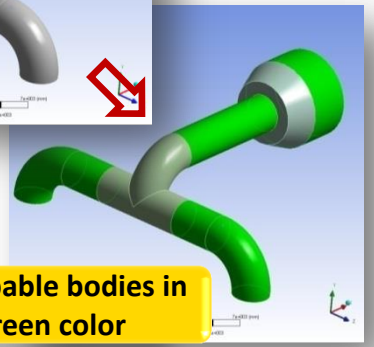
Identifying sweepable bodies

- **Automatic detection of sweepable bodies**
  - Rotational ones are not identified
- **Identification method**
  - Right click on mesh object
    - **Outline tree**
    - **Select : Sweepable Bodies**



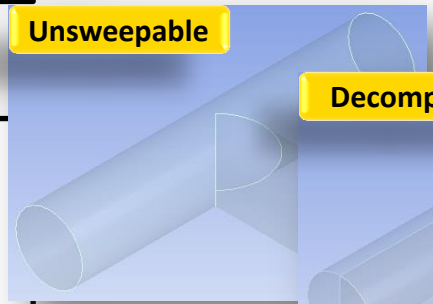
Right mouse button

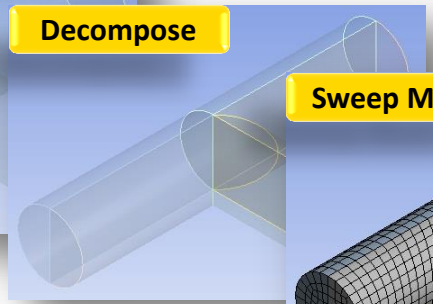


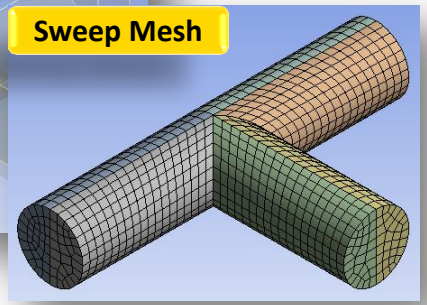


Making bodies sweepable

- **Decompose bodies into multi-simple topological shapes**
- **Perform decomposition in CAD/DM**







Multizone Meshing

Mesh Method & Behavior

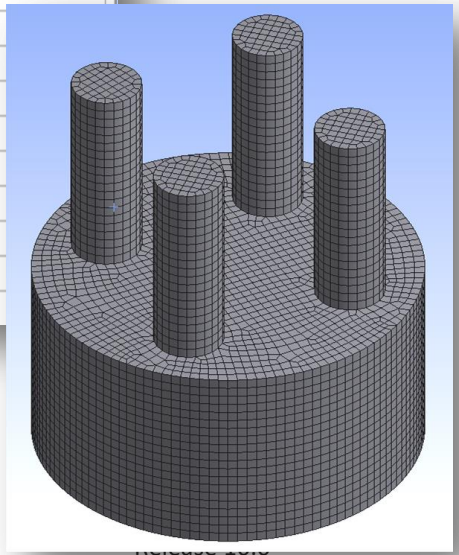
- Based on blocking approach (ANSYS ICEM CFD Hexa)
- Automatically decomposes geometry into blocks
- Generates structured hexa mesh where block topology permits
  - Remaining region filled with unstructured Hexa Core or Tetra or Hexa dominant mesh
- Src/Trg Selection
  - Automatic or Manual source selection
  - Multiple source faces
  - Select Target faces as “Source”
- Compatible with 3D Inflation ✓

To access it

- Insert Method ➔ Set to Multizone

Details of "MultiZone" - Method

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	MultiZone
Mapped Mesh Type	Hexa
Surface Mesh Method	Program Controlled
Free Mesh Type	Not Allowed
Element Midside Nodes	Use Global Setting
Src/Trg Selection	Manual Source
Source Scoping Method	Geometry Selection
Source	4 Faces
Sweep Size Behavior	Sweep Element Size
Sweep Element Size	Default
Advanced	
Preserve Boundaries	Protected
Mesh Based Defeaturing	On
Defeaturing Tolerance	Default(1.586e-005 m)
Minimum Edge Length	9.4248e-003 m
Write ICEM CFD Files	No

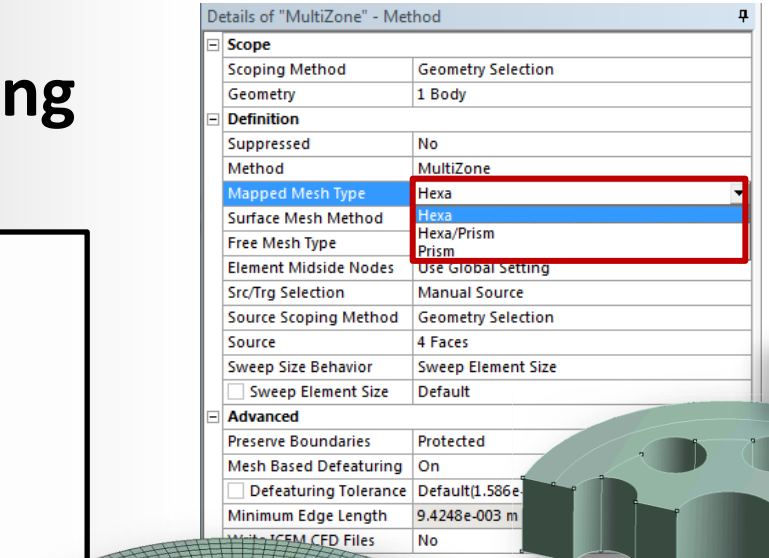


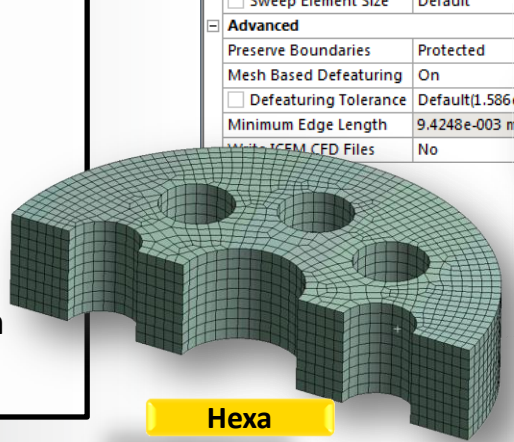
Multizone Meshing

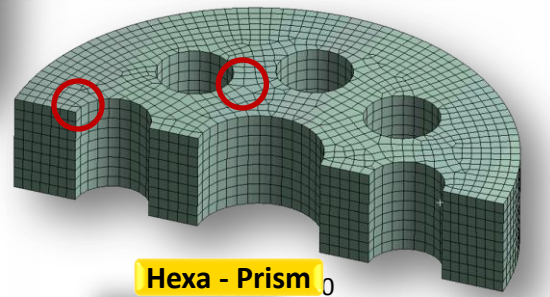
Mapped Mesh Type

Determines which elements to use

- **Hexa**
  - Default
  - Only Hexahedral elements are generated
- **Hexa/prism**
  - For quality and transition, triangles will be inserted on the surface mesh (sources)
- **Prism**
  - Only prisms will be generated
  - Useful when the adjacent volume is filled in with tet mesh







Multizone Meshing

Surface Mesh Method

Specify a method to create the surface mesh

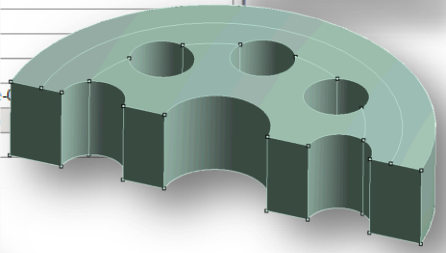
- **Uniform**
  - Uses a recursive loop-splitting method which creates a highly uniform mesh
- **Pave**
  - Creates a good quality mesh on faces with high curvature, and also when neighboring edges have a high aspect ratio
- **Program controlled**
  - Combination of Uniform and Pave methods
  - depends on the mesh sizes set and face properties

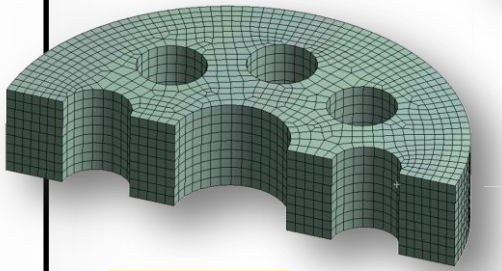
Details of "MultiZone" - Method

Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	MultiZone
Mapped Mesh Type	Hexa
Surface Mesh Method	Program Controlled
Free Mesh Type	
Element Midside Nodes	
Src/Trg Selection	
Source Scoping Method	Geometry Selection
Source	4 Faces
Sweep Size Behavior	Sweep Element Size
Sweep Element Size	Default
Advanced	
Preserve Boundaries	Protected
Mesh Based Defeaturing	On
Defeaturing Tolerance	Default(1.586e-
Minimum Edge Length	9.4248e-003 m
Write ICEM CFD Files	No

Program Controlled
Uniform
Pave

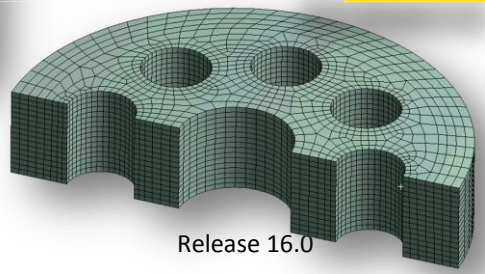
Geometry



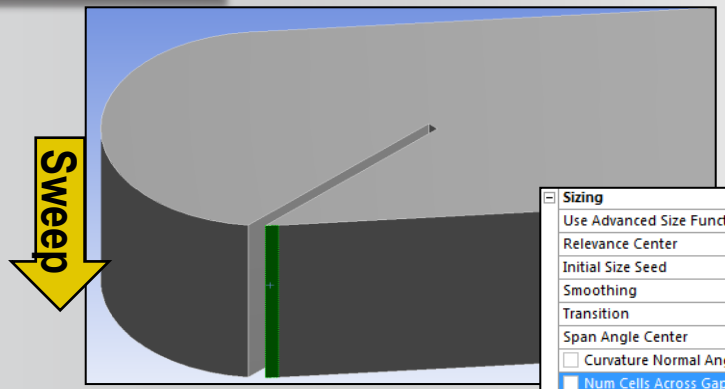


Uniform

Pave



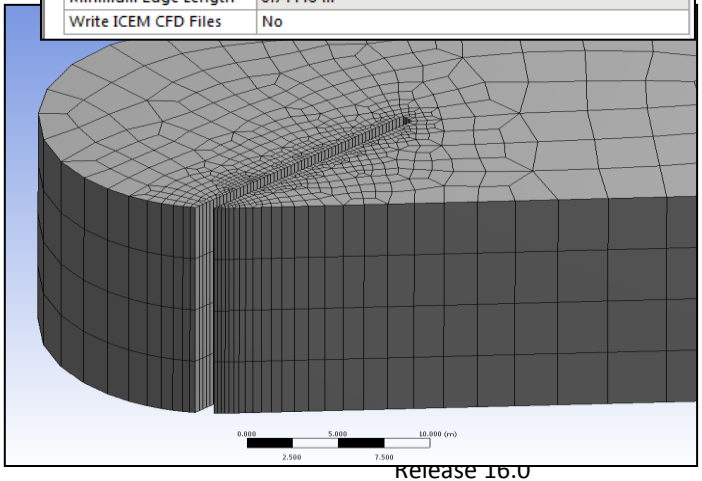
Multizone Meshing



Sizing	
Use Advanced Size Function	On: Proximity and Curvature
Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Slow
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Num Cells Across Gap	Default (3)

Details of "MultiZone" - Method

Scope	
Scoping	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	MultiZone
Mapped Mesh Type	Hexa
Surface Mesh Method	Program Controlled
Free Mesh Type	Not Allowed
Element Midside Nodes	Use Global Setting
Src/Trg Selection	Automatic
Source Scoping Method	Program Controlled
Source	Program Controlled
Sweep Size Behavior	Sweep Element Size
Sweep Element Size	5. m
Advanced	
Preserve Boundaries	Protected
Mesh Based Defeaturing	Off
Minimum Edge Length	0.74446 m
Write ICEM CFD Files	No



2.5 D Type of Meshes

Multizone allows to have effect of global size function on only just Source faces

- **Sweep Size Behavior**
  - **Sweep Element Size**
    - Allows to select a swept mesh size on sides irrespective of Source mesh sizing
  - **Sweep Edges**
    - Allows for Edge Selection for biasing

Automatic Method

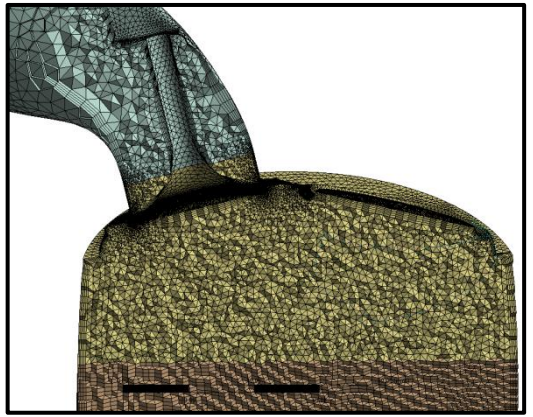
Mesh Method & Behavior

- **Combination of Tetrahedron Patch Conforming and Sweep Method**
  - Automatically identifies sweepable bodies and creates sweep mesh
  - All non-sweepable bodies meshed using tetrahedron Patch Conformal method
- **Compatible with inflation**

To access it

- **Default method**
- **Insert method ➔ Set to Automatic**

Details of "Automatic Method" - Method	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Method	Automatic
Element Midside Nodes	Use Global Setting



Agenda

- Meshing Methods for Part/Body Meshing
  - Assembly Meshing covered separately
- Methods & Algorithms for
  - Tetrahedral Meshing
  - Hex Meshing
  - **2D Meshing**
- Meshing Multiple Bodies
  - Selective Meshing
  - Recording Meshing Order

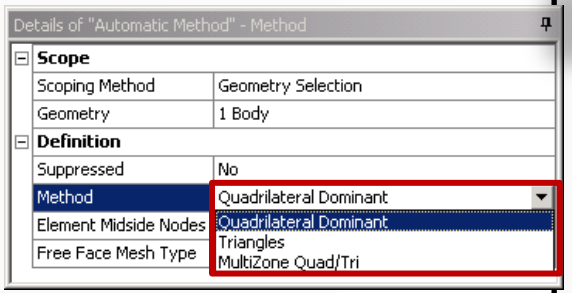
3 methods available

- **Quadrilateral Dominant**
- **Triangles**
- **Multizone Quad/Tri**

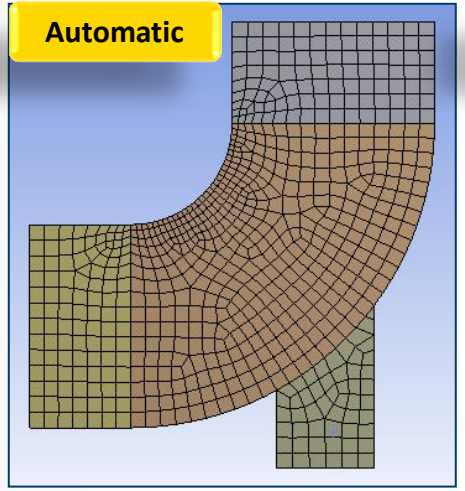
2D Meshing

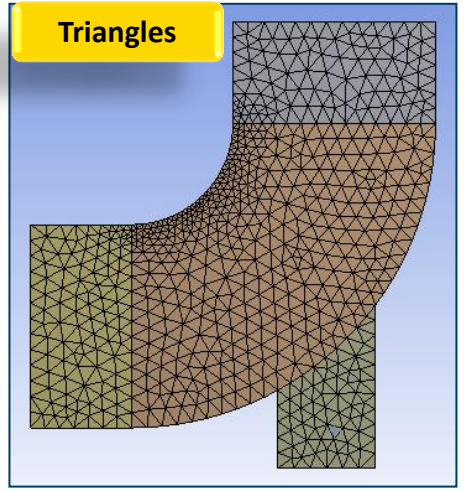
Mesh Method & Behavior

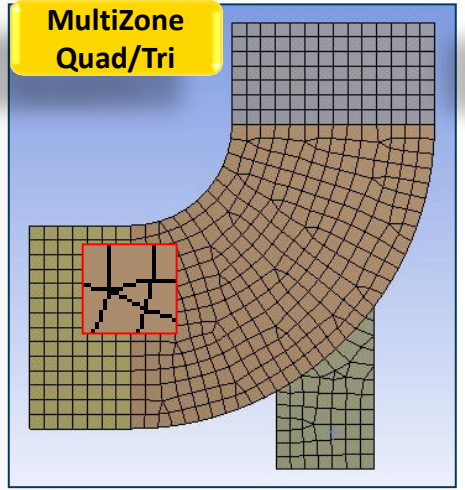
- **Quadrilateral Dominant & Triangles**
  - Patch conforming methods
- **MultiZone Quad/tri**
  - Patch Independent Methods
  - Associated with face mesh type
    - **All Tri**
    - **Quad/tri**
    - **All Quad**

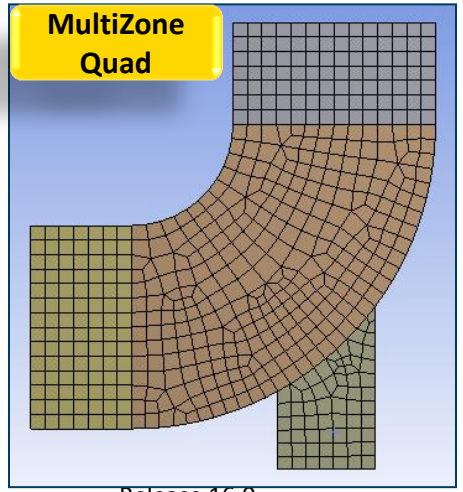


- **Advanced size function & local size controls are supported**









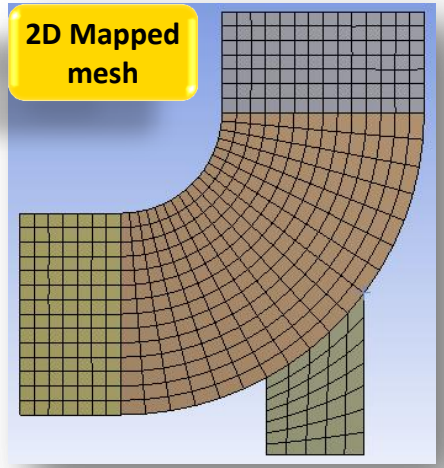
2D Meshing

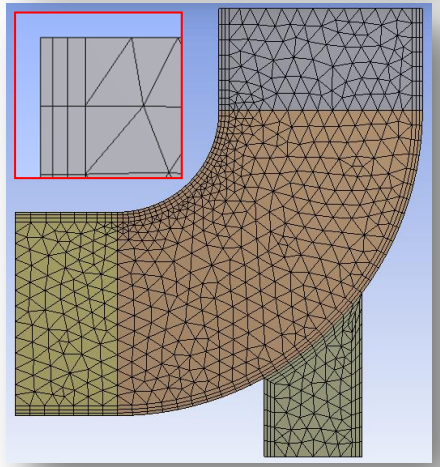
Control

- Mapped Surface Meshes
  - Local mesh controls
    - Fully Mapped surface meshes
    - Specified edge sizing/intervals

Inflation

- Boundary edges are inflated
- Global & local inflation controls are supported





2D Mesh Solver Guidelines

ANSYS Fluent

- **For a 2D analysis in Fluent generate the mesh in the XY plane**
  - Z = 0
- **For axisymmetric applications $y \geq 0$ and make sure that the domain is axisymmetric about x axis**
- **In ANSYS Meshing, by default, a thickness is defined for a surface body and is visible when the view is not normal to the XY Plane.**
  - This is purely graphical – no thickness will be present when the mesh is exported into the Fluent 2D solver

ANSYS CFX

- **For 2D analysis in CFX, create a volume mesh (using Sweep)**
  - 1 element thick in the symmetry direction, i.e.,
- **Thin Block for Planar 2D**
- **Thin Wedge (< 5°) for 2D Axis-symmetric**

Agenda

- Meshing Methods for Part/Body Meshing
  - Assembly Meshing covered separately
- Methods & Algorithms for
  - Tetrahedral Meshing
  - Hex Meshing
  - 2D Meshing
- **Meshing Multiple Bodies**
  - **Selective Meshing**
  - **Recording Meshing Order**

Selective Meshing

What is ?

- Selectively picking bodies and meshing them incrementally

Why ?

- Bodies can be meshed individually
- Mesh seeding from meshed bodies influences neighboring bodies (user has control)
- Automated meshing can be used at any time to mesh all remaining bodies
- When controls are added, only affected body meshes require remeshing
- Selective body updating
- Extensive mesh method interoperability

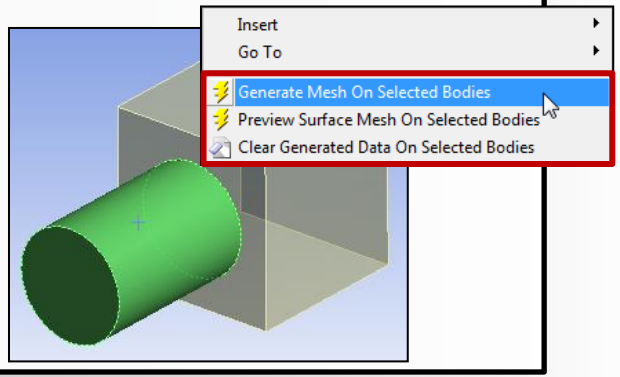
Selective Meshing

Local Meshing

Clear meshes on individual bodies

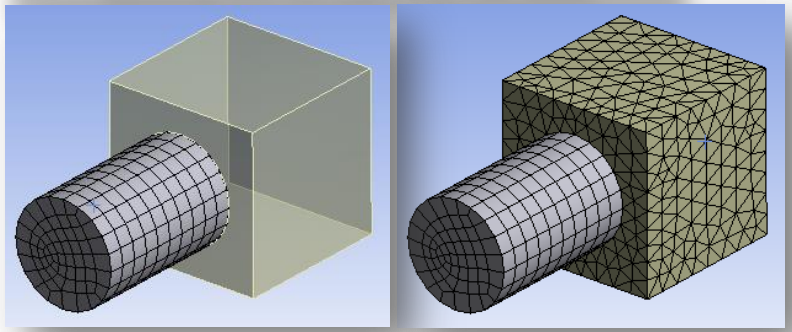
Generate meshes on individual bodies

- Subsequent bodies will use the attached face mesh
- The meshing results (cell types) will depend on the meshing order
- Adjust/add controls – able to remesh only affected body

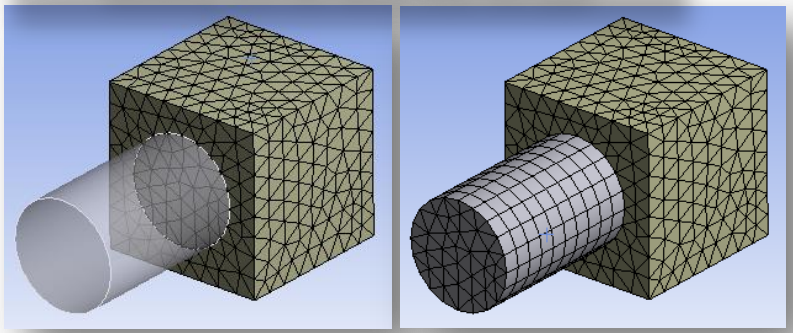


- Select body(s)
  - Right click

Meshing first the pipe then the block



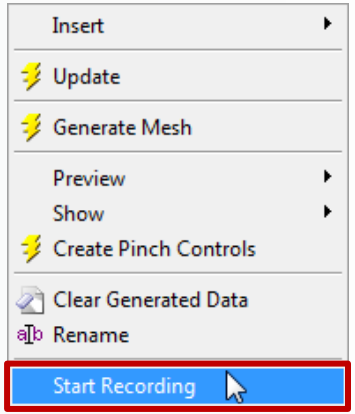
Meshing first the block then the pipe



Selective Meshing

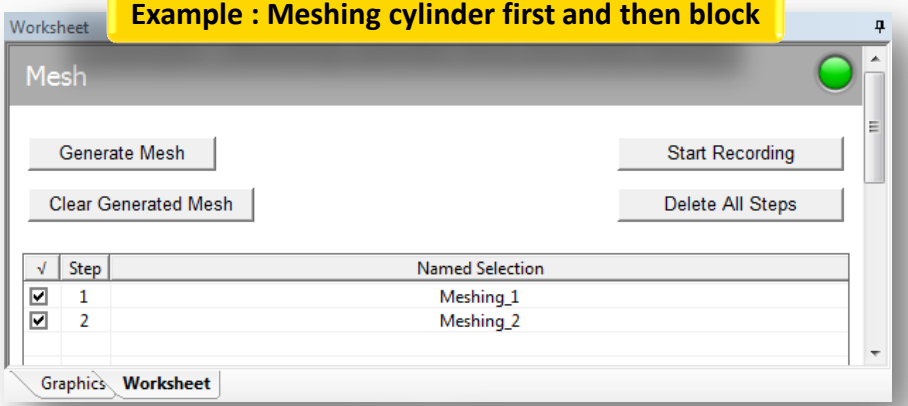
Recording Mesh Operations

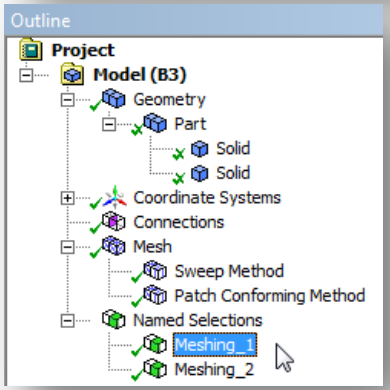
- Use it to record the order of meshing to automate future use
- Right click Mesh in the Outline to access it

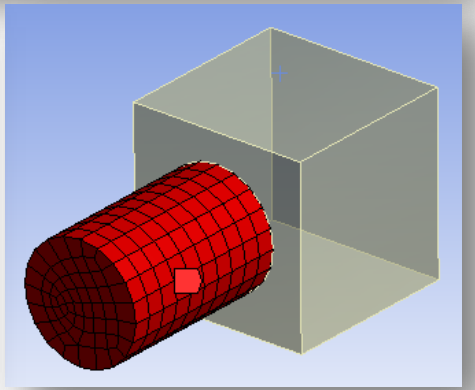


- A Worksheet is generated
  - Record mesh operations as ordered steps
- Named Selections are automatically created for each meshed body for reference in the Worksheet

Example : Meshing cylinder first and then block



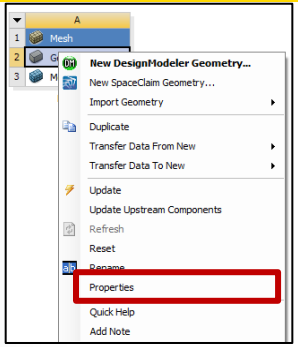


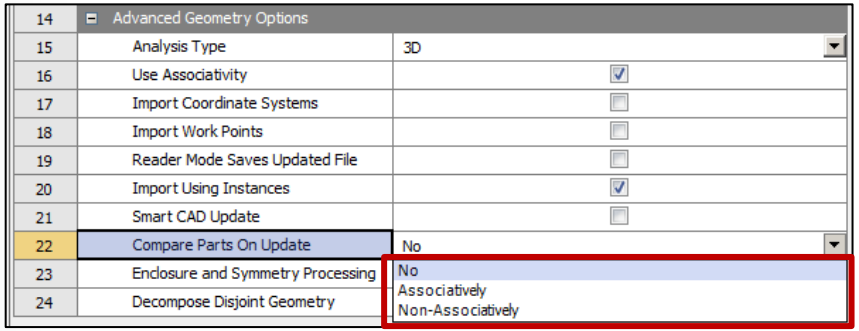


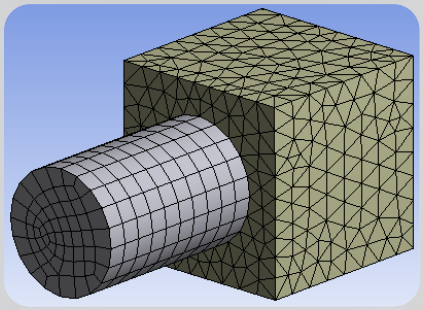
Selective Meshing

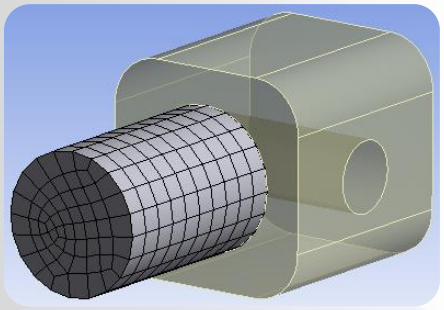
Selective Body Updating

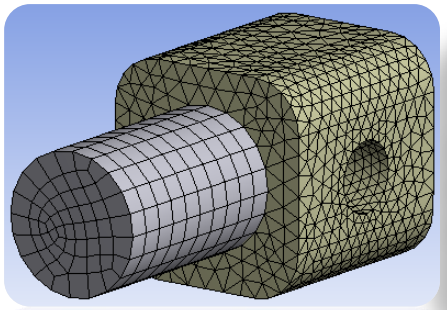
- **Remeshing only bodies that have changed**
- **Access option through RMB click on Geometry → Properties**
  - **No**: All geometry updated, all bodies remeshed.
  - **Associatively**: Accommodates for body topology change (add/delete) (slower)
  - **Non-Associatively**: Assumes no topology change (faster)











Example : Geometric change to block

Summary

- **We have studied the different Methods & Algorithms at disposal into Meshing**
  - **Tetrahedral Meshing**
    - **Patch Conforming** (bottom up approach)
    - **Patch Independent** (top down approach)
  - **Hex Meshing (best suited for CFD)**
    - **Sweep meshing** – requires a sweep direction, a source face and a target
    - **Multizone** which handles multiple source and target faces with a sweep direction
  - **2D Meshing**
- **Meshing Multiple Bodies**
  - **Selective Meshing –** Define the order of meshing
  - **Recording Meshing Order – Worksheet**

Workshop 4.1: Meshing Methods