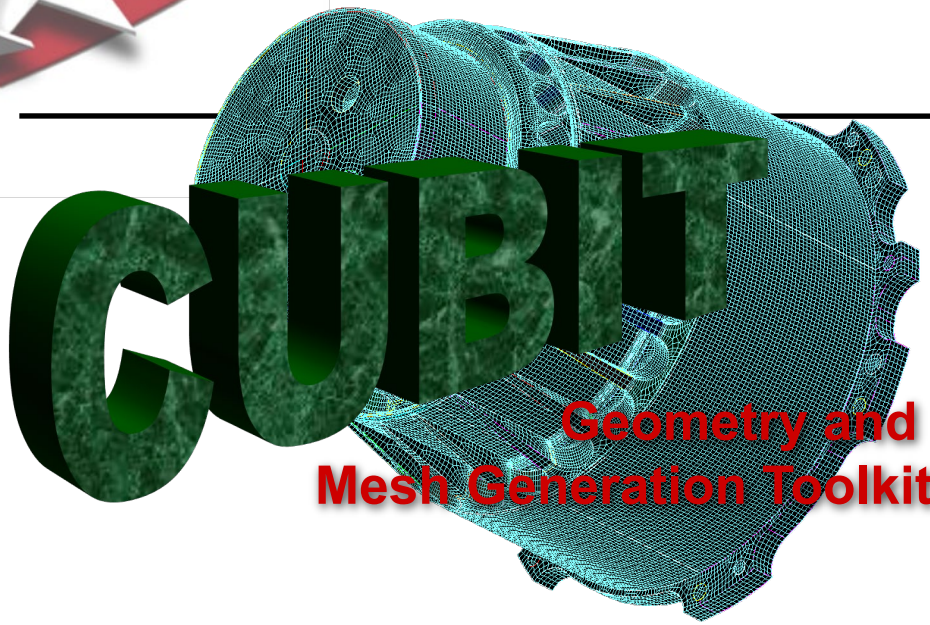

Simulation Modeling Sciences

CUBIT Fast-Start Tutorial

26. Tet Meshing Best Practices

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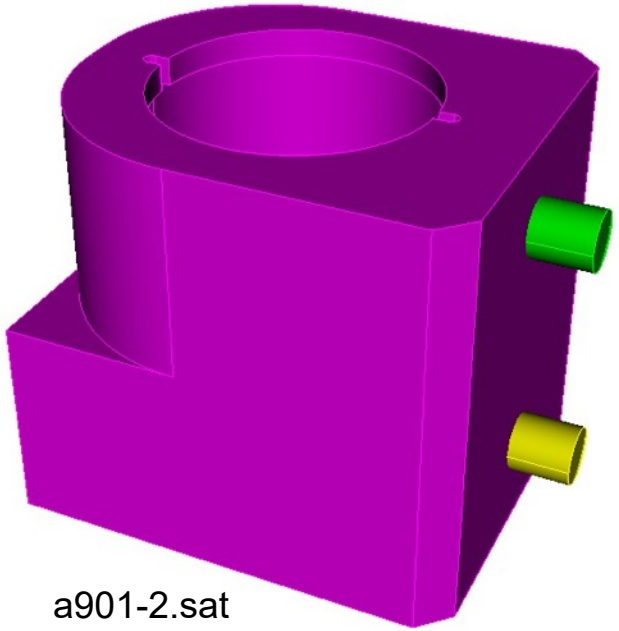
Tet Meshing Best Practices

- **Automatic Tet Meshing**
  - No decomposition required
  - But geometry issues must be addressed
    - **Small features**
    - **Gaps, overlaps, misalignments**
  - Ensure elements are good quality
    - **Scaled Jacobian**
    - **In-radius (size) to ensure reasonable time step**
- **Best Practices**
  - Depends on application
  - Check with colleaugues
    - **wiki pages**
    - **journal files**
  - Recommended operations, practices
    - **presented here**

Selected Best Practices

- **Block Assignment**
- **Time Step Metric**
- **Defeaturing**
  - Heal and Regularize Operations
  - Remove Cone Surfaces
  - Geometry Power Tool
  - Surface Removal/Composting
  - Blunt Tangency
- **Imprint/Merge**
- **Tet Meshing**
  - Deviation and Gradation
  - Geometric Sizing
- **Overlap Detection/Correction**
  - Geometry Overlap
  - Mesh Overlap
- **Massive Composite Operation**
  - Tiny Edge Length
- **Grouping with Extended Parsing**



a901-2.sat

For this tutorial we will be using the following model to illustrate some of the best practices

import acis "a901-2.sat"

Block Assignment

Create Blocks

Blocks are used to group elements together according to a common material

Creating blocks and assigning volumes to blocks is good practice

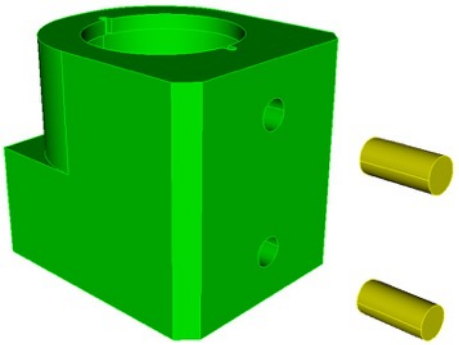
Tets that we create later will be automatically assigned to the blocks

Name the blocks for easier reference

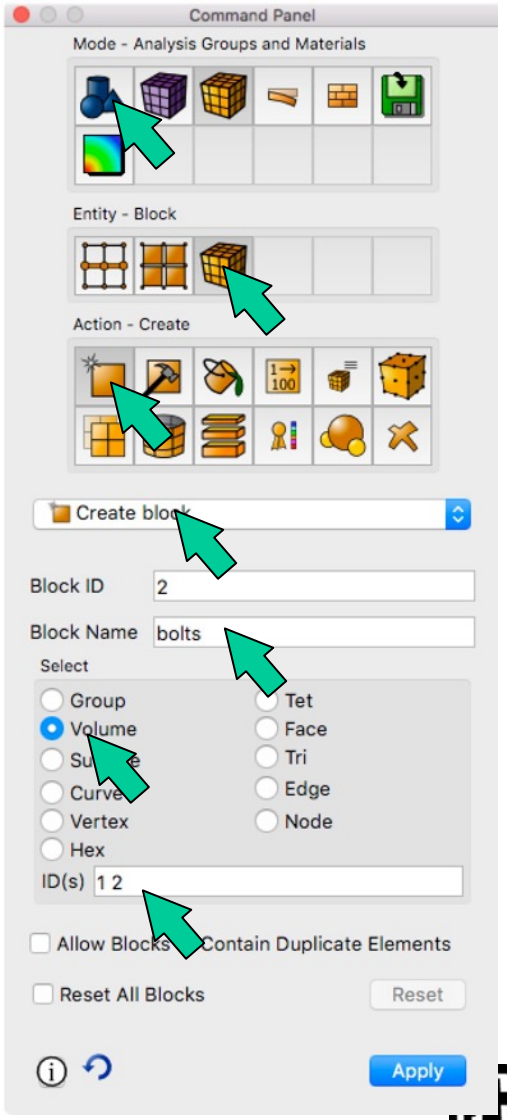
block 1 volume 3
block 1 name "casting"

block 2 volume 1 2
block 2 name "bolts"

draw casting
draw bolts



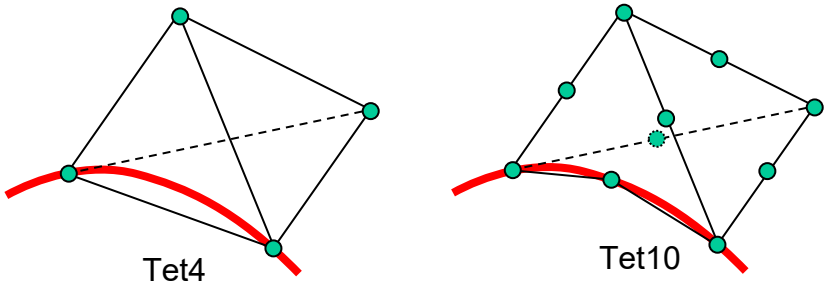
casting bolts



Block Assignment

Element Type

Tet10 elements are preferred over Tet4s



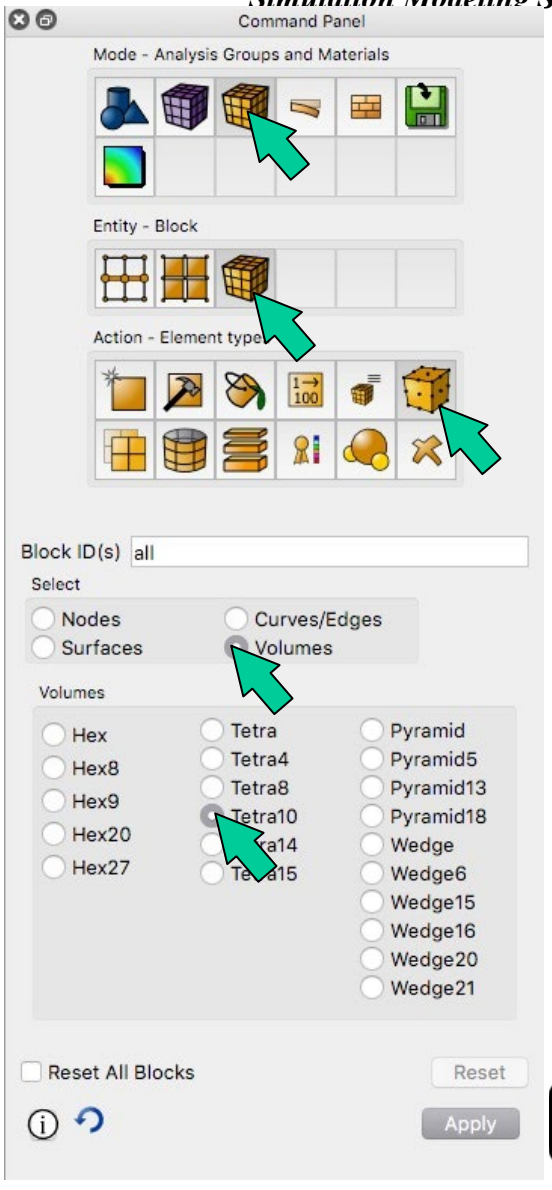
Element types are defined on the block (one element type per block)

bolts element type tetra10
casting element type tetra10

Ensure mid-side nodes will be projected to geometry when needed

set node constraint smart

(should be default)



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Time Step Metric

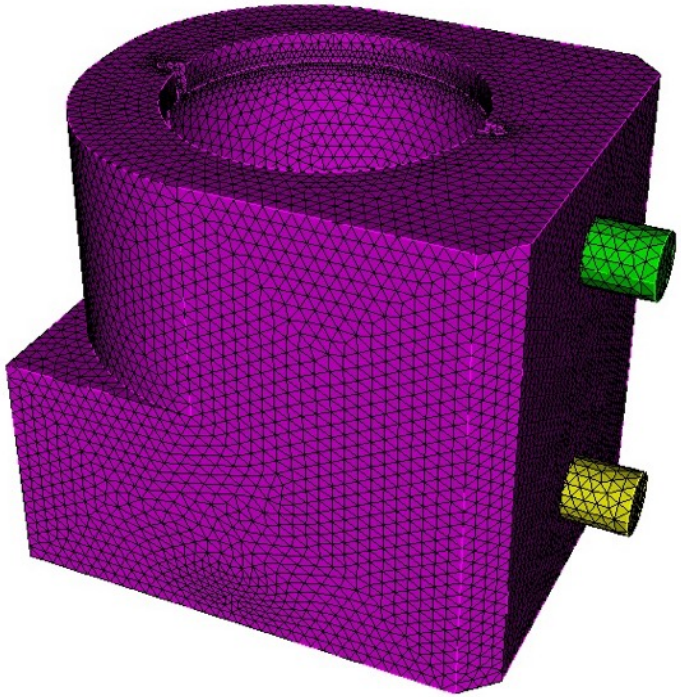
- Small elements can result in very small time steps in your analysis.
- Smallest element size can control how long your analysis will take to run when using explicit transient dynamics codes.
- Cubit can display metric based on time step

vol all scheme tetmesh

vol all size 0.2

mesh vol all

list totals



Time Step Metric

From the Command Panels, create a material by copying Default-Steel and then assign the new material to the blocks

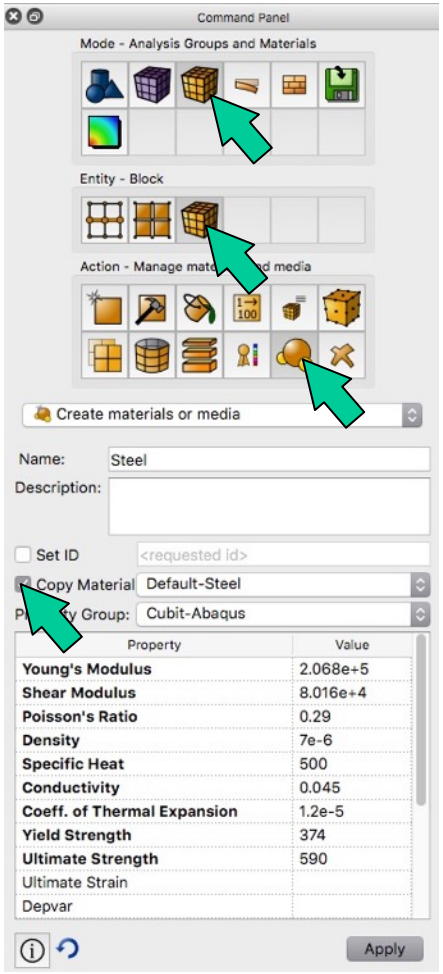
Or from the command line:

create material name 'steel'
elastic_modulus 2.068e5
poisson_ratio 0.29
density 7e-6

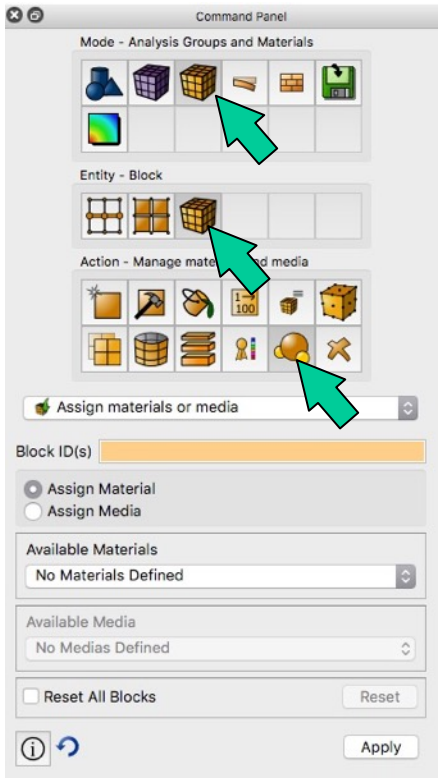
casting material 'steel'

bolts material 'steel'

1. Create Material



2. Assign Material to Block

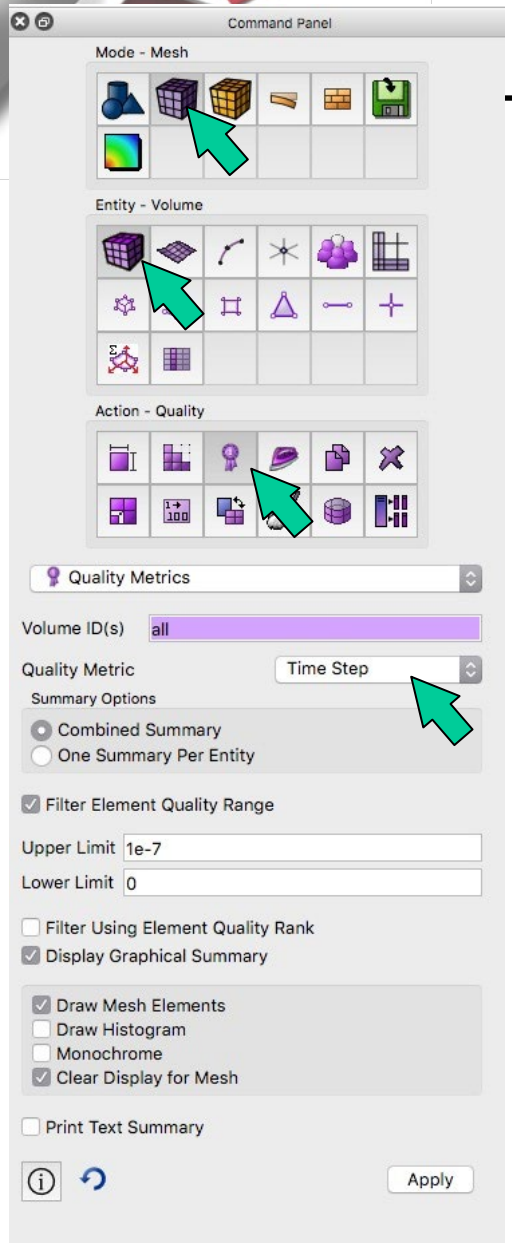


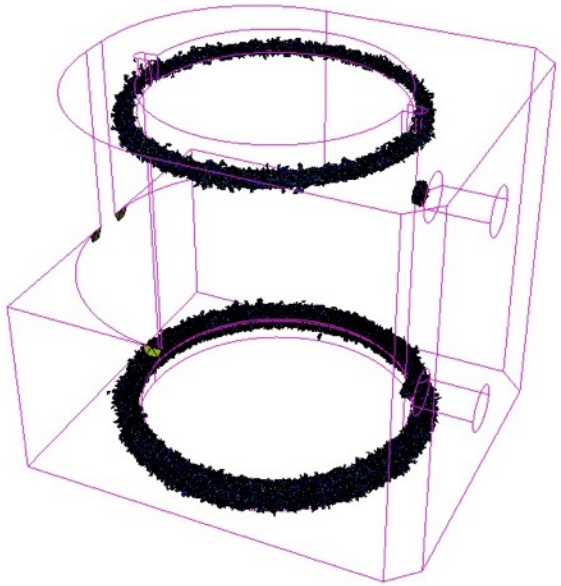
Time Step Metric

Note that materials can be created from command line. Consider creating a set of commonly used materials in a journal file

Display the time step metric on the current tet mesh

Filter the element quality to display only elements with time step less than 1.0e-7

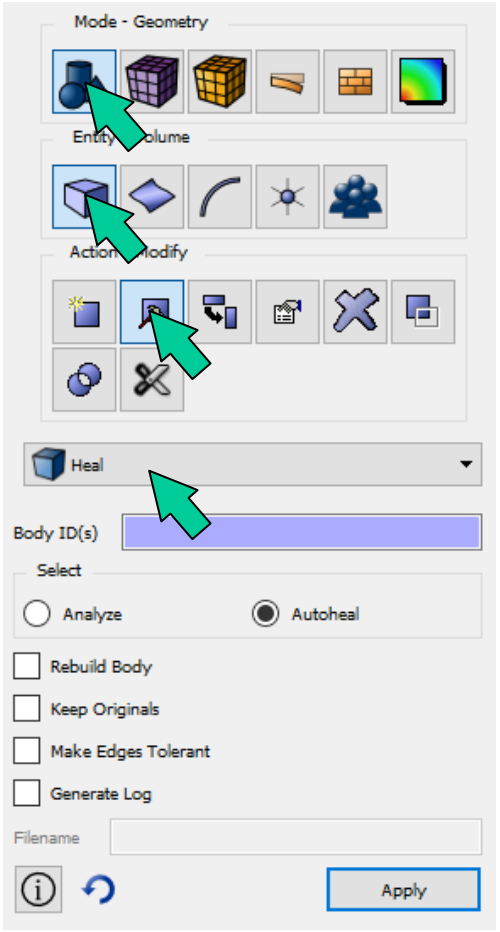




Note where "poor" elements are located. What is causing elements to be "small"?

Healing

Healing can fix geometry problems introduced by the CAD tool that was used to build the model



Analyze Lists problems with the selected volumes

healer analyze volume all

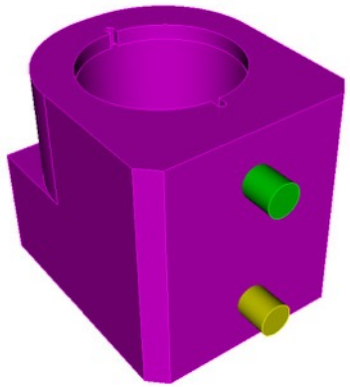
validate volume all

AutoHeal Attempts to fix the problems

healer autoheal volume all

HEALER ANALYSIS SUMMARY:

Analyzed 3 Volumes: 1 to 3
Found 0 bad Vertices.
Found 0 bad Curves.
Found 0 bad CoEdges.
Found 0 Bodies with problems.

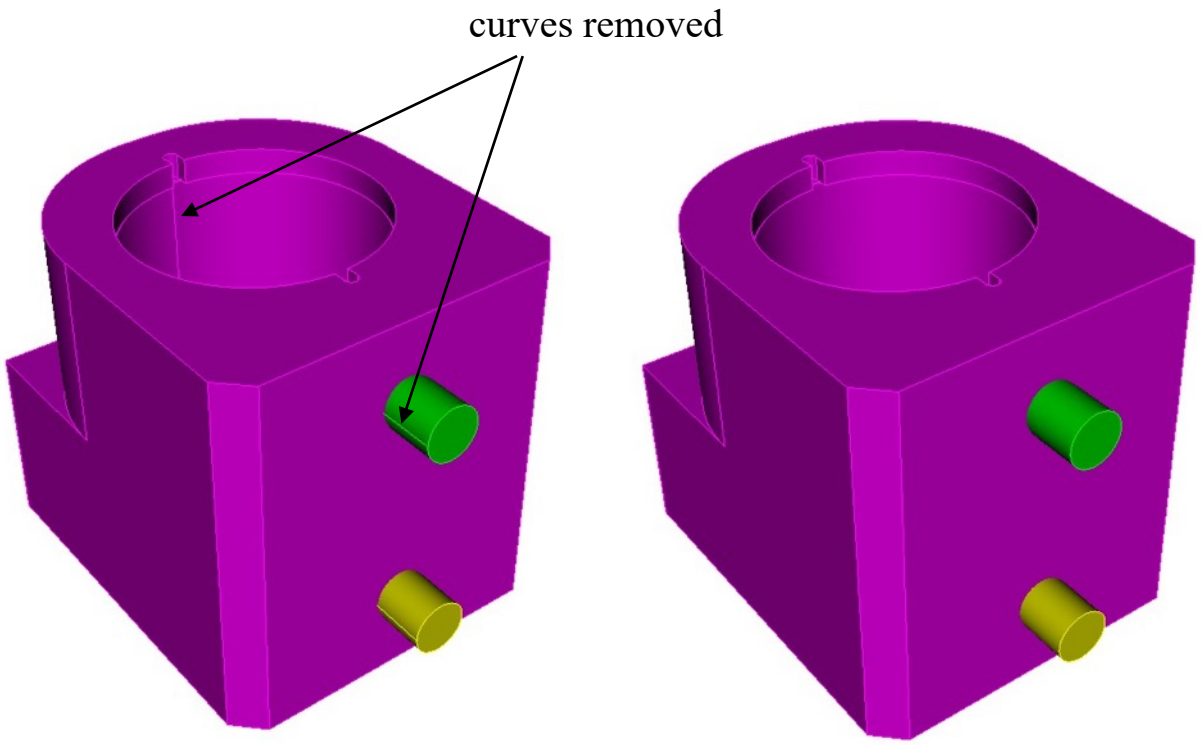


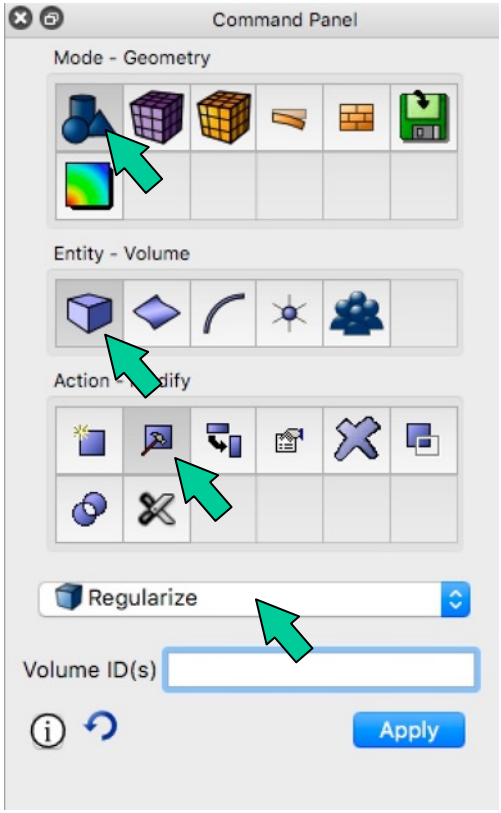
Regularize Operation

Adjacent surfaces that share the same analytic definition can be combined

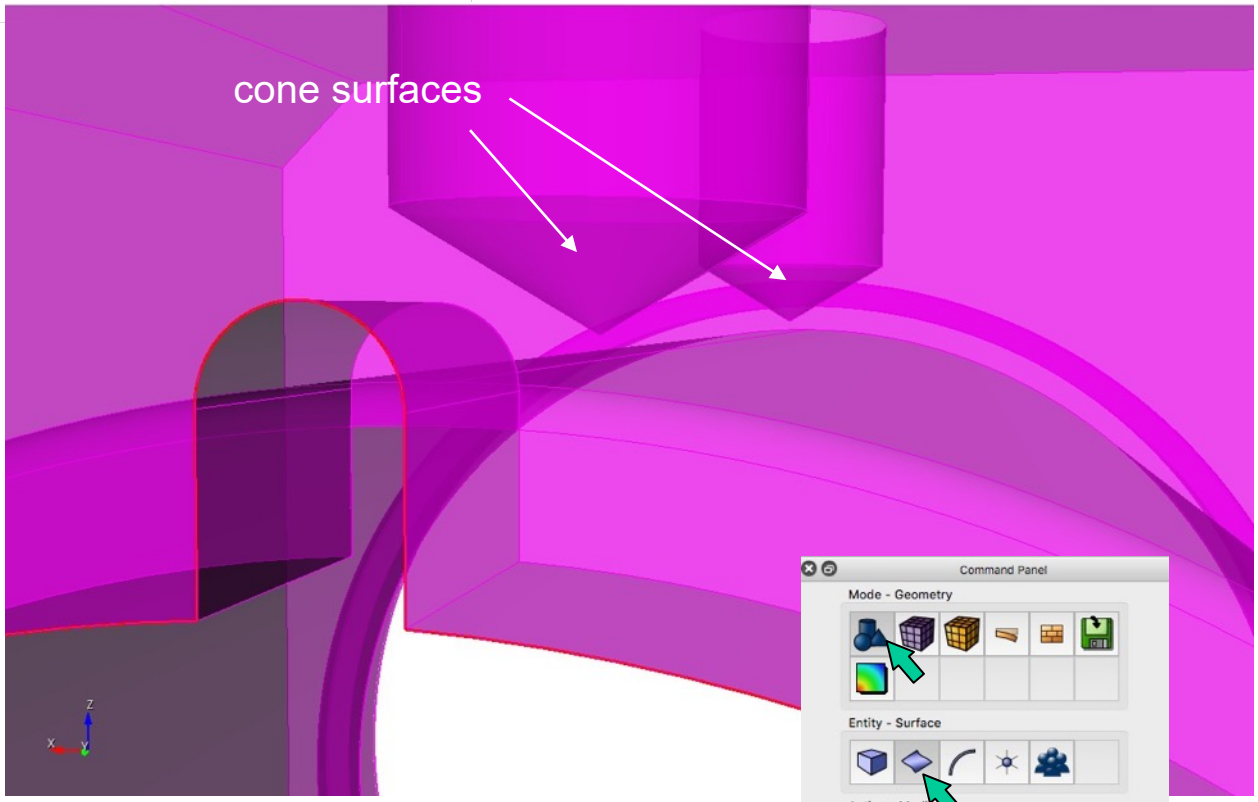
Removes unnecessary curves

regularize vol all





Remove Cone Surfaces



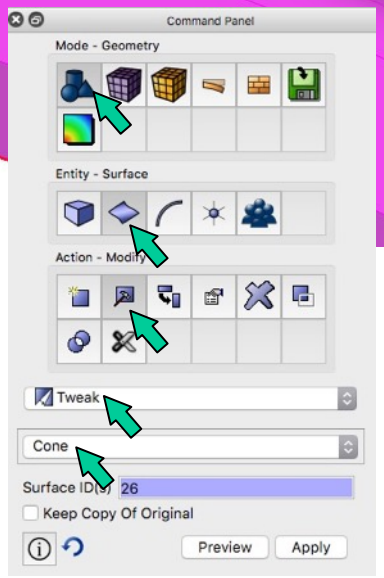
Cone Surfaces often occur at the bottom of cylindrical holes.

The vertex at the apex of the cone can result in very small tets.

Its usually safe to remove cone surfaces

To remove cone:

tweak surface 50 cone
tweak surface 26 cone



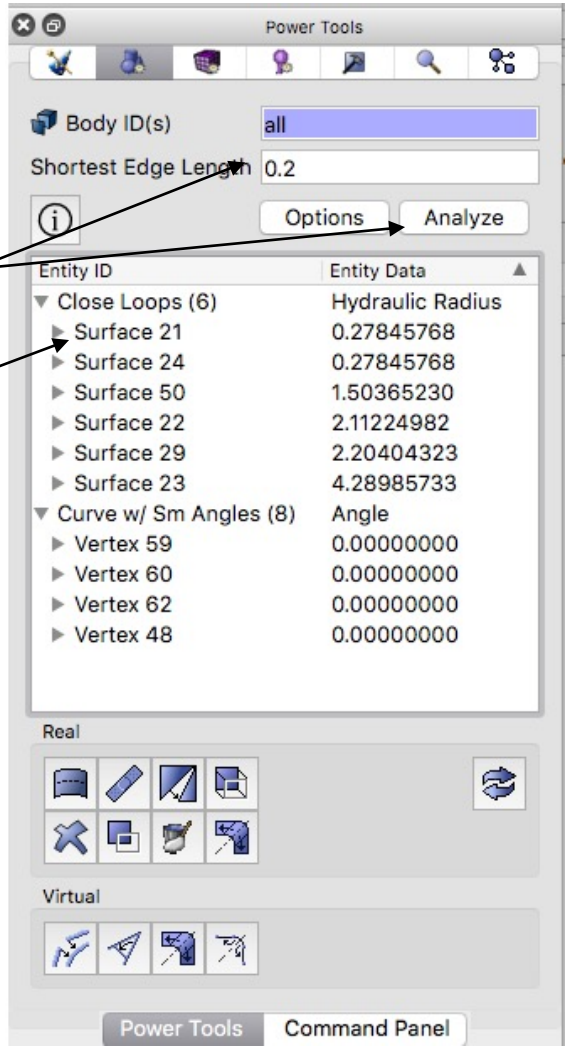
Tweak Remove Cone Command Panel

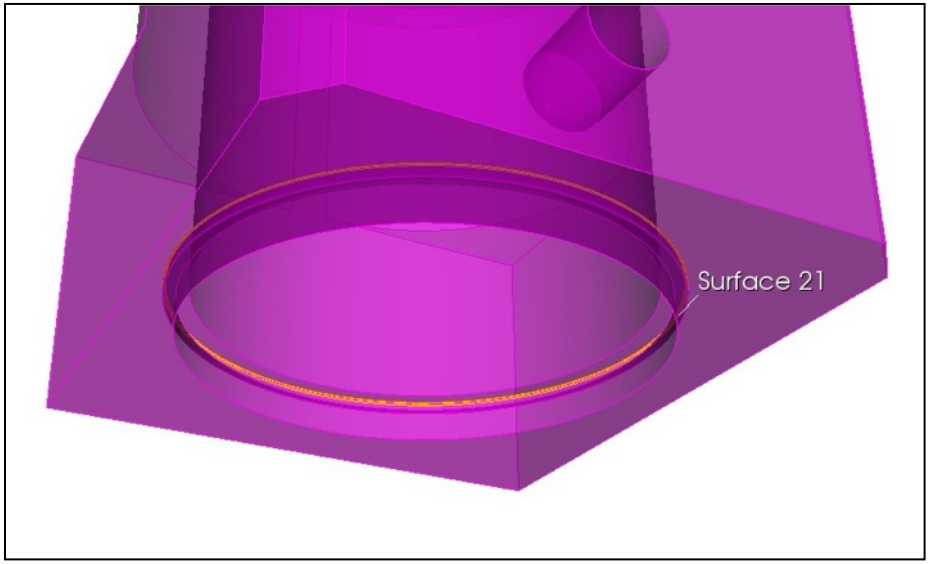
Geometry Power Tool

Use the Geometry Power Tool to detect small curves and surfaces that may be constraining the element sizes

Enter a small edge length and click Analyze

Right Click and Select Fly-in or Zoom to examine each





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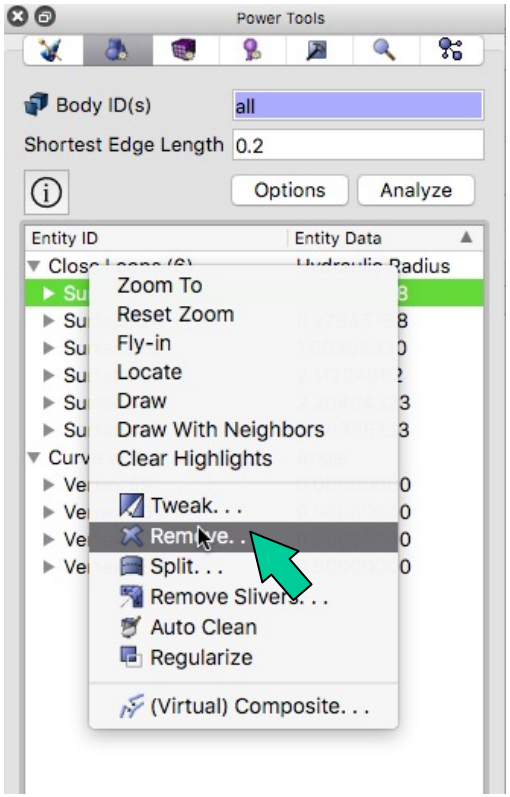
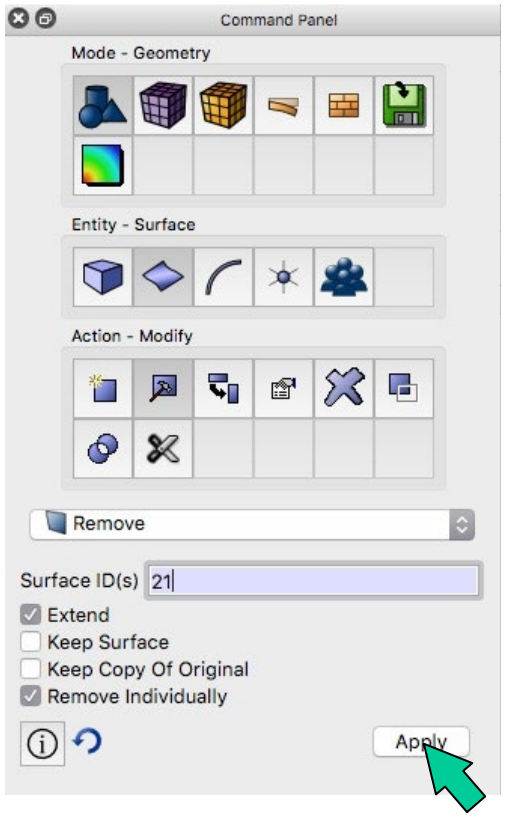
Geometry Power Tool

Remove Close Loops



Right Click on Surface ID and Select **Remove...**



Remove Surface panel should appear. Select **Apply**

Try removing other surfaces identified as **Close Loops**

Check for Errors.

Note that all **Close Loops** may not be able to be removed in this manner.

Try other operations if "Remove" does not work

Hint: *tweak replace with surface, webcut with surface extended, unite volumes, etc..*

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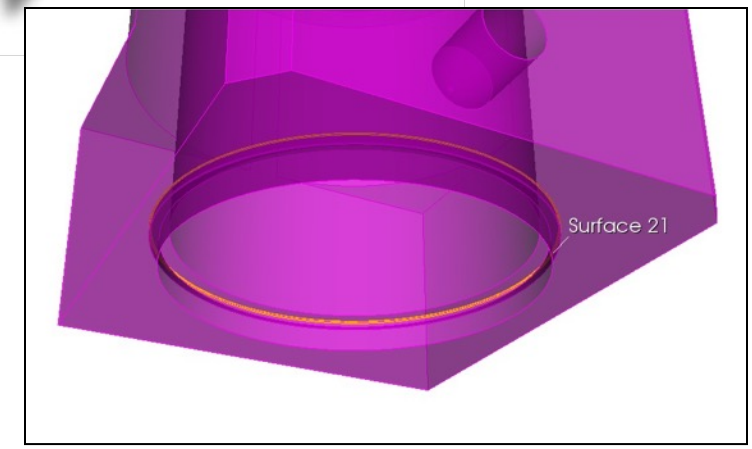
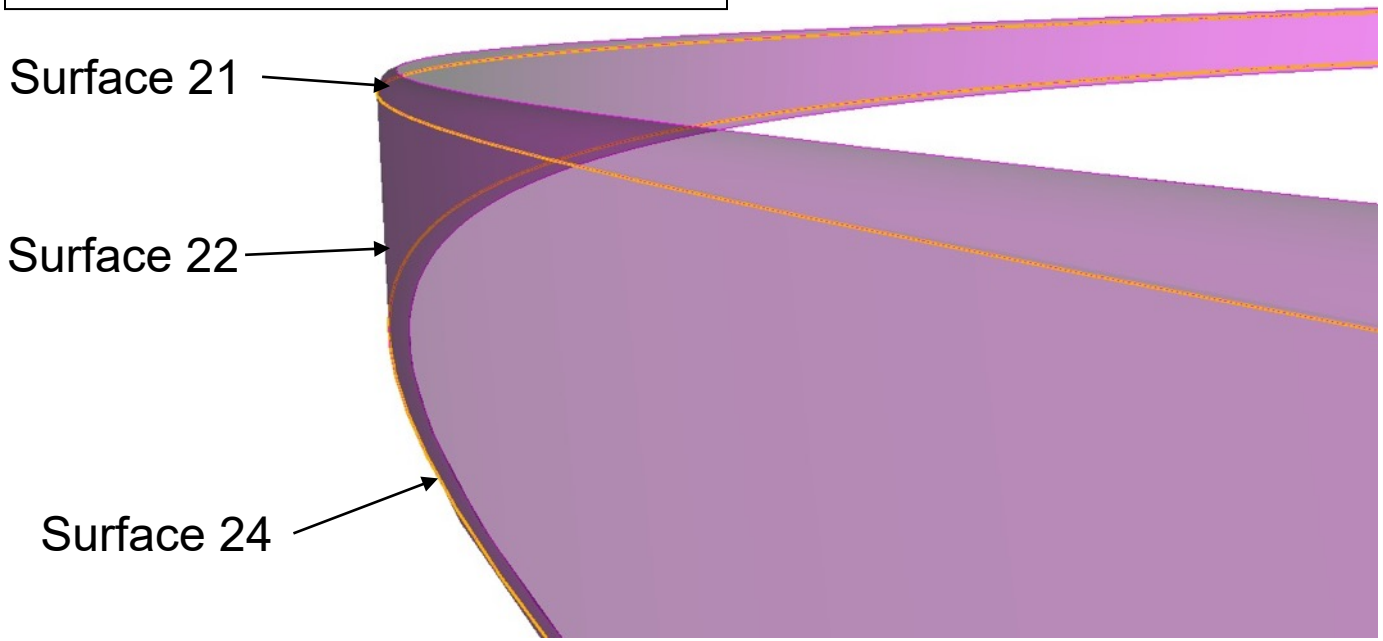
Geometry Power Tool



Remove skinny (close loop) surfaces

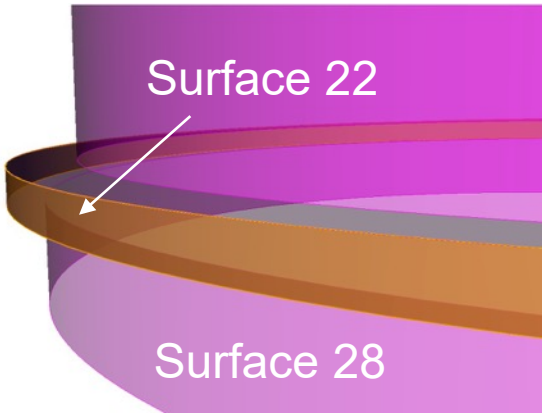
tweak surface 21 remove extend
tweak surface 24 remove extend

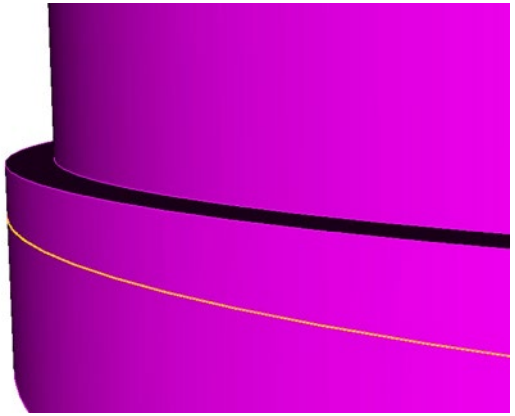


Geometry Power Tool

Remove indentation by tweaking surface 22 to surface 28

draw curve in surface in curve in surface 22





tweak replace

regularize

tweak surface 22 replace with surface 28

regularize vol all

Geometry Power Tool

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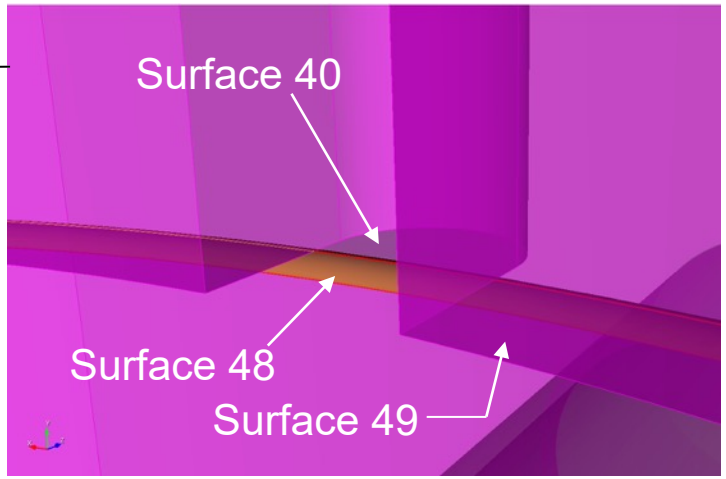
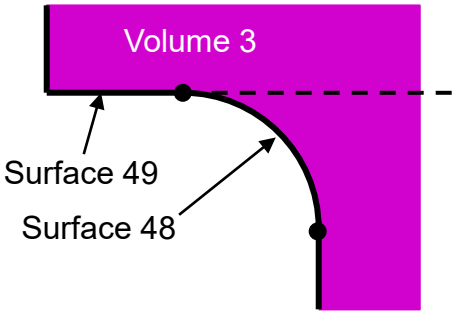


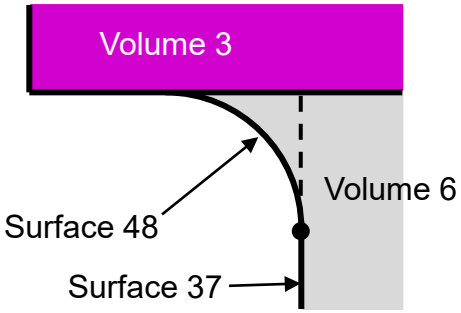
Remove fillet at surface 48 by webcutting

- **tweak remove** can not be used for surface 48 because adjacent surfaces can't be extended to fill

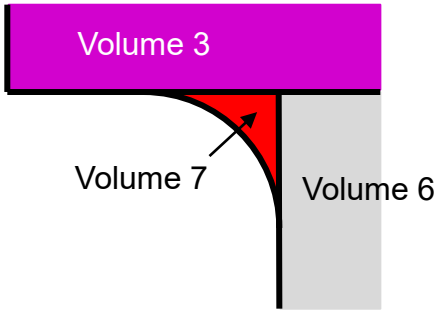
zoom surface 40



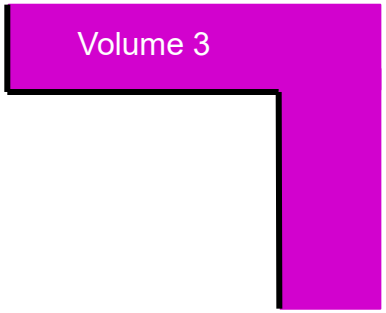
1. webcut with surf 49



2. webcut with surf 37

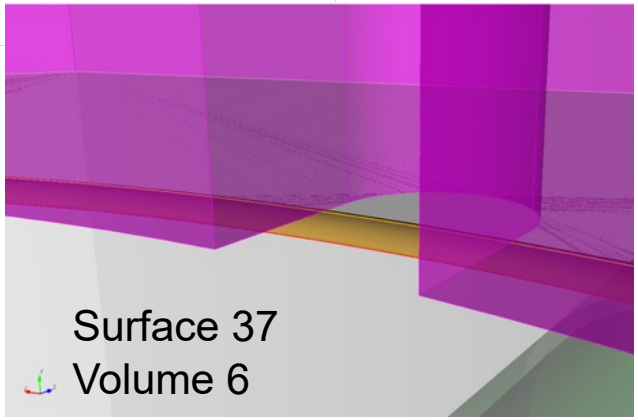


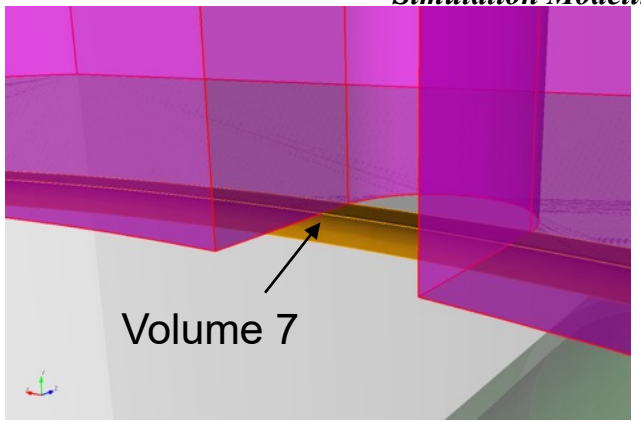
3. delete vol 7



4. unite vol 3 6

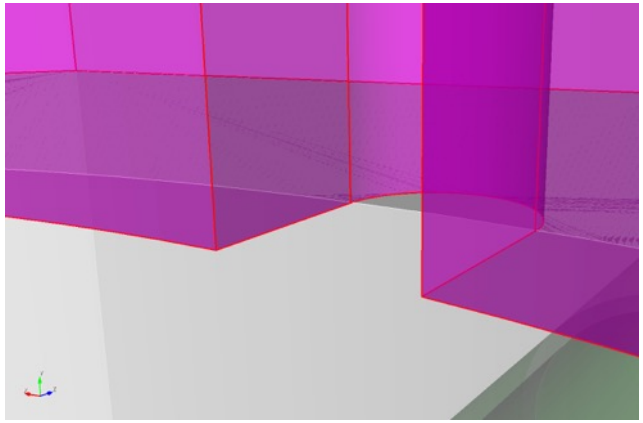
Geometry Power Tool



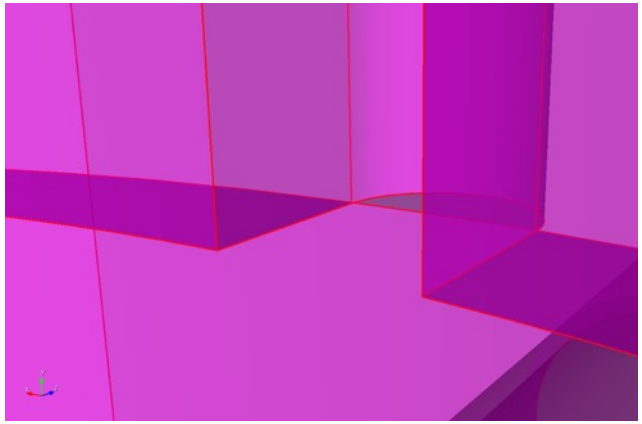


webcut volume 3 with sheet extended from surface 49

webcut volume 6 with sheet extended from surface 37

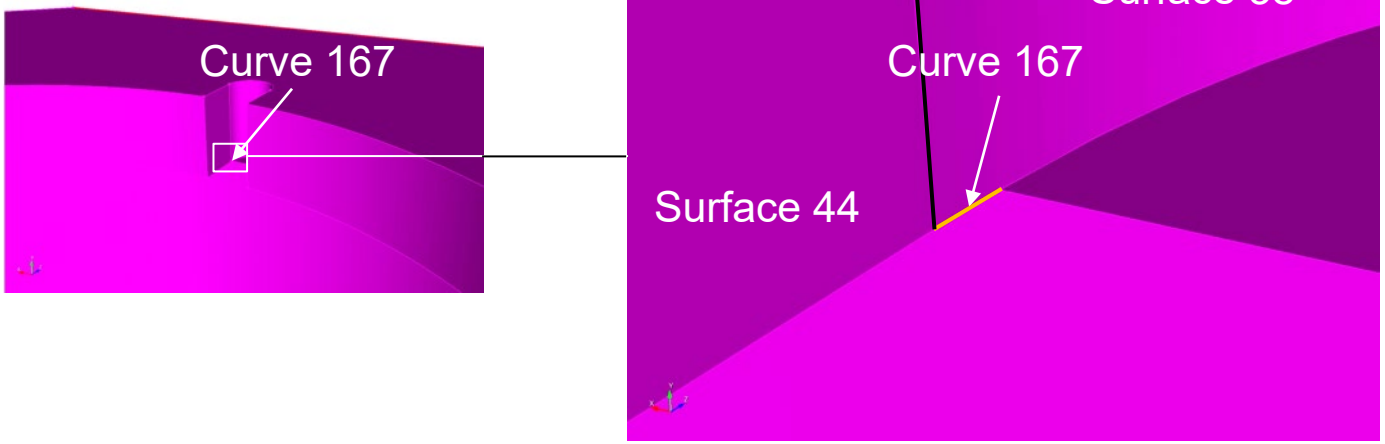


delete volume 7



unite volume 3 6

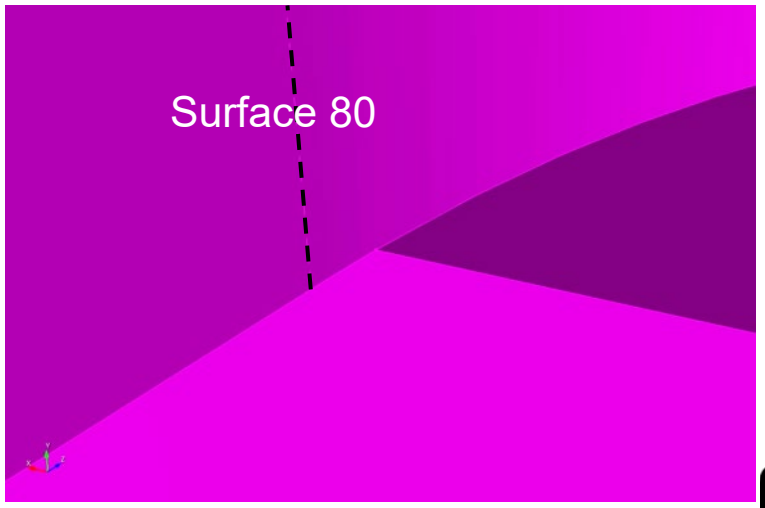
Geometry Power Tool



Remove small curves by compositing adjacent surfaces

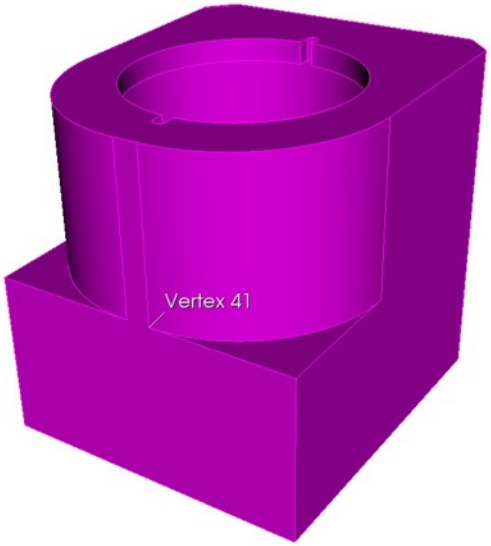
zoom curve 167

composite create
surface 44 38 43
composite create
surface 42 45 39



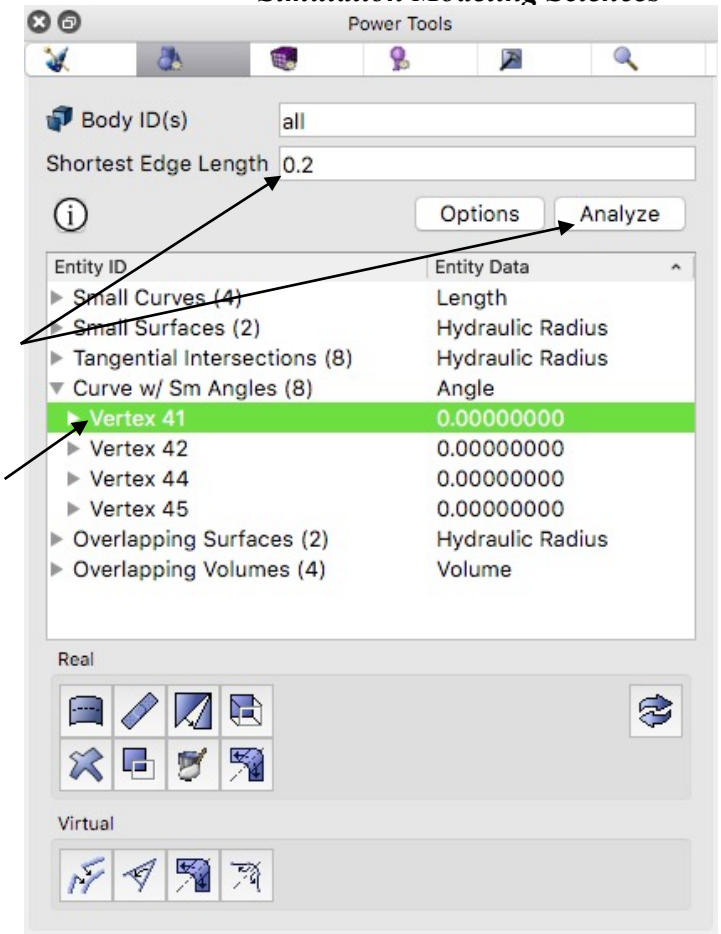
Geometry Power Tool

Curves with small angles (tangencies) can constrain mesher resulting small angles

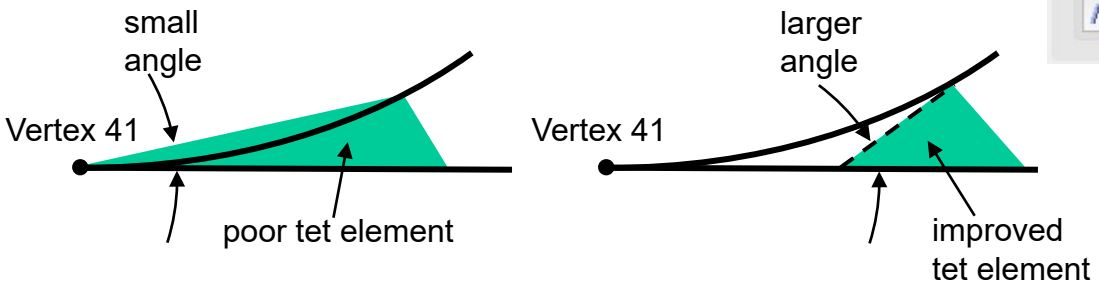


Enter a small edge length and click Analyze

Right Click and Select Fly-in or Zoom to examine each



Blunt Tangency Operation



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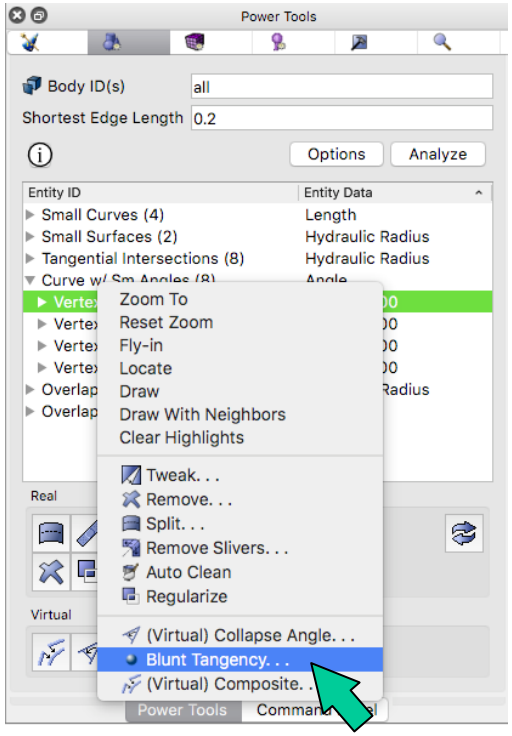
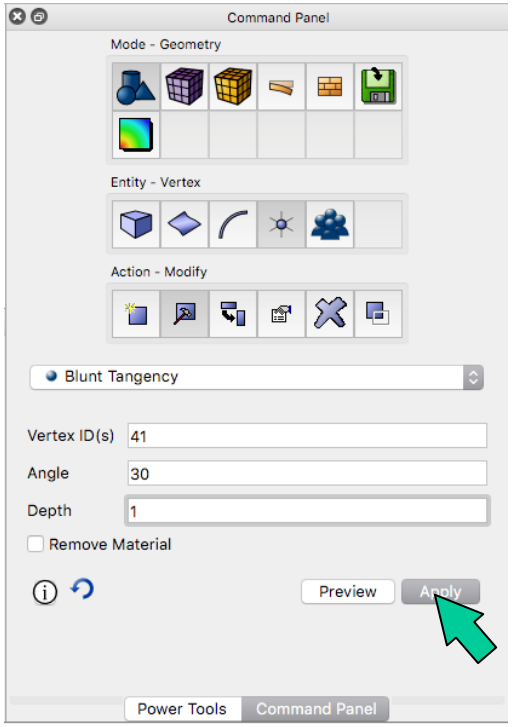
Geometry Power Tool

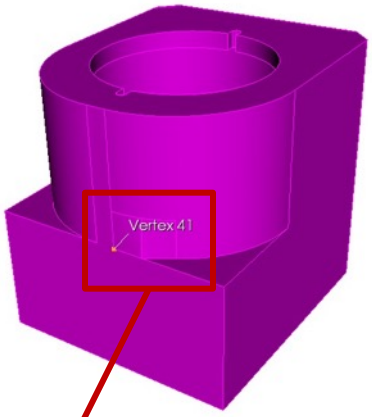
Remove Small Angles at Vertices

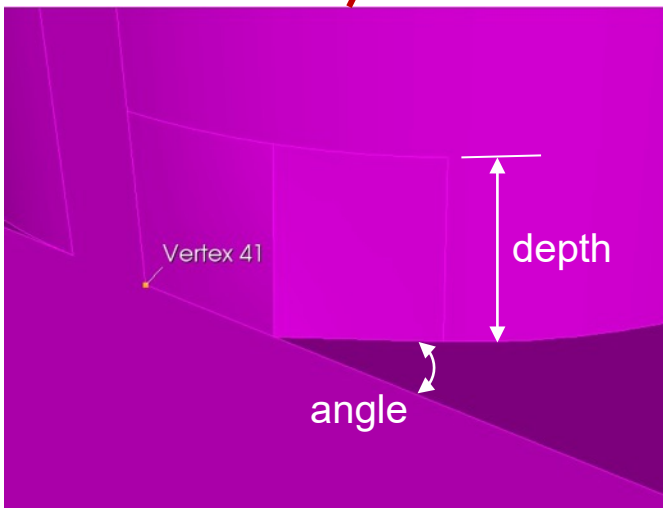


Right Click on Vertex ID and select **Blunt Tangency...**



Set an Angle and Depth (or use Default). Click **Preview** and **Apply**





Blunt Tangency will "blunt" the angle at a vertex to avoid small angles in tets

Try removing all tangencies

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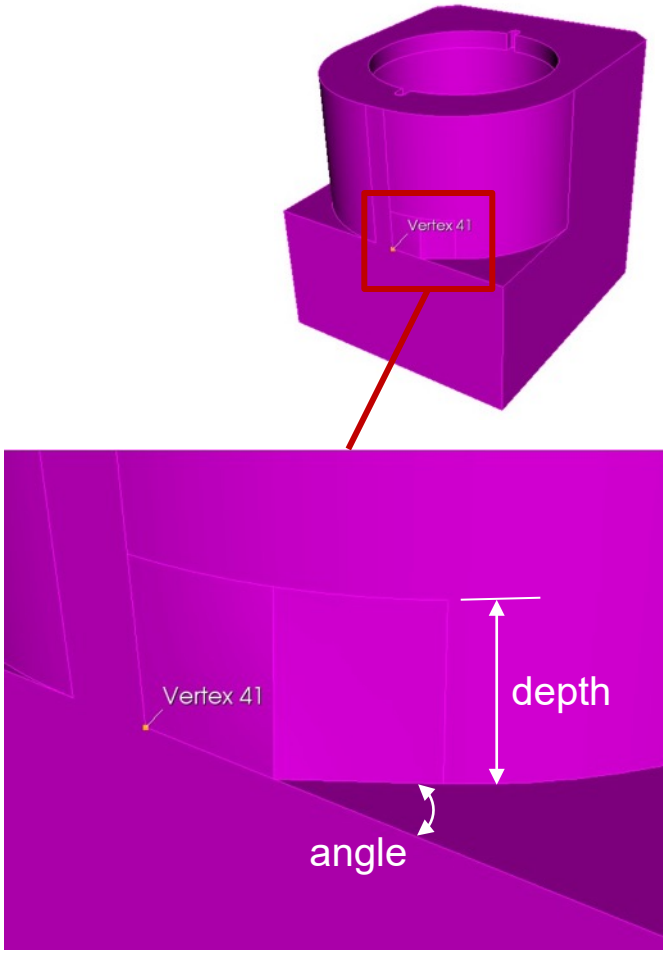
Geometry Power Tool

Blunt Tangency

blunt tangency vertex 41 angle 30 depth 1
blunt tangency vertex 42 angle 30 depth 1
blunt tangency vertex 44 angle 30 depth 1
blunt tangency vertex 45 angle 30 depth 1



Overlap Detection/Correction

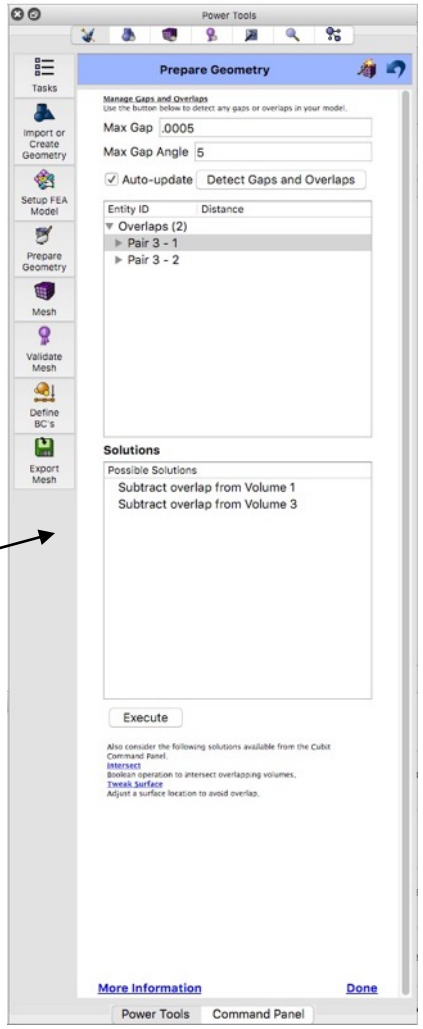
Check to see if any volumes overlap

measure volume all overlap

Pairs of intersected volumes are as follows:
Volume 1 (Volume 1) and Volume 3 (Volume 3) Overlap.
Volume 2 (Volume 2) and Volume 3 (Volume 3) Overlap.

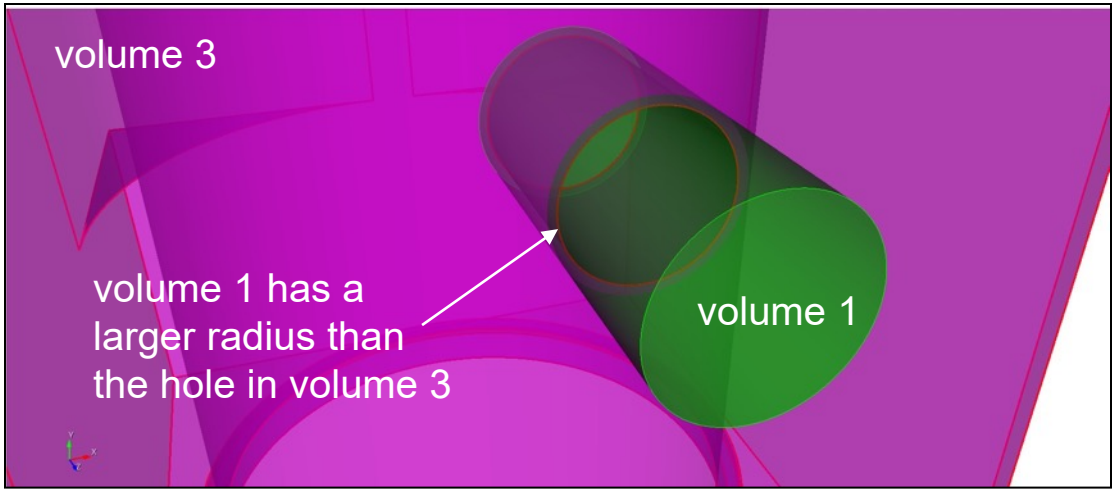
The Manage Gaps and Overlaps Tool in the ITEM Wizard can also be used to interactively explore overlaps

- Click on Power Tools
- Wizard Icon
- Prepare Geometry
- Connect Volumes
- Manage Gaps and Overlaps



Overlap Detection/Correction

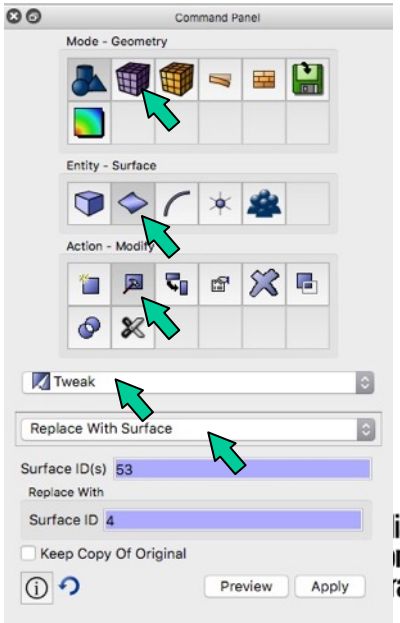
Note the overlap between cylinder and hole. This can be a common occurence



draw volume 1 3

Tweak Replace operation can be used to increase the radius of the hole or decrease the radius of the cylinder

Tweak Replace command panel



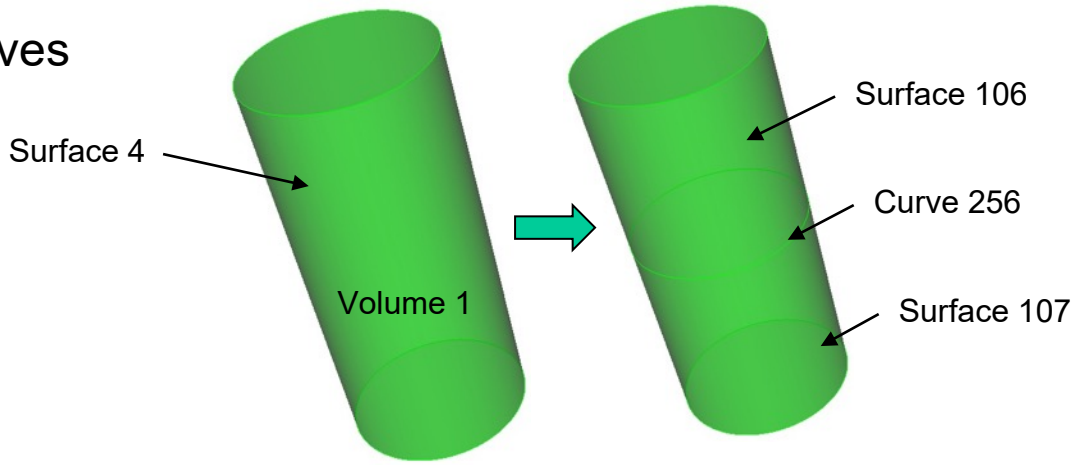
tweak surface 51 replace with surface 4

tweak surface 27 replace with surface 8

Imprint and Merge

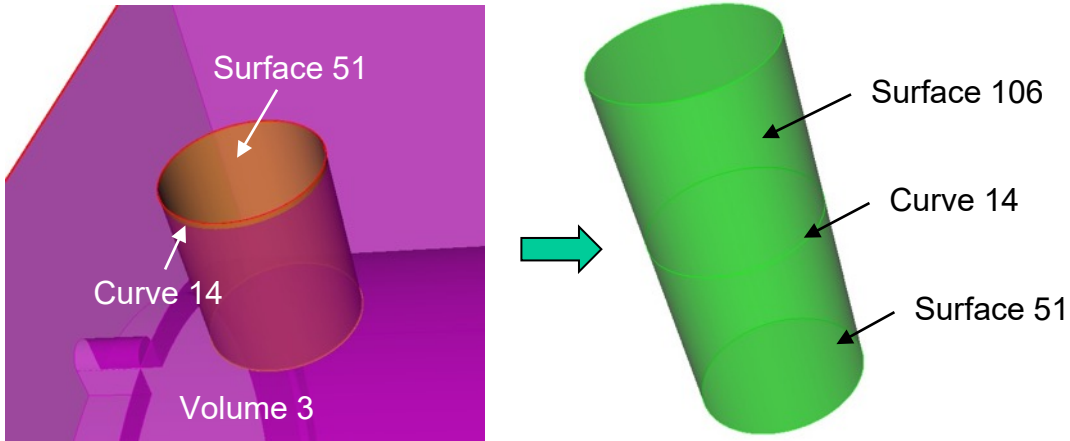
Imprint operation adds curves and surfaces

imprint all



Merge operation combines curves and surfaces

merge all



After meshing, faces and nodes will be shared across merged surfaces

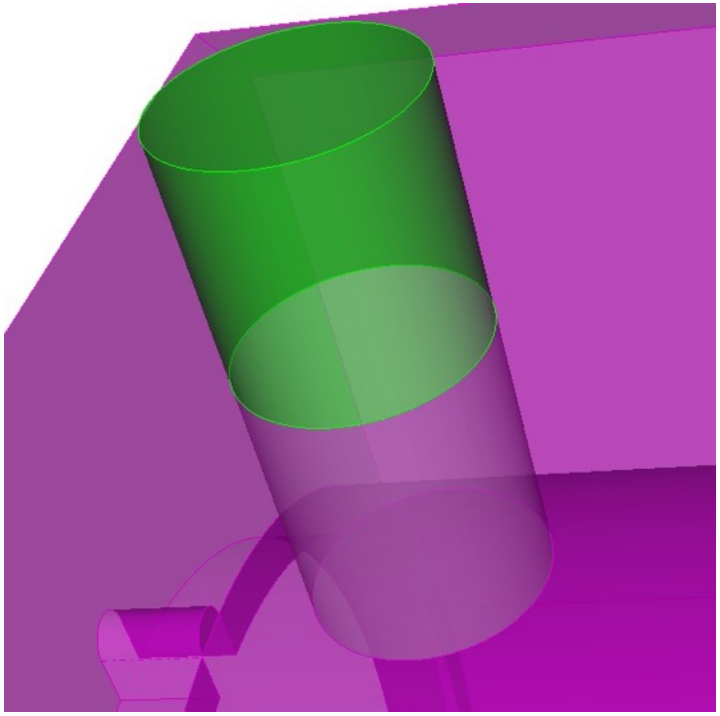
Imprintand Merge

Following merge operation, check Cubit output

- Should be 0 curves and 0 vertices merged

```
Cubit>merge all

...Merging all features in the model

...Merging all Surfaces in the model
Consolidated 4 pairs of surfaces

...Merging all Curves in the model
Consolidated 0 pair of curves

...Merging all Vertices in the model
Consolidated 0 pairs of vertices
All detected matches successfully merged
Journaled Command: merge all
```

Cubit output from merge all command



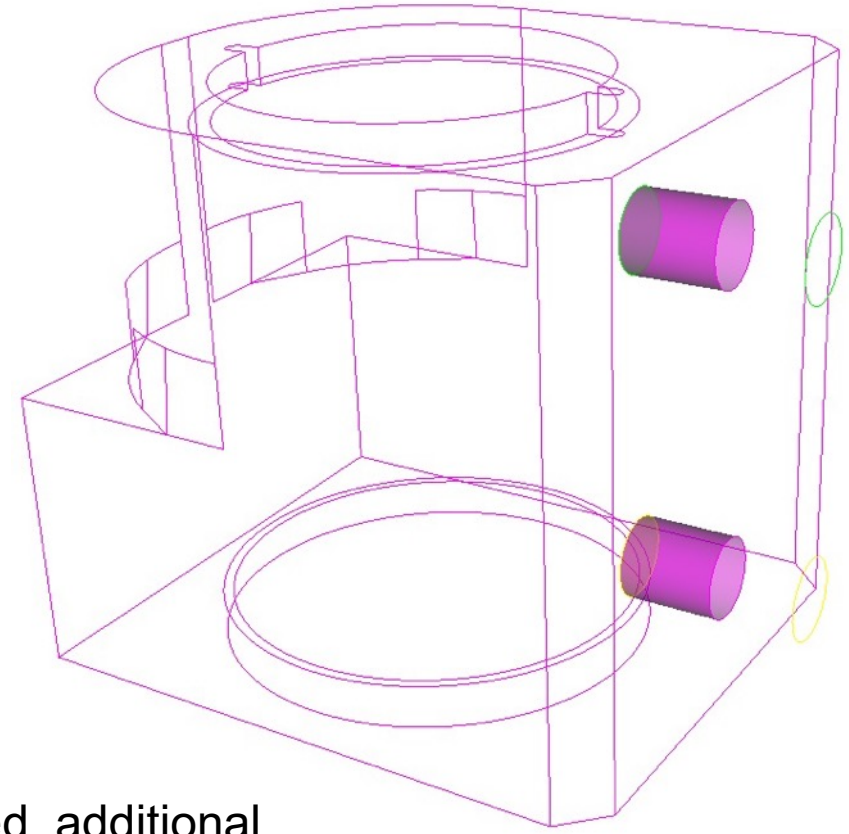
Imprint and Merge

Check merged surfaces

Use **is_merged** keyword to verify all surfaces are correctly merged

draw surface with is_merged

draw curve all add

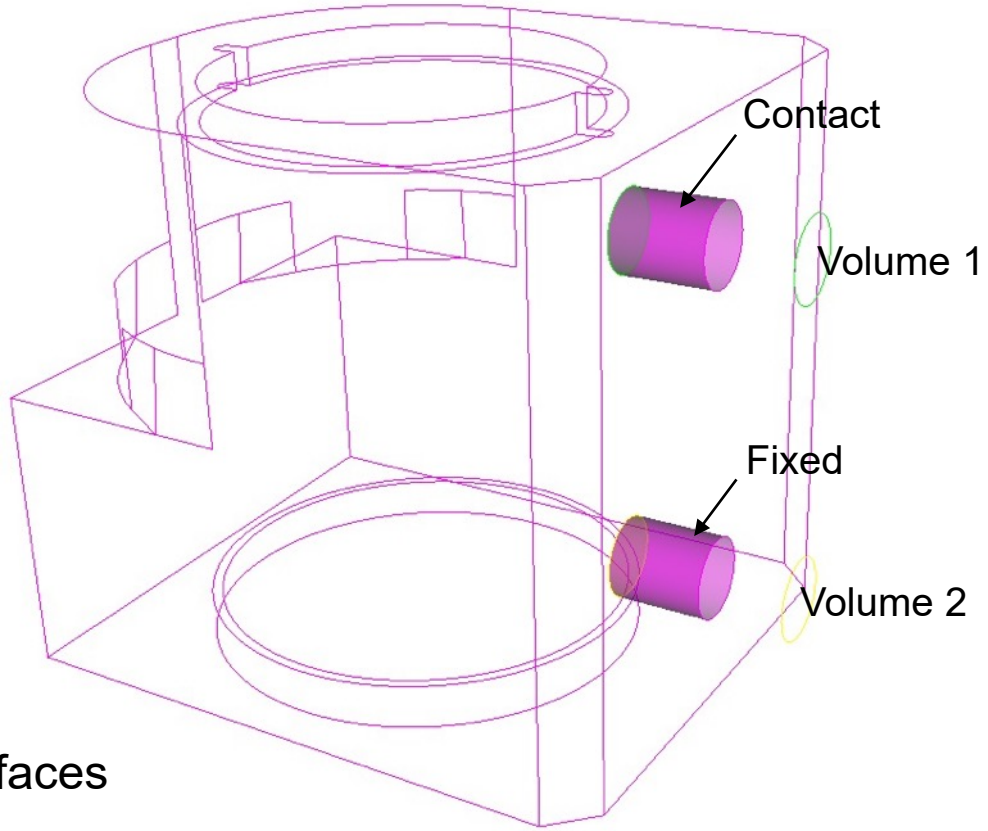


If surfaces are not correctly merged, additional geometry operations may be necessary to correct gaps, overlaps and misalignments

Identify Contact Surfaces

Identify surfaces that will be in contact

For our example: Assume volume 1 bolt in contact with casting, Volume 2 bolt is fixed to casting



Unmerge operation will replace surfaces that were combined during merge

unmerge volume 1

Use **is_merged** again to verify surfaces that are not in contact

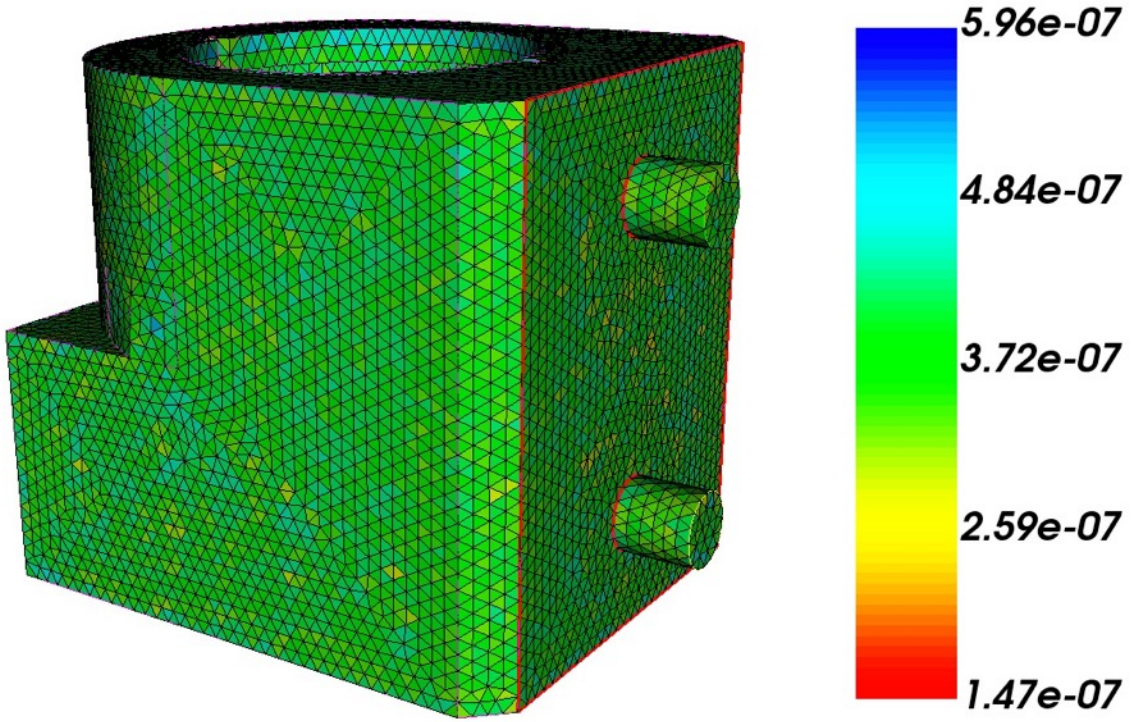
draw surface with not is_merged

draw curve all add

Remesh

Mesh the volumes

vol all scheme tetmesh
vol all size 0.2
mesh vol all
list tot



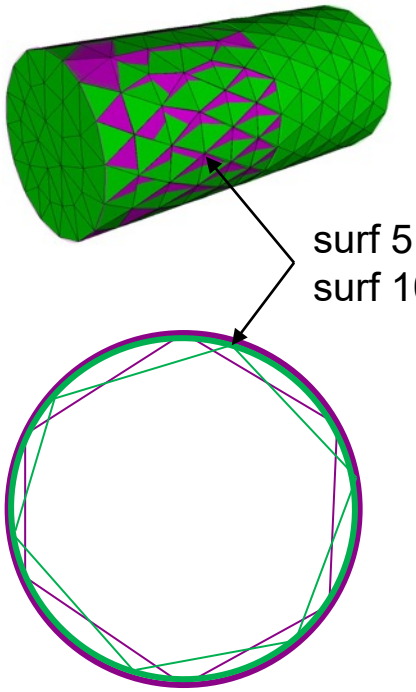
Check the numer of tets and time step metric
How does it compare to the original mesh?

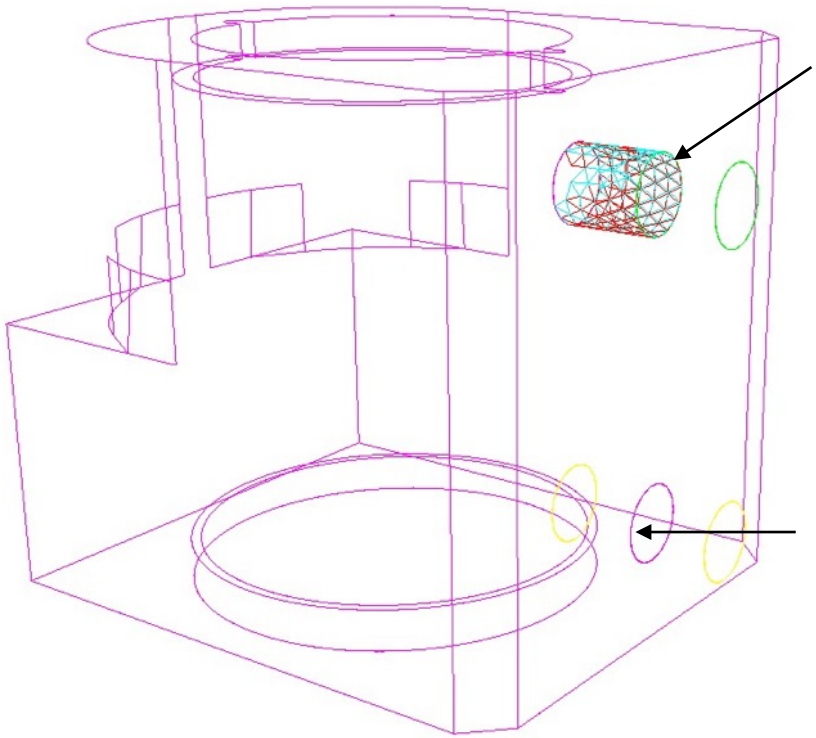
quality volume all time step draw mesh

Mesh Overlap Detection

Mesh may overlap at contact surfaces. This can cause problems in the analysis. Best practice to remove mesh overlap before analysis

find mesh intersection surface all draw
draw curve all add





Mesh Overlap Correction

Simulation Modeling Sciences

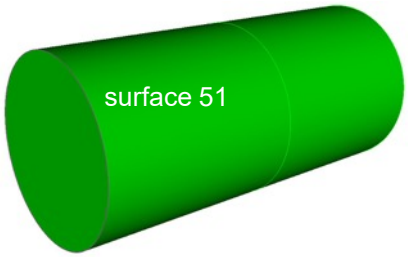
QTri Method

One way to address mesh overlap on contact pairs

1. First merge the unmeshed surfaces.
2. Mesh the merged surface with a mapped mesh
3. Perform **qtri** operation
4. Unmerge

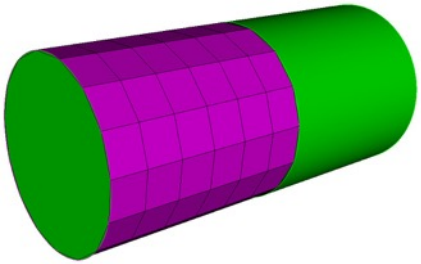
This guarantes the same (non-overlaping) mesh but maintains the contact/slip condition

1



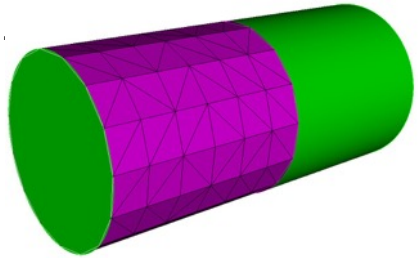
delete mesh
imprint vol 1 3
merge vol 1 3

2.



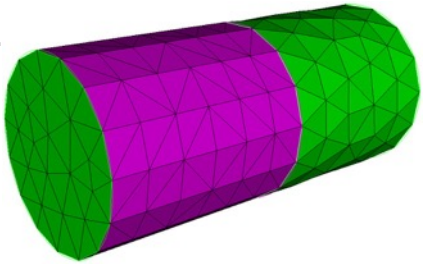
surf 51 scheme map
mesh surf 51

3.

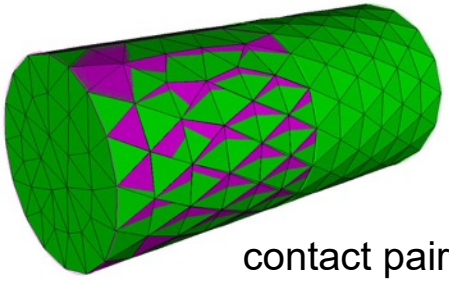


qtri surf 51

4.



vol all scheme tetmesh
mesh vol all
unmerge vol 1



contact pairs contain overlapping surfaces

creating a *qtri* mesh may be benefial in avoiding future mesh intersections if cylinder moves along its axis

check for mesh overlap again.

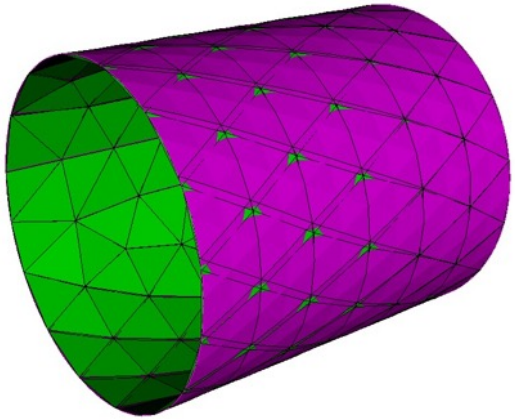
Mesh Overlap Correction

Move Node Method

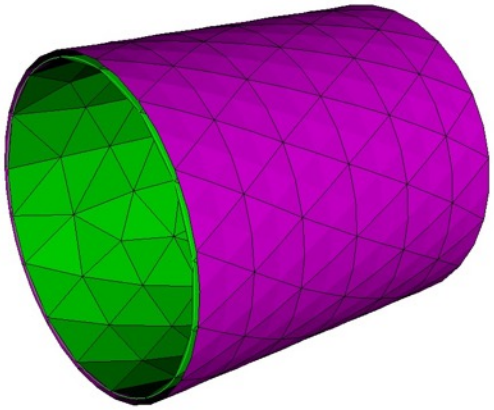
Move the nodes on one of the surfaces a small distance to avoid overlap

This creates a small gap between the elements at the contact surfaces

before moving nodes



after moving nodes



Determine offset distance, *d*, from trial and error

First delete the elements created with the QTri Method

delete mesh
surf all scheme trimesh
mesh vol all

draw surf 51 107
zoom surf 51 107

Move the nodes in surface 51 a distance of d=0.02 normal to surface 107

node in surface 51 move normal to surface 107 distance 0.02

check for mesh overlap

find mesh intersection surface all draw

check for mesh overlap

find mesh intersection surface all draw

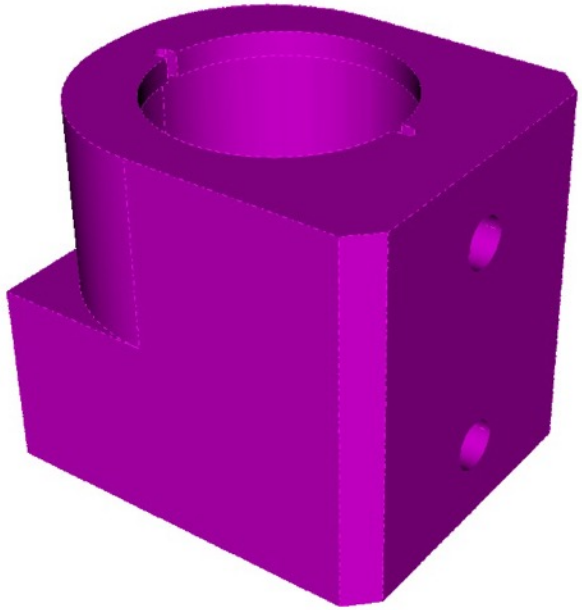
Sandia National Laboratories

Massive Composite

By combining all surfaces in a volume together Surface mesher has more freedom to automatically remove small features (defeature)

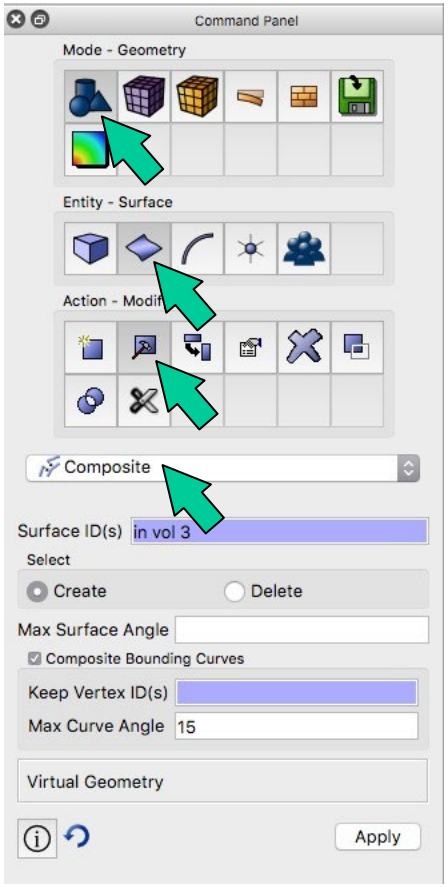
Can avoid tedious defeaturing operations

reset
import acis 'a901-2.sat'
composite create
surface in vol 3
vol all scheme tetmesh
vol all size 0.2
mesh vol 3



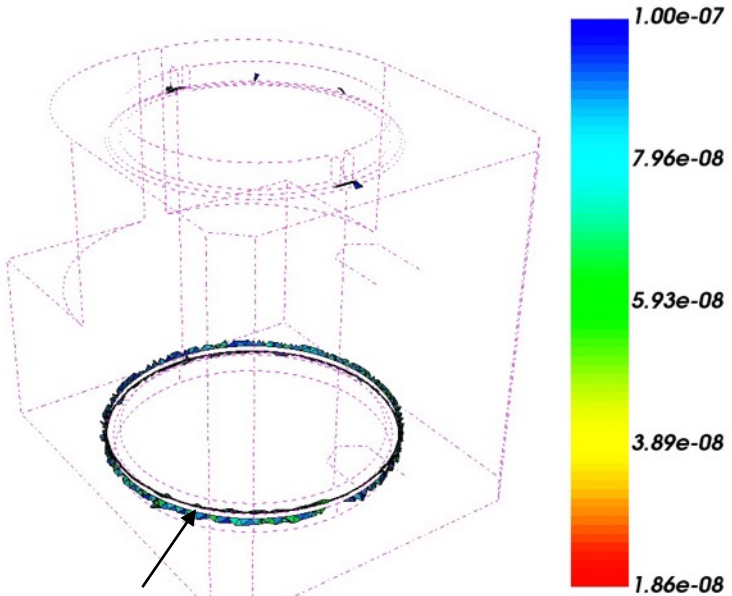
Volume 3 has all of its surfaces composited into a single topologic surface, but maintains its sharp corners

Caution: individual curves and surfaces in composite can no longer be used to assign BCs



Command Panel for Composite Surfaces

Massive Composite



small tets contriol the timestep

Check the time step metric after meshing with massive composite

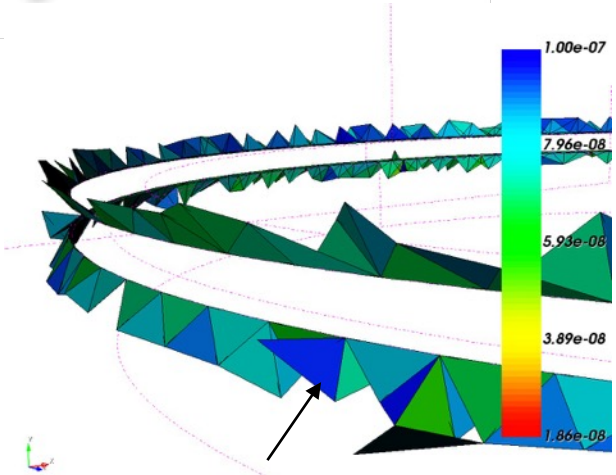
First create the block and material again

```
block 1 volume 3
block 1 name 'casting'
create material name 'steel'
   elastic_modulus 2.068e5
   poisson_ratio 0.29 density 7e-6
casting material 'steel'
```

Display the time step metric

```
quality volume all time step
   global draw mesh
quality volume all time step
   global high 1.0e-7 low 0 draw
   mesh
```

Massive Composite



small tets contriol the timestep

When using the massive composite option, small elements may still exist

The ***tiny edge length*** option can help to eliminate small elements by internally collapsing features in the composite regions

set dev on
set trimesher remove tiny edge length 0.05

Tiny edge length represents size of features that will be ignored

Caution: setting tiny edge length too large can cause problems! However too small and it will have no effect. It is worthwhile to experiment

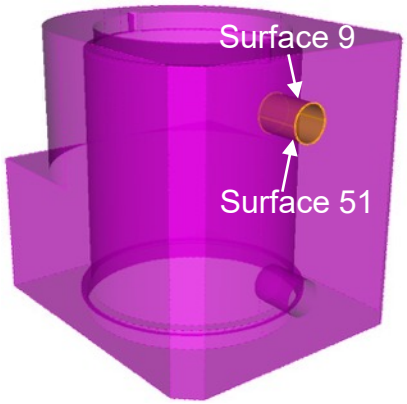
Exercise:
Remesh volume 3 using the **tiny edge length option** and try to select a size that will improve the timestep to greater than 1e-7

Massive Composite

Limited Compositing

- Massive composting of all surfaces will hide curve and surface definitions.
- Boundary Conditions (nodesets and/or sidesets) or important features may require curves or surfaces

Preserve important curves and surfaces by ***not*** including them in the composite operations



Exercise:
First delete the mesh and remove the composite surface definition

```
delete mesh
composite delete surf in vol 3
```

Identify surfaces 9 and 51 as sidesets and create a qtri mesh on them

```
sideset 1 surf 9 51
surf 9 51 scheme map
mesh surf 9 51
qtri surf 9 51
mesh surf 9 51
```

Composite all surfaces except surfaces 9 and 51 on volume 3 and mesh

```
composite create surf in vol 3
   except surf 9 51
vol 3 scheme tetmesh
mesh vol 3
draw sideset 1
```

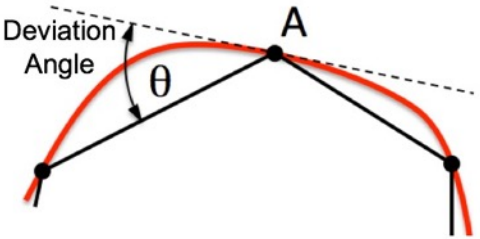
Geometry Sizing

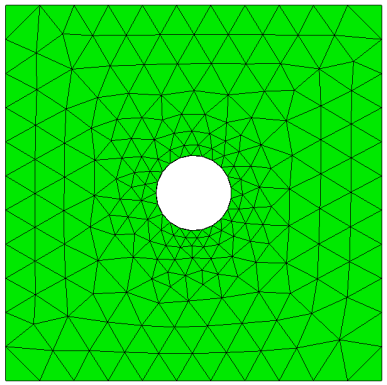
Default geometry sizing attempts to capture curvature by reducing local element sizes

Turning OFF geometry sizing may help to decrease DOF and increase timestep

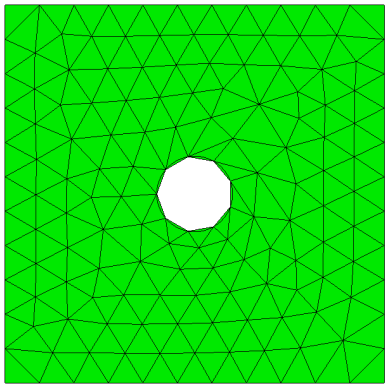
trimesher geometry sizing off

Removes *deviation angle* requirement

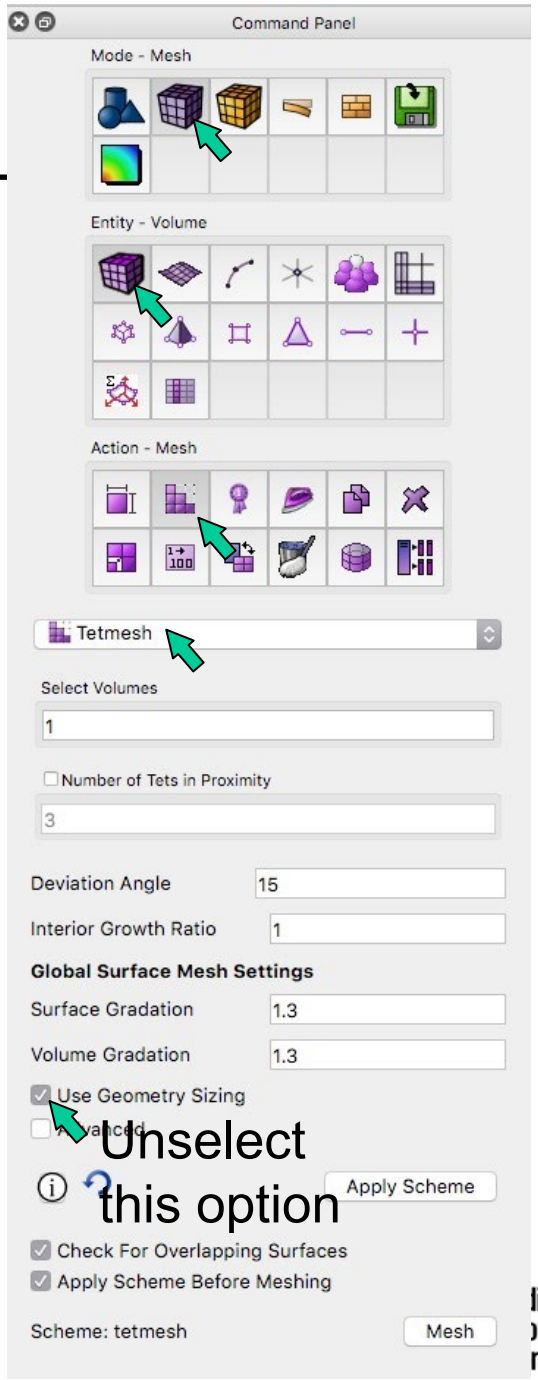




small deviation angle



larger deviation angle

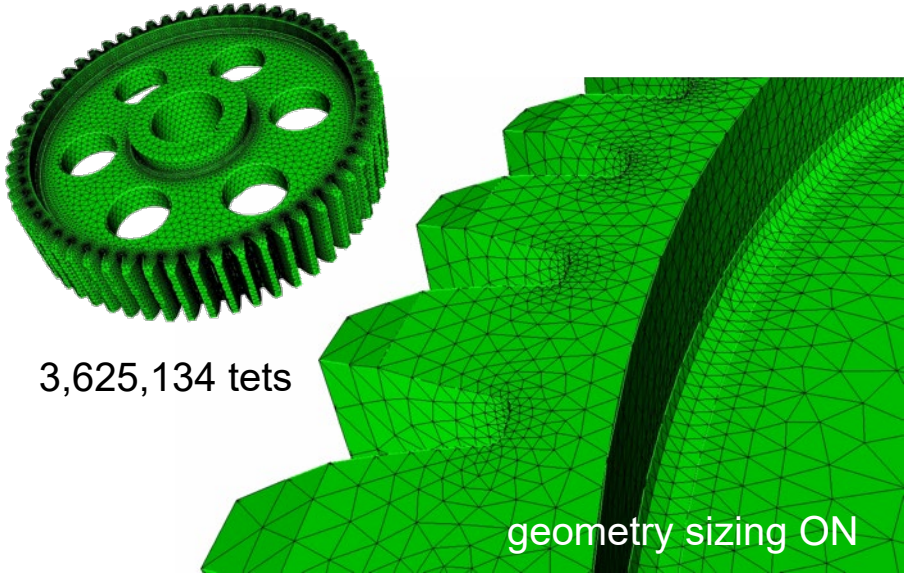


Unselect this option

Geometry Sizing

Exercise:

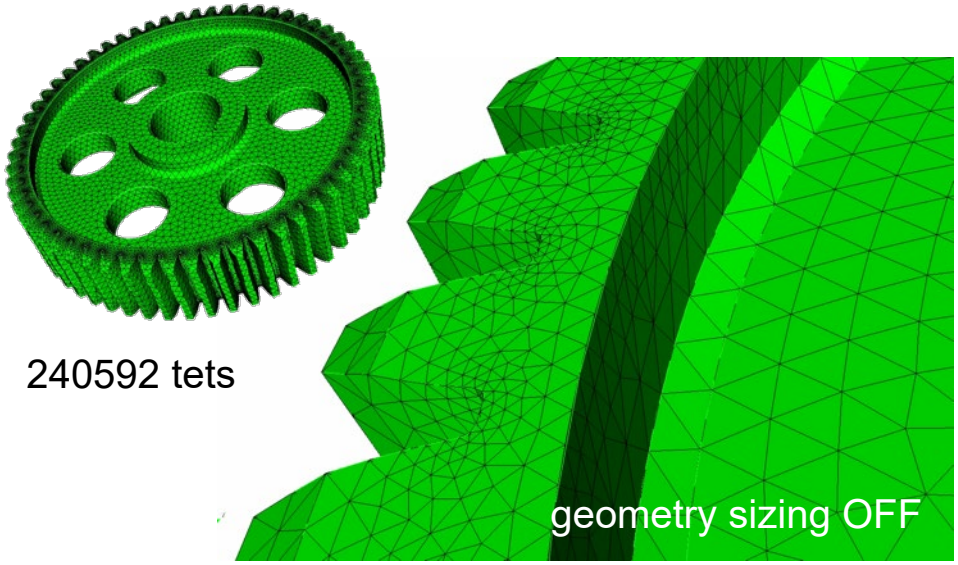
import acis "gear.sat"
vol 1 size 6.0
vol 1 scheme tetmesh
mesh vol all



3,625,134 tets

geometry sizing ON

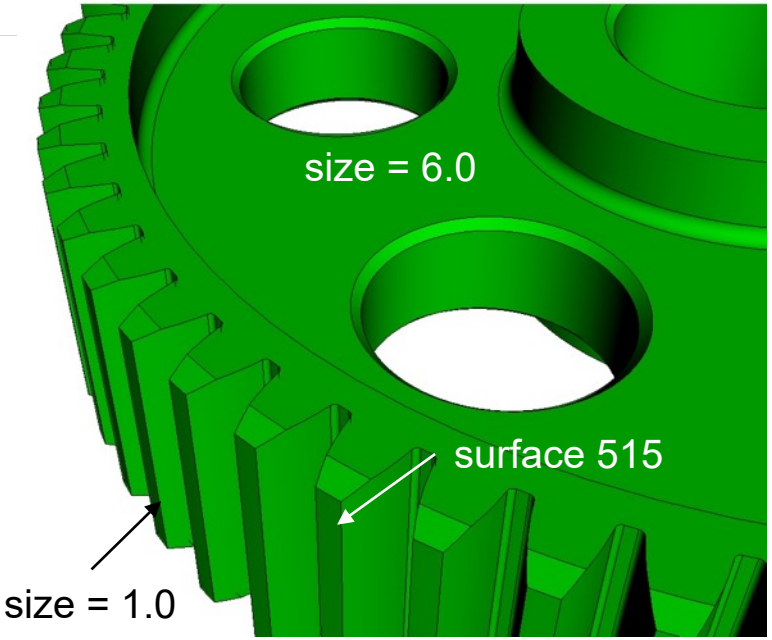
delete mesh
trimesher geometry sizing off
mesh vol all

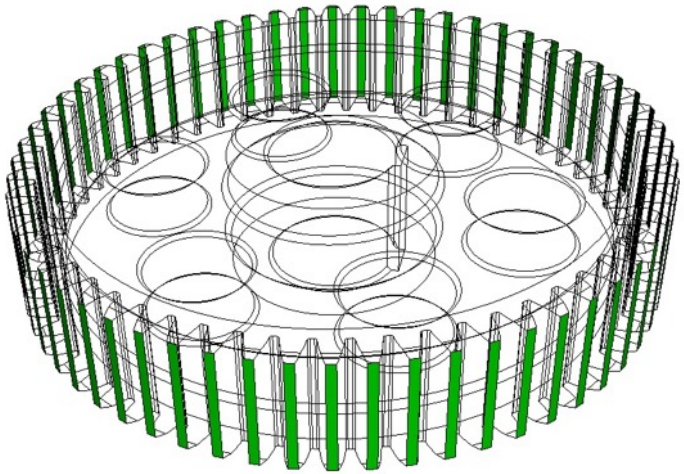


240592 tets

geometry sizing OFF

Grouping with Extended Parsing





Groups can be used to help in assignment of mesh sizing or other properties

Example:

Assign a size of 1.0 to teeth, but transition to size 6.0 on the interior of the gear

1. Identify characteristic area for surface of tooth

   list surface 515 geometry

   Surface Area: 258.817952

2. Create group teeth and add surfaces of similar area

   group "teeth" add surface with area > 258 and area < 259
   draw teeth

3. Assign size property to all surfaces in *teeth* group

   surf in teeth size 1.0

4. Mesh

   vol 1 size 6.0
   mesh vol 1