Lecture 5
Prism Meshing

Introduction to ANSYS
ICEM CFD
Prism Meshing

Inflation layers
• To better simulate boundary layer effects
• Mesh orthogonal to surface with faces perpendicular to boundary layer flow direction

Procedure
• Set *Global Prism Parameters*
• Select *Parts* to grow layers from
  – Typically wall boundaries and holes
• Set Local Parameters for each part
  – Local overrides global
  – Zero or blank entries will defer to global settings
• Run mesher
  – From existing mesh
    • Extrude into tetra/hexa mesh
    • Extrude from surface tri mesh, then fill volumes
  – Run automatically during *Volume Mesh* creation
**Prism - Global Parameters**

**Global Prism Parameters**

- **Growth law**
  - *exponential*: \( \text{height} = h(r)^{(n-1)} \) [\( n \) is layer #]
  - *linear*: \( \text{height} = h(1+(n-1)(r-1)) \)
  - *wb-exponential*: \( \text{height} = h \times \exp((r-1)(n-1)) \)
- **Initial height** of first layer – \( h \) in formulae above
  - Auto calculated if not specified
- Based on factor of edge length of base triangle/quad
- Height determined so that top layer volume is slightly less than that of tetra/hex just above it
- **Number of layers** \( n \)
- **Height ratio** \( r \)
- **Total height** - of all layers
- Usually specify 3 of the above 4 parameters
  - *Compute params* will calculate the remaining parameter (total height usually left blank)
- Or specify only *Height ratio* and *Number of layers* for auto calculation of initial height
- Individual surface/curve height/ratio/layers will override these global defaults if set

**Other global parameters explained later**
Growth Law Comparison

• The growth rate of *Wb-exponential* is greater than *exponential*
• The growth rate of *exponential* is greater than *linear*
Smooth Tetra/Prism Transition

Leave initial height as “0”

• This causes the initial height to float in order to reduce the volume change between the last prism and adjacent tetra.

Initial height specified

Initial height = 0
Setting Prism Parameters on Parts

Prism extrusion areas defined by the parts

- **Mesh > Part Mesh Setup**
- Toggle on **Prism** for parts where inflation layers are desired
  - Surface mesh (tri/quad) gets extruded into prisms
- Set **Height, Height Ratio, Num Layers**
  - Will use global defaults if not set or zero

Applying these settings causes these parameters to be applied to each individual surface within each part.

If **Apply inflation parameters to curves** is toggled on, they will also be set on each curve within each part.
Setting Prism Parameters on Volume Parts

- Normally toggle prism on only for parts that contain surfaces (becomes surface mesh)
- Can also toggle on prism for parts that contain material points (becomes volume mesh)
  - For interior surface mesh, this defines the allowable volumes for extrusion
  - Selecting no volume parts has the same result as selecting all volume parts

![Prism Parts Data]
Setting Prism Parameters on Surfaces

- **Mesh > Surface Mesh Setup**
- You can specify different local *height* and *ratio* on any selected surface without moving the surface to a new part
- Usually set *height* and/or *ratio* smaller on specific surfaces to avoid collision

Collisions occurred when the height was 0.4 on all surfaces

No collisions after
Setting Prism Parameters on Curves

- **Mesh > Curve Mesh Setup**
  - You can get Prism to transition linearly across a surface by not setting a height (height = 0) on the surface, but instead set a different height on each curve on the opposite sides of the prism surface.
  - **Height ratio** and **Num. of layers** have no affect on prism for curve settings.
Run Prism

Can run separately

- **Mesh > Compute Mesh > Prism Mesh**
- The **Select Parts for Prism Layer** button pops up the same menu as the **Part Mesh Setup**, except non-prism related columns aren’t displayed

Input

- **Existing Mesh**
- **From File** (saves memory by not loading mesh)

Or run automatically linked into volume mesh

- Toggle on Create Prism Layers when tetra meshing
- Not advisable if this is the first mesh for a particular geometry
- Must be confident about setup parameters and sizing
- Running prism separately allows you to smooth and error-check the tri or tetra mesh first.
Input as Surface or Volume Mesh

- Input can be a surface mesh or volume mesh
  - Surface mesh
    - Must be a closed boundary mesh
    - Must specify a volume part
    - Use tetra fill methods after:
      - Delaunay
      - Advancing Front
      - Ansys TGrid
  - Volume mesh
    - Moves and reconnects tetras

Prism extrudes into existing tetras

Delaunay fill
Prism – Quality Control Options

Fix marching direction
• Maintains normal from surface
• Can cause intersections with other mesh

Min prism quality
• Either re-smooth directionally or cap/replace with pyramids if quality not met (minimum allowed = 1x10⁻⁶)

Ortho weight
• Weighting factor for node movement from 0 - improving triangle quality, to 1 - improving prism orthogonality

Fillet ratio

Max prism angle

Max height over base

Prism height limit factor

Ratio multiplier (m)
• For varying exponential growth: \[ \text{height} = h(r)^{(n-1)} (m)^{(n-1)} \]

See next slides
Prism Options – Fillet Ratio

– Blends prism grid lines around sharp corners
  • 0 = no fillet
  • 1 = fillet ratio equals last prism height
– Improves angles further away from the corner
– Orients prisms more in direction of flow
– If meshing tight spaces with tight curves (less than 60°), may not have space for a fillet ratio

\[ \text{Fillet Ratio} = \frac{r}{h} \]

Fillet Ratio = 0.0  Fillet Ratio = 0.5  Fillet Ratio = 1.0
Prism options – Max Prism Angle

– Controls prism layer growth around bends or adhering to adjacent surfaces

– If the $\textit{Max}$ (internal) $\textit{Prism Angle}$ is not met, the prism layers will end and be capped off with pyramids in those locations

– Usually set in the $120^\circ$ to $179^\circ$ range

– Experience pays off here. If extruding from one part and not its neighbor, and the angle between the two surfaces is greater than the $\textit{Max Prism Angle}$, the prisms will detach and be capped off with pyramids. This prevents bending the prisms that might create lower-quality internal angles. However, the pyramids are usually of lower quality, too.

– It’s usually better to run prism along adjacent surfaces until it can meet at a smaller angle, leaving quad faces. Pyramids will be avoided.

Original mesh

Max prism angle = $180^\circ$

Max prism angle = $140^\circ$. 

Pyramids
Prism Options – Max Prism Angle - Continued

A high (up to 180°) *Max Prism Angle* keeps the prism layers connected around tight bends.

- Set this at 180 to prevent pyramids where possible

Max Prism Angle = 140

Max Prism Angle = 180
Prism Options – Max Height Over Base

- Restricts prism aspect ratio
- Prism layers stop growing in regions where prism aspect ratio would exceed specified value
  - Number of prism layers would not be preserved locally
- Mesh is made conformal with pyramids at prism boundaries
- Acceptable values vary widely (typically 0.5 – 8)

Max Height Over Base not set

Max Height Over Base = 1.0
Prism Options – Prism Height Limit Factor

- Restricts prism aspect ratio
  - Prism height will not expand once this factor is met
- Uses the same height over base factor as the previous metric except prism layers are not capped off with pyramids
- Preserves the specified number of prism layers
- Will fail if sizes of adjacent elements differ by more than a factor of 2
- Acceptable values vary widely (typically 0.5 – 8)

\[
\frac{\text{Height (h)}}{\text{Base (b)}} = \frac{\text{Largest height over smallest base length}}{h/b}
\]

Limit factor not set

Limit factor = 0.5
Prism Options-Part Control

**New volume part**
- Can specify new Part for prism elements
  - Must specify if extruding from surface-only mesh
  - If extruding into volume mesh, prism will inherit tetra volume Part if not specified

**Side part**
- For quad faces on side boundary

**Top part**
- For tri faces capping off top of last prism layer

**Extrude into orphan region**
- Extrude prisms away from existing volume, not into it
- Must specify *new volume, side and top part*, or they’ll be in ORFN

Leaving these parts blank will inherit the names from the current mesh.
Prism Options - Smoothing

• Preparés tri/tetra for best prism quality
  – Set surface/volume steps to 0 if only extruding one layer or if tri/tetra mesh is already smoothed
    • Otherwise defaults adequate
    • Value depends on model/user experience
  – Set surface smoothing steps to zero for a tri/tetra mesh that is already smoothed
  – Triangle quality type
    • Laplace typically best for eventual prism quality
    • Other types may be better when marching directions condense at inside corners
  – Max directional smoothing steps
    • Redefines extrusion direction based on initial prism quality
    • Internally calculated for each layer

• Other Advanced Prism Meshing Parameters
  – Detailed in Help menu (usually left default)
Prism Parameters File

- **Read a Prism Parameters File**
  - To set all prism values from a prism settings file (*.prism_params)
  - Written to the working directory every time prism is run
Smoothing a Tetra/Prism Mesh

After generating prisms:

*Edit Mesh > Smooth Mesh Globally*

- Prisms are smoothed during prism generation
- If input mesh was a tetra mesh, the tetras adjacent to the last prism layer will be messed up
- First smooth only the tetras and tris
  - Set PENTA_6 to Freeze
  - Don’t want to modify the prism layers at this point
- Once tetra and tri elements are as smooth as possible, smooth all elements
  - Set PENTA_6 to Smooth
  - Decrease the *Up to quality* value so as not to distort prism elements too much

The prisms get compromised a bit when everything is on smooth

![Diagram showing mesh smoothing process]
Splitting Prism Layers

If many prism layers are desired, it is faster, but less robust – to create “fat” layers and then split them with mesh editing.

- **Edit Mesh > Split Mesh > Split Prisms**
  - **Fix ratio:** The layer is split such that its resulting layers employ the given growth ratio (height is free variable)
  - **Fix initial height:** The layer is split such that its first sub-layer is of the given height (ratio is free variable)

Specify the number of layers to result from each existing layer

- Can split specified or all existing layers
Redistributing Prism Layers

Redistribute prism layers after splitting

- **Edit Mesh > Move Nodes > Redistribute Prism Edge**
  - **Fix ratio:** The initial height and subsequent layer heights will be adjusted to achieve this growth ratio
  - **Fix initial height:** The growth ratio is the variable that will be adjusted to achieve this initial height
  - The total prism thickness remains fixed and layers are adjusted within this thickness
Demo – 3D Pipe Junction

- Setting prism parameters
- Extrude prism into tetra mesh
- Initial height as zero
- Smoothing
- Cut plane
Workshops

• Workshop 1 – Waterjacket Section
  – Setting prism parameters
  – Prism into tetra mesh
  – Inspecting pyramids
  – Setting local heights
  – Remesh to get rid of pyramids
  – Redistribute prisms

• Workshop 2 – Wingbody
  – Prism from surface mesh
  – Create a density region
  – Delaunay fill
  – Smoothing
  – Hexa core fill