

STL File Repair in Rhinoceros



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Using Rhino with STL Files

Stereolithography (SLA), or 3-D printing, is the most widely used rapid prototyping (RP) technology. SLA provides a way for turning a 3-D model into a solid object that you can hold in your hand.

STL is the standard format for rapid prototyping systems. While STL was originally developed for use with stereolithography, many other processes now use it. Since SLA machines usually require the STL file to be a watertight mesh, Rhino provides tools for repairing mesh files to remove gaps.

3-D Printing

Using Rhino's Bonus Tools, you can print 3dm, STL, IGES, STEP, DWG, 3DS, and many more file formats directly to a stereolithography printer or file.

This allows you to take nearly any 3-D model and send it to a prototyping machine. As with any model going to a printer, the output STL file must be watertight. Rhino has many tools to repair STL files that are not watertight and to create watertight geometry to send to a 3-D printer. The tutorials that follow show you how to diagnose and repair gaps in the STL file.

If you have a 3-D printer installed on your system, a Print 3-D menu item is added to Rhino's File menu, and your printer will display in the list. Currently supported systems include:

- Delft Spline Systems DeskProto: www.deskproto.com
- Roland MODELA Player: www.roland.com
- Solidscape ModelWorks: www.solid-scape.com
- Stratasys Catalyst: www.dimensionprinting.com
- Z Corporation ZPrint: www.zcorp.com

Tools for Mesh Repair

Tools for repairing meshes and printing directly to a stereolithography printer are free additions to Rhino 3.0 included in the Bonus Tools plug-ins. In addition to mesh repair and rapid prototyping support, the Bonus Tools includes many other useful features that are under development. A description of the Bonus Tools is available at www.rhino3d.com/3/bonus.htm. You must download the Bonus Tools plug-ins to use the commands and features described in this document.

To download the latest version of Bonus Tools

- ▶ Go to www.rhino3d.com/3/bonus.htm to start the download process.



Basic STL Repair Tutorial

Rhino's Bonus Tools includes commands for analyzing and repairing STL files to make them watertight. There are new tools for advanced display, edge matching, selection, and filling holes. These tools let you manipulate meshes in ways previously not possible in Rhino.

While Bonus Tools mesh covers many new commands, the commands that are used for STL repair can be grouped into a few categories:

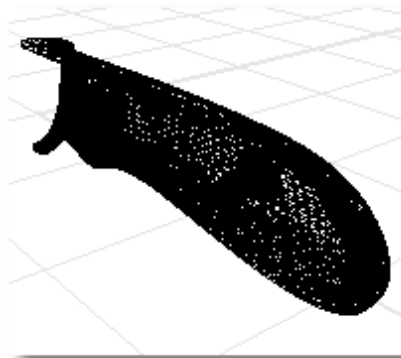
- Display
- Remove unwanted detail
- Display and close gaps
- Offset (thicken)

Display Mesh Wires

The advanced display settings it easier to locate parts that need repair by displaying the mesh wires in shaded views, displaying the mesh wires in a specified color, and displaying backs and fronts of the mesh faces in different colors.

To turn on advanced display options

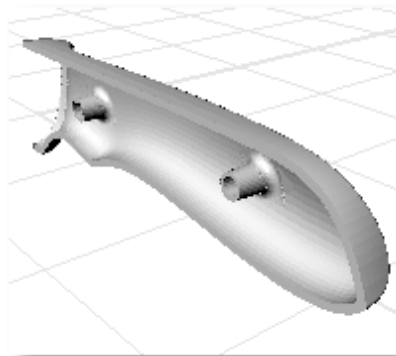
- 1 Open the model **STL_Handle.3dm**.
The mesh object displays as a mass of wires.





- 2 To set the viewport to shaded mode, right-click the viewport title (**Perspective**) and from the menu, choose **Shaded Display**.

Though you can now get a better idea of the object's shape, it is still not easy to find the information you need to repair the mesh in this display mode.



- 3 With the Bonus Tools installed, from the **Bonus** menu, choose **View**, and then choose **Advanced Display Settings**.
- 4 To show the mesh edges, in the **Advanced Display Settings** dialog box, under **Shaded/Rendered display options**, check **Show mesh wires in shaded view**.
- 5 To turn the wires black, check **Fixed wire color for all objects**, and set the color to **Black**.



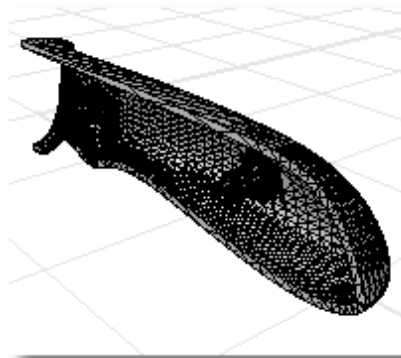
Mesh faces have a front and a back. The front direction is called the *normal* of the face. Some STL meshes need to have consistent normals to work correctly. By default, the front of a face is colored the layer or object color. When you run Rhino in shaded mode, you can show the mesh edges and color the backs of the mesh faces a different color than the fronts of the faces. This provides a quick check of face normal direction.

- 6 To color the backs of the mesh faces a different color, check **Color backfaces**, and set the color. In these examples, **Aquamarine** was used.
- 7 Click **OK**.



Now the edges of the mesh triangles display in black and the backs of the faces are colored aquamarine, so you will easily be able to determine which way the face normals are pointing.

In this example, all of the back faces are inside the model, so they are not visible yet.



Remove Unwanted Detail

One of the first steps in repair is to remove detail you do not need from the model. In this example, you can remove the drilled holes in the bosses of the handle center. To do this, select the hole surfaces, delete them, and then fill in the hole that will be left.

To remove holes in the boss

- 1 From the **Bonus** menu, choose **Mesh**, and then choose **Extract > Connected** (ExtractConnectedMeshFaces command).
- 2 At the **Select mesh face or change option. Press Enter** (*SelectFaces=LessThan* *AngleBetweenFaces=0* *GetBorder=No*) prompt, choose the **AngleBetweenFaces** option.

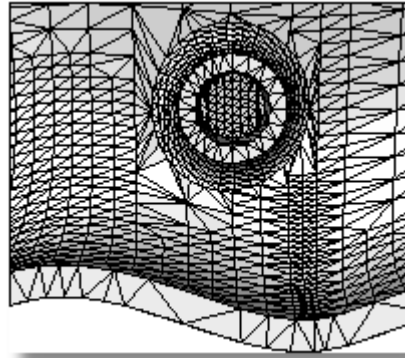
This lets you select a single face, and Rhino will select all the faces that are connected to that face within a break angle of the angle setting.

- 3 At the **Angle...** prompt, enter **45**.

Forty-five degrees is a good setting to start with if you want the selection to stop at 90-degree edges.



- 4 Rotate the view so you are looking down the hole.

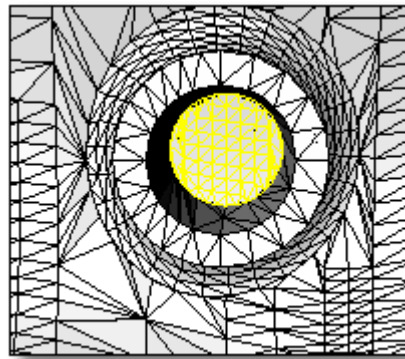


- 5 At the **Select mesh face...** prompt, select one of the faces at the back of the hole.

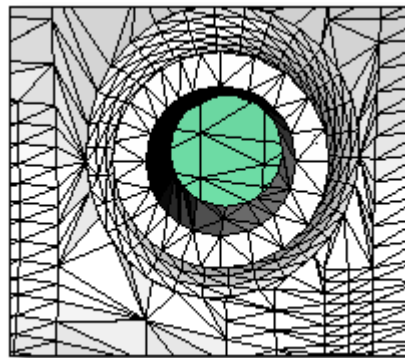
The bottom of the hole highlights.

- 6 At the **Select mesh face...** prompt, press **Enter** to extract the faces.

The faces stay highlighted.



- 7 To delete the faces, press the **Delete** key.



- 8 Repeat the **ExtractConnectedMeshFaces** command.

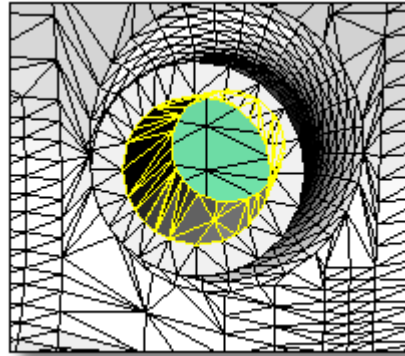


- 9 Select one of the faces at the inside of the hole.

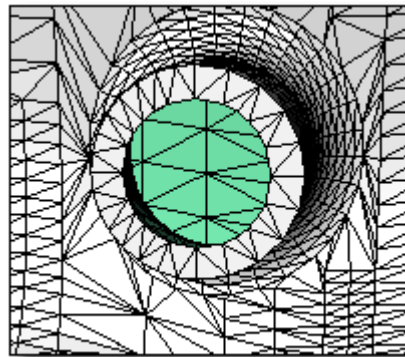
The inside of the hole highlights.

- 10 Press **Enter** to extract.

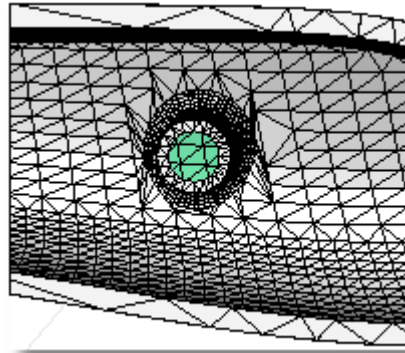
The faces stay highlighted.



- 11 To delete faces, press the **Delete** key.

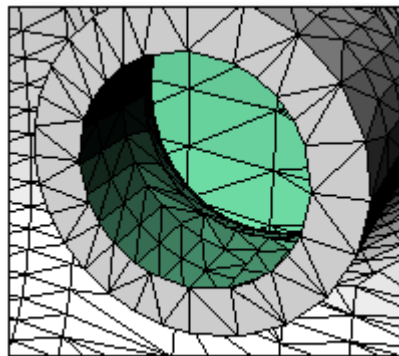


- 12 Repeat these steps for the other hole.





With these faces removed, you can see inside the mesh. Since the backs of the faces display in a different color, you can tell the difference between the inside and outside.



To fill holes in the boss

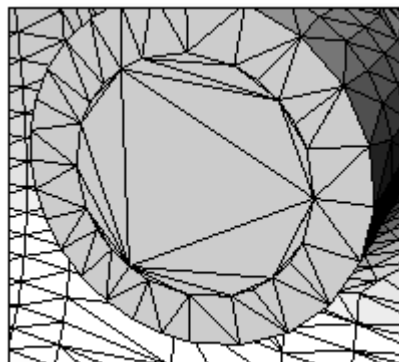
- 1 From the **Bonus** menu, choose **Mesh**, and then choose **Fill Hole** (FillHole command).

This command closes holes with a mesh patch.

- 2 At the **Select mesh edge on hole boundary...** prompt, select the open edge of the hole.

The hole fills.

- 3 Repeat for the other hole.



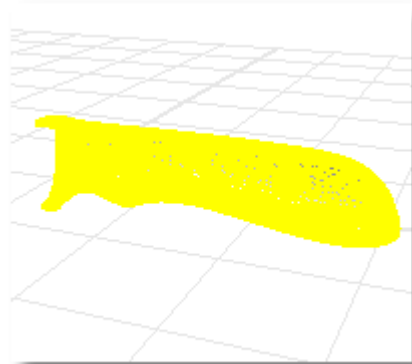


Display Gaps

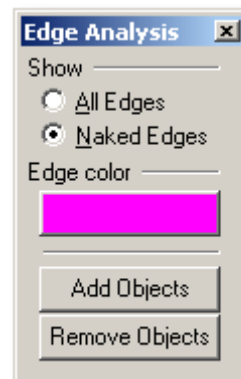
Now that the larger holes of the mesh are taken care of, you can display the open edges that still need to be stitched. Naked edge display shows you these edges.

To show naked edges

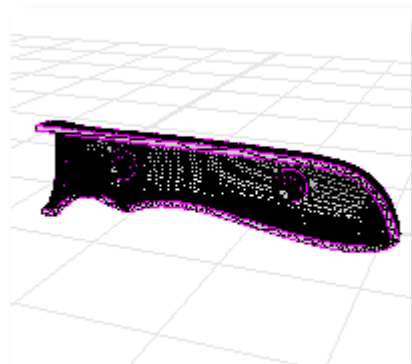
- 1 From the **Analyze** menu, choose **Edge Tools**, and then choose **Show Edges**.
- 2 At the **Select surfaces, polysurfaces or meshes for edge display...** prompt, select the mesh.



- 3 In the **Edge Analysis** dialog box, choose **Naked Edges**.



The naked edges display in the **Edge color**. These edges have gaps. The command line displays the number of open edges.





Close Gaps

Small seams in the mesh can be repaired with the MatchMeshEdge command. This command lets you specify a tolerance. This tolerance is the maximum distance the command will move the edges and points to close a gap. You can run the command on a whole mesh or specify edges to stitch together.

To stitch naked edges

- 1 From the **Bonus** menu, choose **Mesh**, and then choose **Match Mesh Edge** (MatchMeshEdge command).
- 2 At the **Select mesh edges** (PickEdges DistanceToAdjust=*0.001* RatchetMode=*No*) prompt, choose the **DistanceToAdjust** option.
- 3 At the **Pick first point or type distance** prompt, type **1**.

The tolerance is sensitive to the size of the model. For complicated models, it is effective to start with a small tolerance and then to gradually increase it. This way you fix the smaller problems first and keep as much detail as possible.

- 4 At the **Select mesh edges ...** prompt, select the mesh.

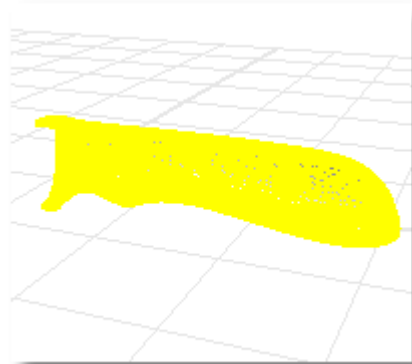


Final Check

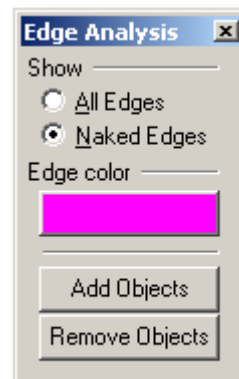
Since the output STL file must be watertight, make a final check to be sure all the gaps are closed.

To check for a closed mesh

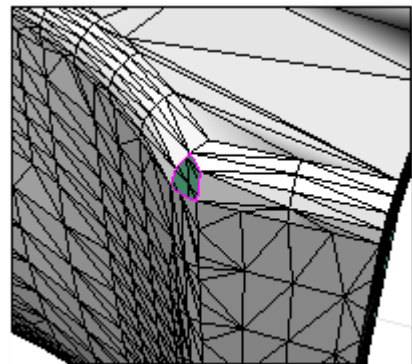
- 1 From the **Analyze** menu, choose **Edge Tools**, and then choose **Show Edges**.
- 2 At the **Select surfaces, polysurfaces or meshes for edge display...** prompt, select the mesh.



- 3 In the **Edge Analysis** dialog box, choose **Naked Edges**.



- 4 Check the command line for the number of naked edges.
A small hole in the model still needs to be filled.



- 5 From the **Bonus** menu, choose **Mesh**, and then choose **Fill Mesh Hole**.



- 6 At the **Select mesh edge on hole boundary** (JoinMesh= Yes) prompt, select the open edge of the hole.

The hole fills.

- 7 To check again for naked edges, in the **Edge Analysis** dialog box, click **Add Objects** and select the mesh again.

The command line display the message:

"Found <x> total edges; no naked edges."

The file is ready to print.

Advanced STL Repair Tutorial

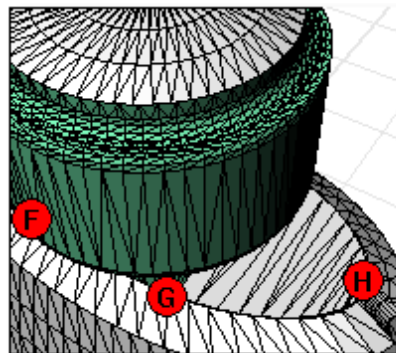
In this section, we will look at a few more problem areas and discuss more advanced repair techniques.

Display Settings

As in the previous examples, use the Advanced Display Settings to improve the visibility of problem areas in the mesh.

To turn on advanced display settings

- 1 Open the model **STL_Bottle.3dm**.
- 2 If it has not already been done, set the **Advanced Display Settings** as discussed on page 5.
- 3 Turn on **Show mesh wires in shaded view**.
- 4 Set **Fixed wire color for all objects to Black**.
- 5 Set **Color backfaces to Aquamarine**.
- 6 Set the viewport to **Shaded Display**.



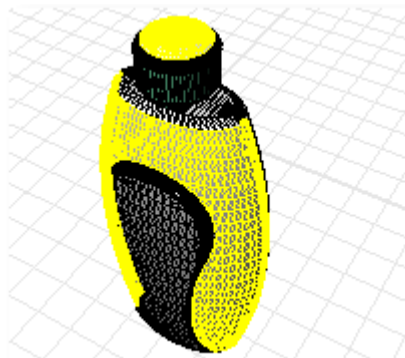


Join the Mesh

Unlike the previous example, this mesh consists of separate parts.

Try clicking the bottle to see the separate parts.

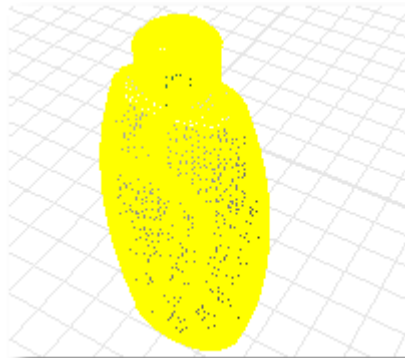
Before investigating gaps, the model needs to be joined into a single mesh object.



To join the mesh

- 1 From the **Edit** menu choose **Select Objects**, and then choose **All Objects**. (SelAll command or Ctrl+A).
- 2 From the **Edit** menu, choose **Join** (Join command).

This joins all the parts into a single mesh. The bottle now selects as one piece.





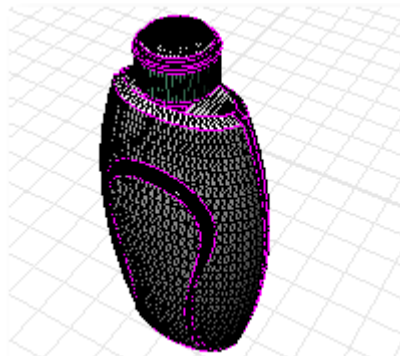
Display Gaps

Display the open edges that need to be stitched.

To show naked edges

- 1 From the **Analyze** menu, choose **Edge Tools**, and then choose **Show Edges**.
- 2 At the **Select surfaces, polysurfaces or meshes for edge display...** prompt, select the mesh.
- 3 In the **Edge Analysis** dialog box, choose **Naked Edges**.

The naked edges display in the **Edge color**. These edges have gaps. The command line displays the number of open edges.



Close Gaps

As in the previous example, start by closing small seams in the mesh with the MatchMeshEdge command.

To stitch naked edges

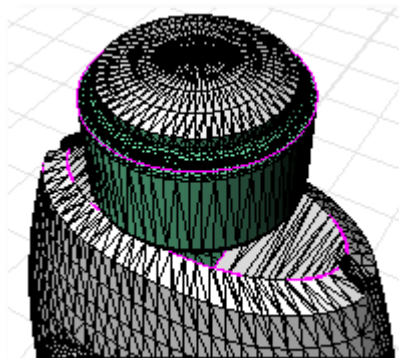
- 1 From the **Bonus** menu, choose **Mesh**, and then choose **Match Mesh Edge**.
- 2 At the **Select mesh edges** (PickEdges DistanceToAdjust= 1 RatchetMode= No) prompt, choose the **DistanceToAdjust** option.
- 3 At the **Pick first point or type distance** prompt, enter **0.01**.

The tolerance is sensitive to the size of the model. For complicated models, it is effective to start with a small tolerance and then to gradually increase it. This way you fix the smaller problems first and keep as much detail as possible.



- 4 At the **Select mesh edges** ... prompt, select the mesh.

Most of the edges stitch together, but a few areas still need some work.



Stitch Larger Gaps

Now that you have the smaller holes of the mesh taken care of, you can use the **MatchMeshEdge** command to fix the larger holes. Because of the larger tolerance needed in this case, it is a good idea to select only the edge to be repaired. Using a large stitch tolerance on the whole mesh can remove important detail.

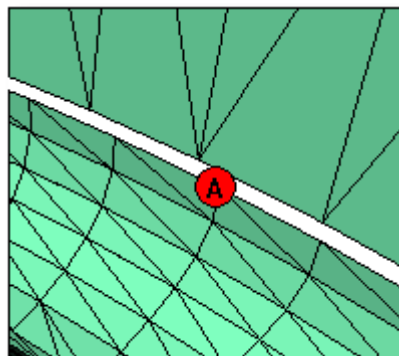
To close larger gaps

- 1 **Zoom** into the bottom of the bottle at dot **A**.

Tip: Select the dot and use the **ZoomSelected** command to zoom to it.

A gap runs along the bottom. This hole was larger than the .01 tolerance we previously used.

Use **MatchMeshEdge** with a larger tolerance to close the gap on this edge only.

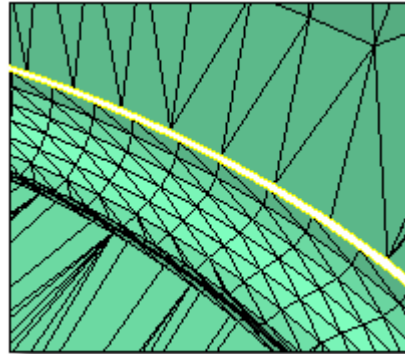


- 2 From the **Bonus** menu, choose **Mesh**, and then choose **Match Mesh Edge**.
- 3 At the **Select mesh edges** (**PickEdges** $DistanceToAdjust=0.01$ **RatchetMode=On**) prompt, choose the **DistanceToAdjust** option.
- 4 At the **Pick first point or type distance** prompt, type **0.1**.



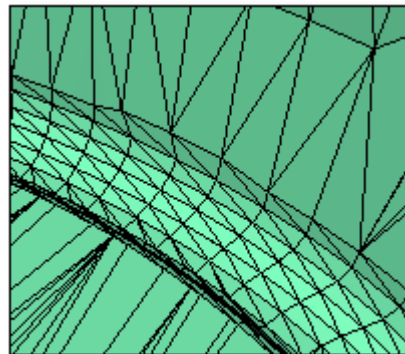
- 5 At the **Select mesh edges...** prompt, select an edge of the hole.

The selection expands around the whole gap.



- 6 Press **Enter**.

The gap closes.



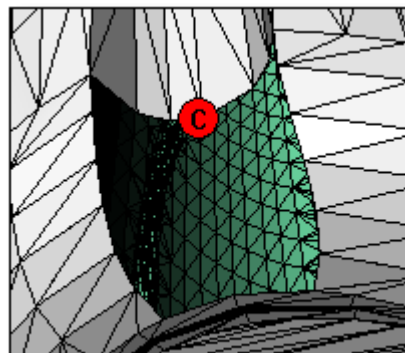
- 7 Repeat these steps for the gap at dot **B**.

Fill Holes

Sometimes there are larger holes that demand more modeling to close. In this example, you can use the FillHole command to fill a selected hole.

To fill a hole

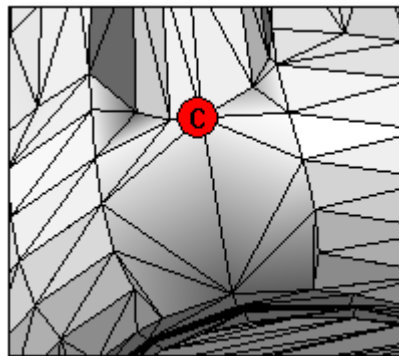
- 1 Zoom in to the bottom of the bottle at dot **C**.
- 2 Rotate the view so you can see the hole.





- 3 From the **Bonus** menu, choose **Mesh**, and then choose **Fill Hole** (FillHole command).
- 4 At the **Select mesh edge on hole boundary** (JoinMesh= Yes) prompt, select one edge of the hole.

The selection expands around the entire hole edge and fills the hole.

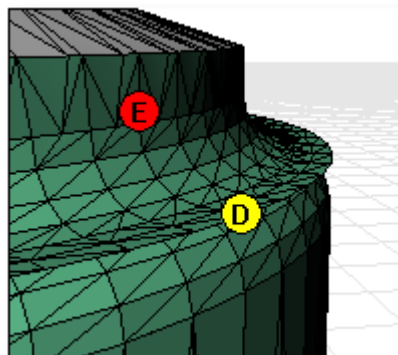


Remove Geometry by Feature

In some cases, you need to remove existing mesh faces. One way to do this is to use the ExtractConnectedMeshFaces command. This works well for finding mesh faces that are part of a feature. In this example, there are some unnecessary untrimmed faces.

To remove a feature

- 1 Zoom into the top of the bottle at dot **D**.
There is a small shelf of unwanted faces in this area.



- 2 From the **Bonus** menu, choose **Mesh**, and then choose **Extract > Connected** (ExtractConnectedMeshFaces command)



- 3 At the **Select mesh face or change option. Press Enter** (*SelectFaces=LessThan* *AngleBetweenFaces=0* *GetBorder=No*) prompt, choose the **AngleBetweenFaces** option.

This lets you select a single face, and Rhino will select all the faces that are connected to that face within the specified angle.

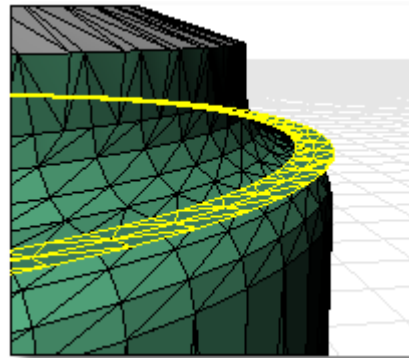
- 4 **At the Angle...** prompt, enter **1**.

Setting the angle to 1 is a good way to find planar faces.

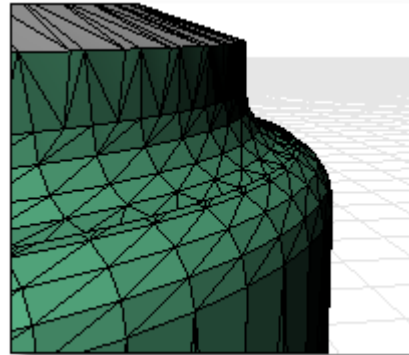
The selection expands around the edge of the lid.

- 5 At the **Select mesh face...** prompt, press **Enter** to extract the faces.

The faces stay highlighted.



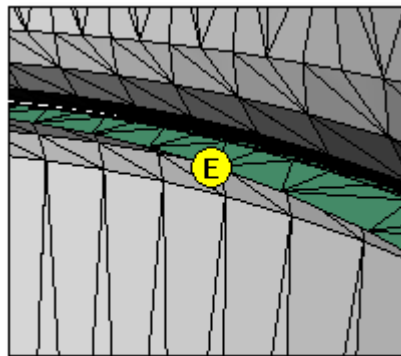
- 6 To delete the faces, press the **Delete** key.



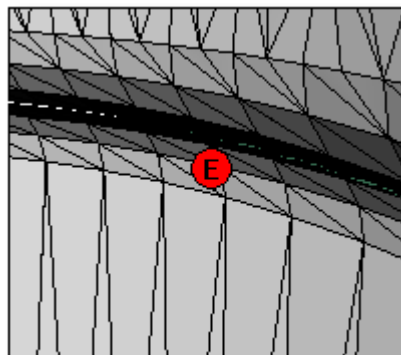
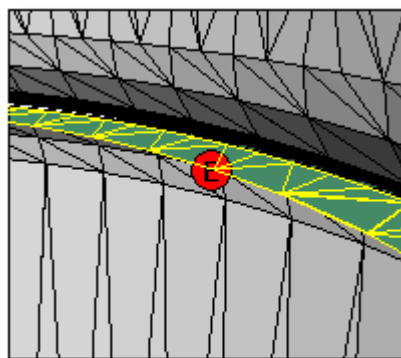


Another set of untrimmed faces on the inside of the bottle is also a problem.

- 7 Zoom into the inside of the bottle at dot **E**.
- 8 Show the naked edges (**ShowEdges** command) so you can see the naked edge on the inside of the part at dot **E**.



- 9 Use the **ExtractConnectedMeshFaces** command again to select and delete the shelf at dot **E**.



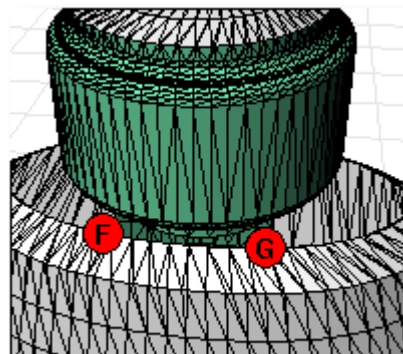


Fill Holes between Objects

Gaps in the lid at dots F and G need repair. This hole is not a single closed hole, but two edges that do not touch.

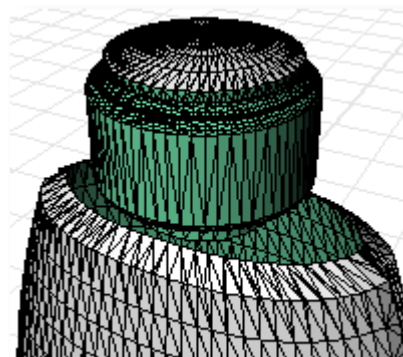
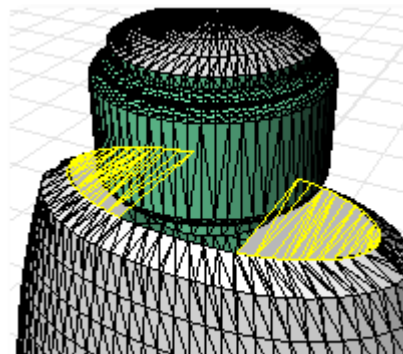
A technique for fixing this type of mesh problem is to use the PatchSingleFace command to create mesh faces that connect the two faces to give control over how the mesh is laid out, then use the FillHole command to finish the filling.

Before starting to fill the hole, we will remove the unwanted mesh faces and replace them with a patch that will fill the hole more efficiently.



To remove the unwanted faces

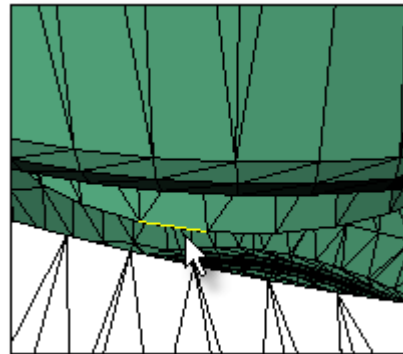
- ▶ Use the **ExtractConnectedMeshFaces** command to extract and delete the two flat areas on the shoulders of the bottle.





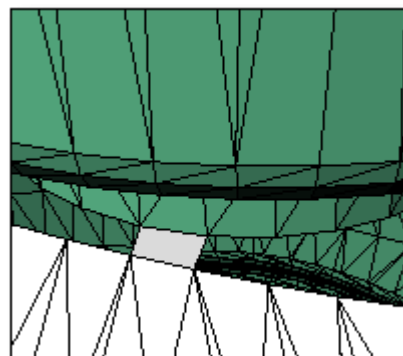
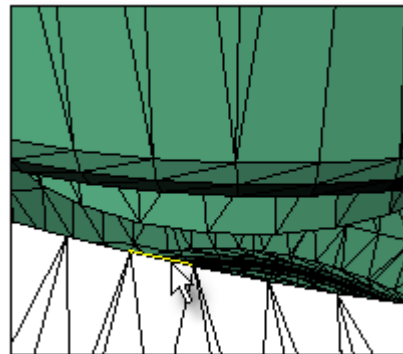
To patch the hole

- 1 From the **Bonus** menu, choose **Mesh**, and then choose **Patch Single Face** (PatchSingleFace command).
- 2 Select in the middle of an edge along one side of the opening.



- 3 Select on an edge adjacent to the first edge across the gap.

This should give you a face that spans the gap as shown.

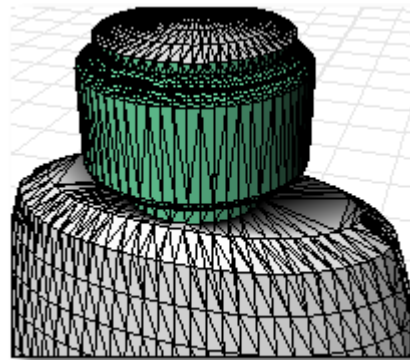


- 4 Repeat the **PatchSingleFace** command at a similar location on the other side of the bottle.



To fill the holes

- ▶ Use the **FillHole** command to fill the faces on the bottle shoulders.

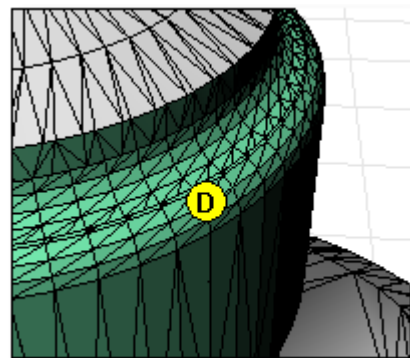


Replace Faces

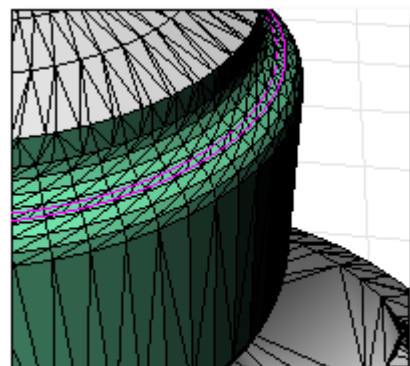
The top of the bottle is the most complicated to close. First, remove the flat areas that are floating out on the bottle top. This leaves a gap in the bottle top. Patch a few faces into the gap to make filling possible, and then fill the holes.

To repair the shelf edge and fill the gap

- 1 Zoom into the bottle top at dot **D**.
A small shelf of faces is difficult to see in this area.

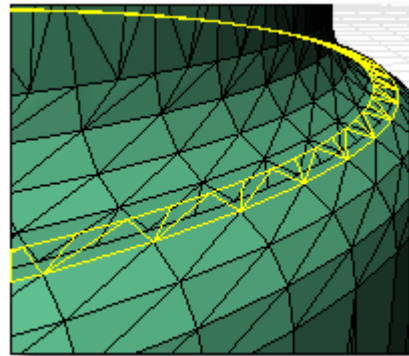


- 2 Show the naked edges to see the shelf.

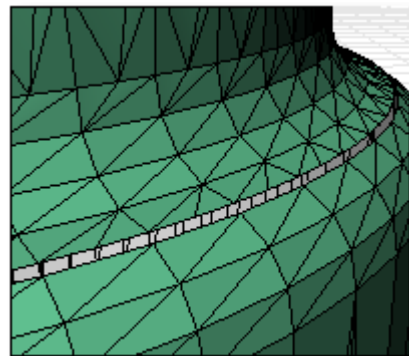




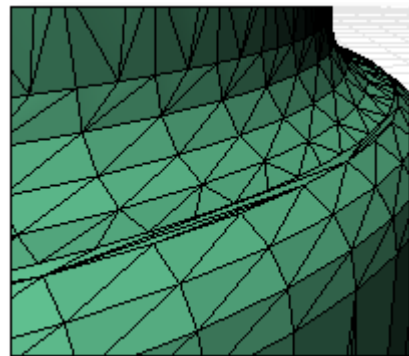
- 3 Use the **ExtractConnectedMeshFaces** command to separate and delete the face.
- 4 Set the **AngleBetweenFaces** option to 1.



Due to the colored backfaces, you can see the gap in the mesh.



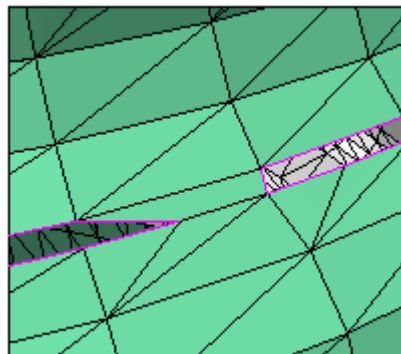
If you use the **FillHole** command to fill the gap left at this point, the resulting mesh has long, thin triangles that do not match well with their neighbors.



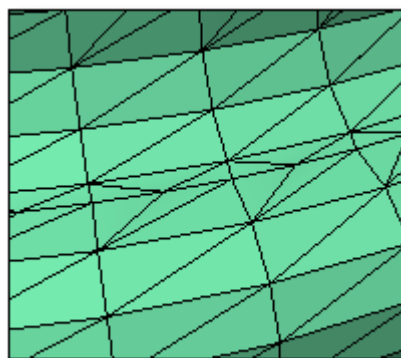


- 5 Use the **PatchSingleFace** command to create a patch between two faces on either side of the gap.

This helps the FillHole command create a well-behaved mesh.



- 6 Use the **FillHole** command to fill the gap.
There will still be a few small naked edges in the model at this point.
- 7 Use the techniques described above to close the remaining holes.

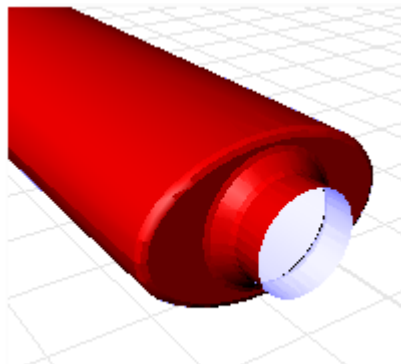


Thicken/ Shell Meshes

Rhino has offset mesh tools that create solids from mesh surfaces or make closed mesh hollow.

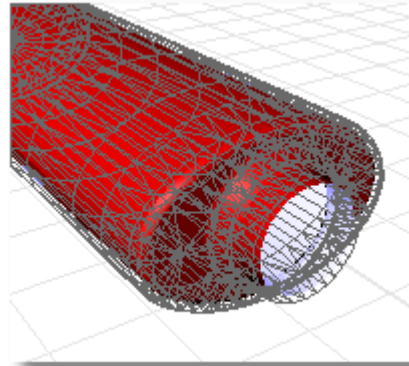
To offset and thicken a mesh

- 1 Open the model **Bottle Offset.3dm**.

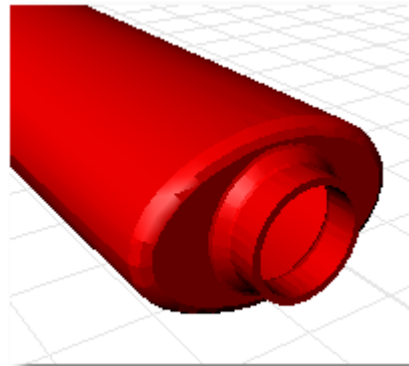




- 2 From the **Bonus** menu, choose **Mesh**, and then choose **Offset Mesh** (OffsetMesh command).
- 3 At the **Select object to mesh** prompt, select the bottle mesh, and press **Enter**.
- 4 Set the **OffsetDistance** option to 0.1.
You will see white mesh lines that preview the new offset mesh.



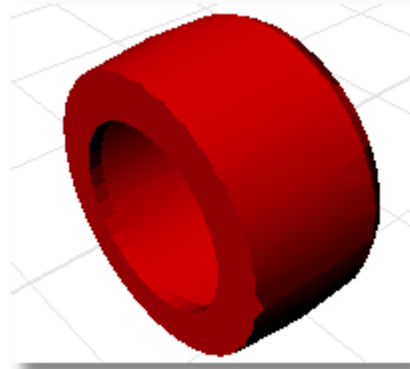
- 5 To close the edges on the offset, set the **CapMeshes** option to **Yes**.
You can click on the mesh to flip the direction of the offset.



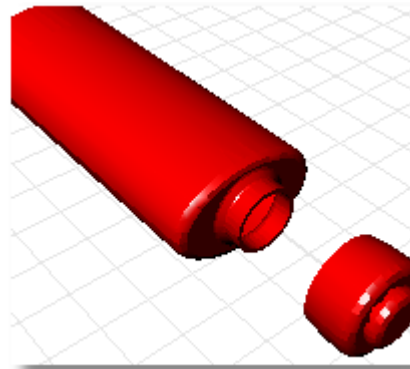
- 6 Press **Enter** to execute the offset.



- 7 Rotate the view and repeat this for the cap.



You will now have a hollow bottle and cap for printing.





Mesh Tools Reference

Standard Display Modes

As you work with meshes, it is important to be able to change how they are displayed in Rhino. Five basic display modes that are particularly useful for mesh repair are available from the Viewport menu: Wireframe, Shaded, Ghosted, Rendered, and Flat Shade.

To set the display mode

- 1 Right-click the viewport name.
- 2 From the menu, choose a display mode.

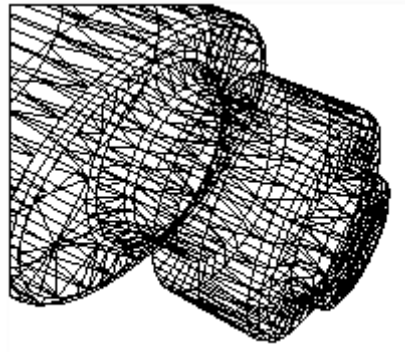




Display modes

Wireframe Display

Shows the edges of all the faces of a mesh. This mode works well when looking for edge conditions.



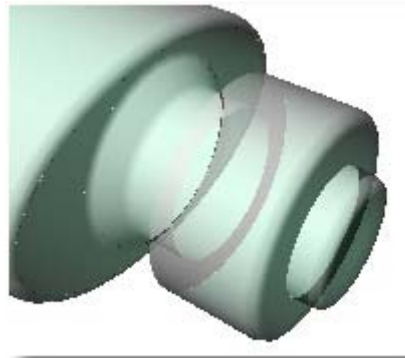
Shaded Display

Lets you pick visible faces.



Ghosted Display

Makes the mesh semi-transparent.





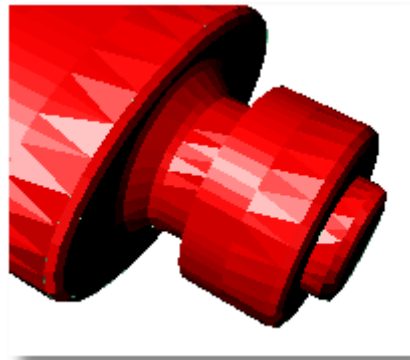
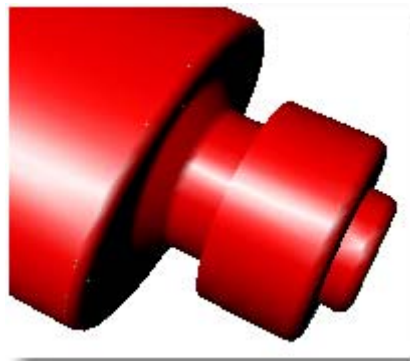
Rendered Display

Shows simple color, transparency, gloss, and texture. Use this mode to see which colors will be transferred to a color 3-D printer.



Flat Shade

Meshes consist of a series of flat faces. In a normal shaded display mode, the mesh looks smooth on the screen. This smooth display method does not mean the mesh is actually smooth. To see the true structure of the mesh, turn on Flat Shade. Flat Shade is a toggle that works with all shaded modes.





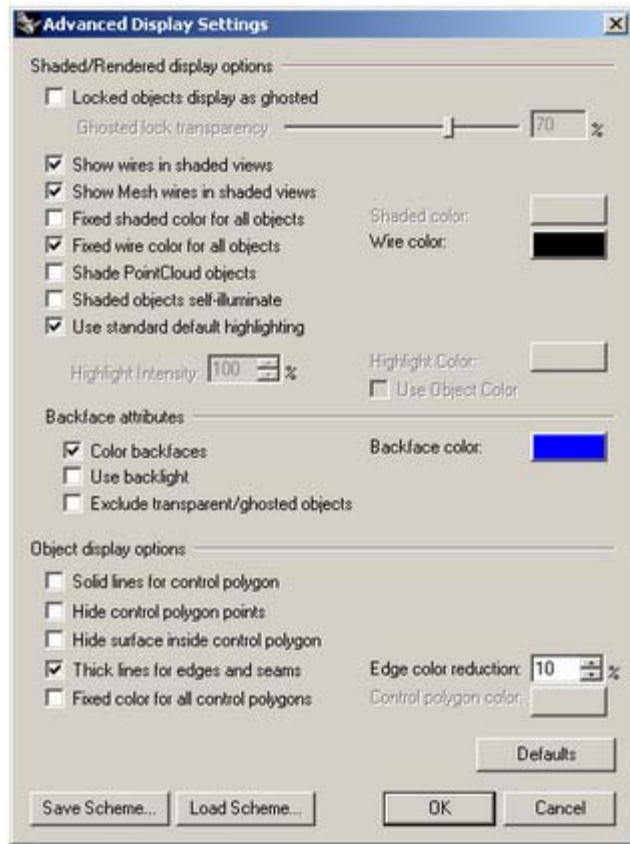
Advanced Display Modes

The Advanced Display Settings let you further customize how Rhino displays meshes.

To change display settings

- ▶ From the **Bonus** menu, choose **View**, and then choose **Advanced Display Settings** (AdvancedDisplay command).

Use these settings to see how a mesh is structured, making it easier to repair.

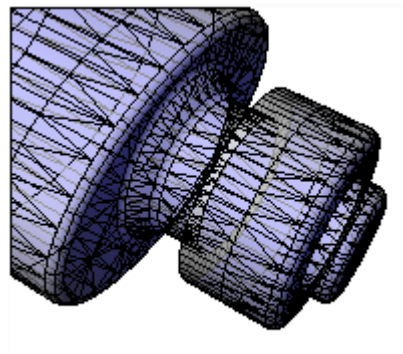
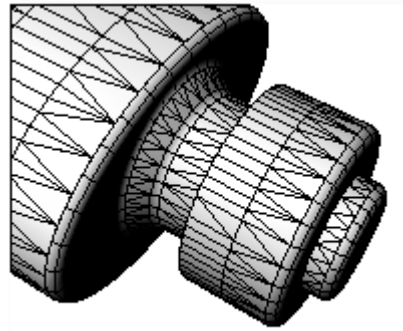




Advanced display options

Show mesh wires in shaded views

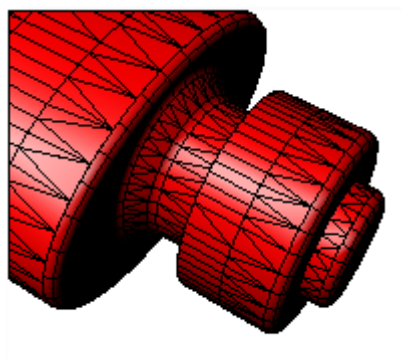
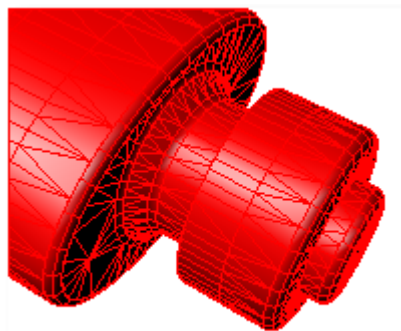
Draws the edges of a mesh so that you can clearly see each face. This display mode is probably the most useful for mesh repair.





Fixed wire color for all objects

By default, the edges of the mesh faces will draw in a slightly lighter or darker shade of the object color. For mesh repair, drawing all wires black, regardless of the mesh object color, can show more contrast and make it easier to see how the mesh is structured.



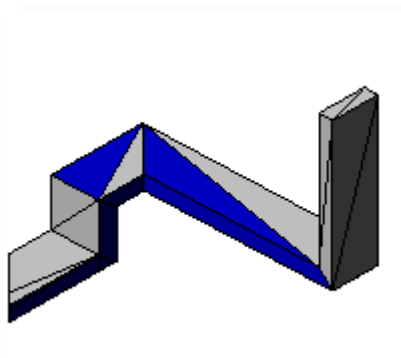
Fixed shaded color for all objects

Color backfaces

Mesh faces have a front and a back. The “front” direction is called the *normal* of the face. Some STL meshes will need to have consistent normals to print correctly. By default, the front of a face will be colored the layer or object color.

Using **Fixed shaded color for all objects** sets the color of all front faces one color.

Color backfaces sets all of the back faces a different color. These two settings let you see if the mesh normals are pointing in the same direction.

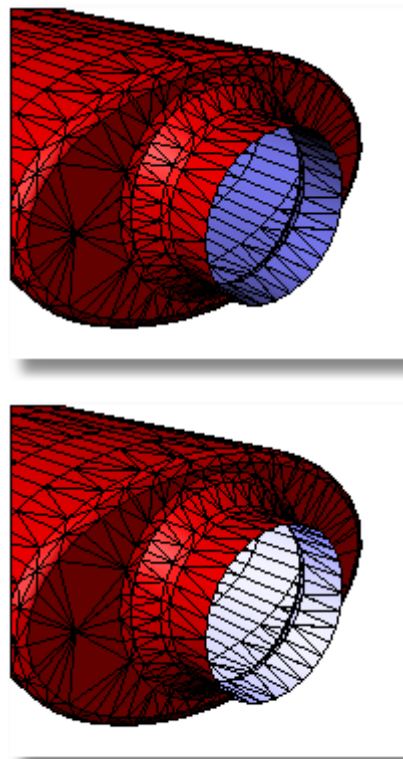




Use backlight

If you look into an enclosed area of a mesh, backfaces may be too dark to see any detail.

The **Use backlight** setting brightens the backfaces so you can see more detail.



Analyze for Watertight Meshes

The goal of repairing STL files is to make all the meshes in the scene watertight. With Rhino, you can identify open meshes and the specific edges in the mesh that are open.

Select open and closed meshes

You can select open meshes only or closed meshes only. This lets you select and hide closed meshes or find open meshes that need attention.

To select open meshes

- ▶ Use the **SelOpenMesh** command.

To select closed meshes

- ▶ Use the **SelClosedMesh** command.



Display open edges

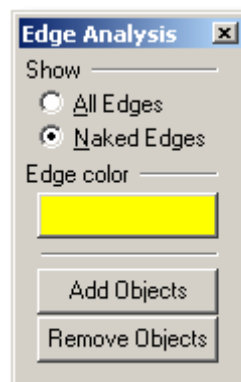
Once you have determined which meshes are open, you can display the open edges in a different color with naked edge display. Naked edge display can be on during other commands, so you can constantly monitor which edges are open.

To display open edges

- ▶ Use the **ShowEdges** command, and in the **Edge Analysis** dialog box, choose **Naked Edges**.

When you select an object, the command line reports the number of naked edges in the object. If no naked edges are reported, the model is watertight.

Open edges of a mesh can be quite small. Set the naked edge display to yellow or other high contrast color, and set the display mode to wireframe, so you can see the naked edges more clearly.



Edit and Repair Tools

Align normal direction

If meshes have faces that do not all point in the same direction or faces and points that are not valid, the following tools can remove invalid elements.

CullDegenerateFaces

Bonus menu: Mesh > Utilities > Cull Degenerate

Removes mesh faces in the model that have no area and mesh vertices that are not referenced by a face.

UnifyMeshNormals

Sets all the face normals in a mesh object to point in the same direction.

Flip

Reverses all the normals.

This is especially useful if the UnifyMeshNormals command makes all the normals face inward and not outward.

RebuildMeshNormals

Bonus menu: Mesh > Utilities > Rebuild Normals

Reconstructs all the normals of the mesh.

Use this command when the UnifyMeshNormals command cannot get all the normals to face the same direction.



RebuildMesh

Bonus menu: Mesh > Utilities > Rebuild Mesh

Strips all information from a mesh and returns only the mesh geometry.



Extract parts

While working on meshes, it is useful to extract parts of the mesh into their own separate meshes to isolate problem areas or to extract parts of the mesh that need to be handled as separate objects. For example, you may need to extract flat areas or to split a mesh in half. The mesh faces that are extracted by these commands form a separate mesh object.

ExtractConnectedMeshFaces

Bonus menu: Mesh > Extract > Connected

Extracts parts of a mesh that are connected by a similar angle between faces.

Finding an angle that works to select the amount of the mesh you want is a matter of experimentation. If the angle is too high, too much of the mesh will select. If it is too low, not enough will select.

It may not be possible to select all of the mesh faces you want using one angle. In this case, you will have to use the command multiple times with different angle settings.

Set the **AngleDegree** option to **1** degree to find planar areas.

Set the **AngleDegree** option to between **10** and **25** degrees to find features.

Options

SelectFaces

If **LessThan**, selects faces connected at an angle less than the AngleBetweenFaces setting.

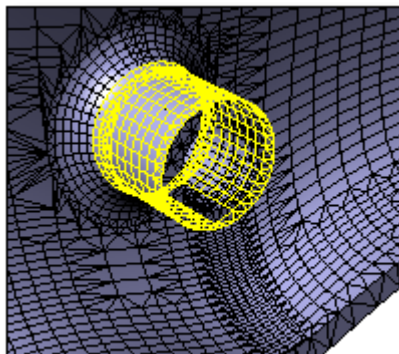
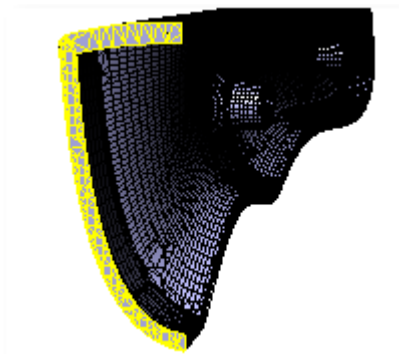
If **GreaterThan**, selects faces connected at an angle greater than the AngleBetweenFaces setting.

AngleBetweenFaces

Sets the angle between the faces to compare.

GetBorder

If **Yes**, creates curves at the borders of the extracted faces.



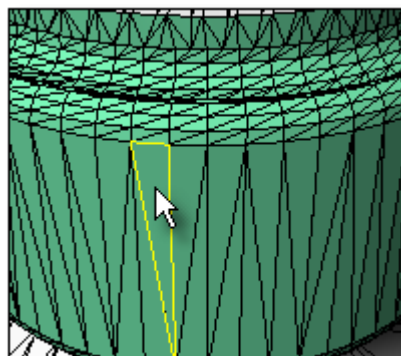


ExtractMeshFaces

Bonus menu: Mesh > Extract > Faces

Extracts faces selected by picking the face or the face edge.

This command works best in shaded mode, because you can pick the shaded faces as well as the face edges.



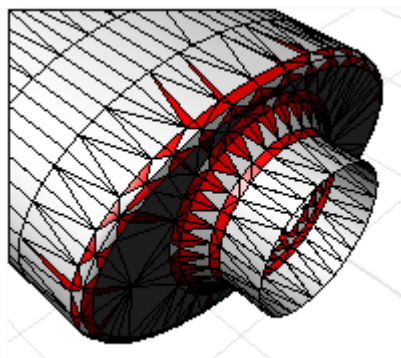
ExtractMeshFacesByEdgeLength

Bonus menu: Mesh > Extract > by Edge Length

Extracts all faces that have an edge greater or less than a specified length.

This command is good for removing small triangles or large triangles that do not belong in the mesh.

In the example image, the extracted red faces have an edge length shorter than 0.1.



Options

SelectFaces

If **LessThan**, selects faces with an edge length less than the EdgeLength setting.

If **GreaterThan**, selects faces with an edge length greater than the EdgeLength setting.

EdgeLength

Sets the edge length to compare.



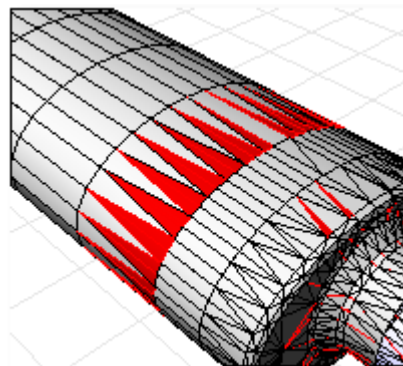
ExtractMeshFacesByAspectRatio

Bonus menu: Mesh > Extract > by Aspect Ratio

Select and extract mesh faces based on the ratio of length to width.

This command is good for finding triangles that are very long compared to their width. A ratio of 25:1 or above is considered long.

In the image, the extracted red faces have an aspect ratio of 9:1 or more.



Option

AspectRatio

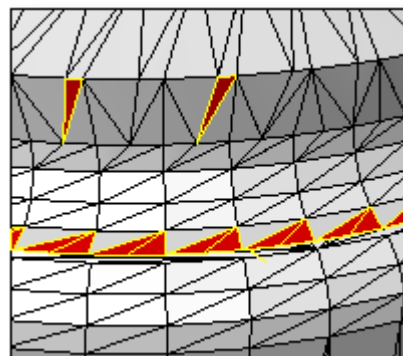
Set the target aspect ratio.

ExtractMeshFacesByArea

Bonus menu: Mesh > Extract > by Surface Area

Extracts mesh faces greater than or less than a specified the surface area. You can specify a size range or pick a surface to use as an example size.

This command works well for removing very small faces from the mesh.



Options

SelectFacesGreaterThan

Selects faces with an area greater than the specified setting.

SelectFacesLessThan

Selects faces with an area less than the specified setting.

PickRangeFromFace

Sets the area by picking an example face. A range of ± 0.1 of the area of the selected face is used.



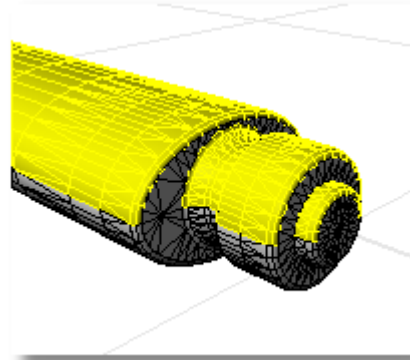
ExtractMeshFacesByDraftAngle

Bonus menu: Mesh > Extract > By Draft Angle

Splits a mesh object based on the angle of the faces to the view.

This command works well for splitting a mesh object for molds or to look for undercut areas.

In the example, the mesh faces were selected in the top view.



Options

StartAngleFromCameraDir

Set the starting angle from the direction of the viewport camera.

EndAngleFromCameraDir

Set the ending angle from the direction of the viewport camera.

GetBorder

If **Yes**, creates curves at the borders of the selected faces.

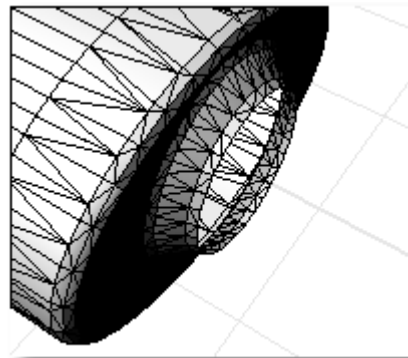
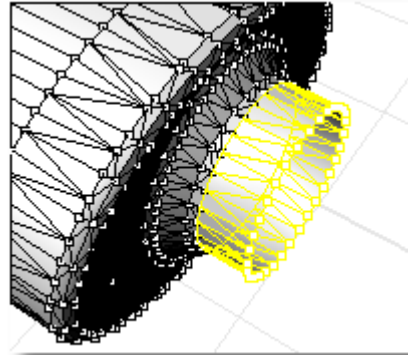


Delete parts

Deleting parts of a mesh lets you remove errors and unnecessary detail.

Delete mesh control points

Turn on the mesh control points, and then select and delete the points by pressing the Delete key.



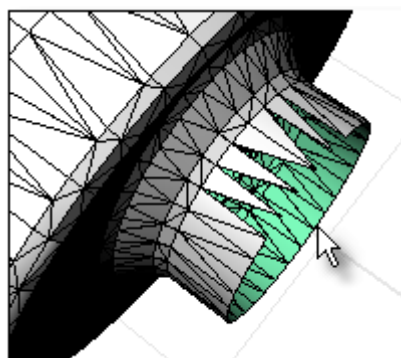
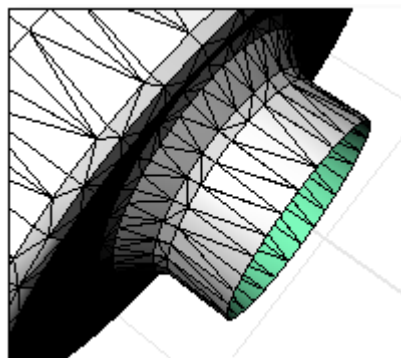


DeleteMeshFace

Bonus menu: Mesh > Delete Mesh Face

Deletes selected faces.

This command is most effective in shaded mode, since you can pick the shaded surface and not just the mesh edges.



ExtractDuplicateMeshFaces

Bonus menu: Mesh > Extract > Duplicate

Extracts duplicate faces to a separate mesh.

ExtractBadMeshFaces

Bonus menu: Mesh > Utilities > Extract Bad Face

Extracts faces that do not have a normal, have collinear vertices, or are otherwise corrupt.



Fill and patch holes

Watertight meshes require that holes and open seams need to be filled or repaired.

MatchMeshEdge

Bonus menu: Mesh > Match Mesh Edge

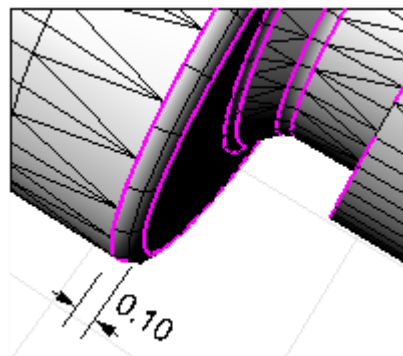
Matches open edges so they will be watertight based on a tolerance.

First, the command will try to match vertices, then it will try to split edges to make the edges match. No part of the mesh is moved more than the specified tolerance.

You can use this command either on the complete mesh or on selected edges.

When selecting a whole mesh, using a high tolerance can create unexpected results. Use larger tolerances only if you select specific edges to close.

Before edge, matching, magenta edges are open. The size of the fillet is labeled.



Result after MatchMeshEdge at 0.05.

Options

PickEdges

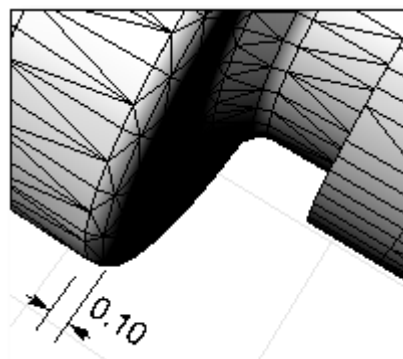
Select specific edges to match.

DistanceToAdjust

Set the tolerance distance.

RatchetMode

If **Yes**, matching the mesh takes place in four passes starting at a tolerance that is smaller than your specified tolerance and working up to the specified tolerance with successive passes. This matches small edges first and works up to larger edges.





FillHole

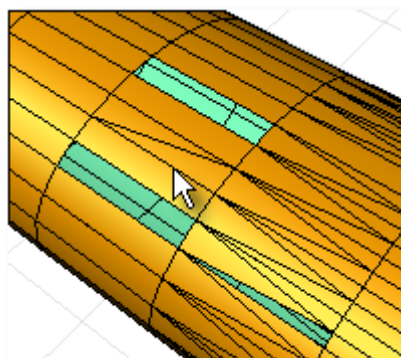
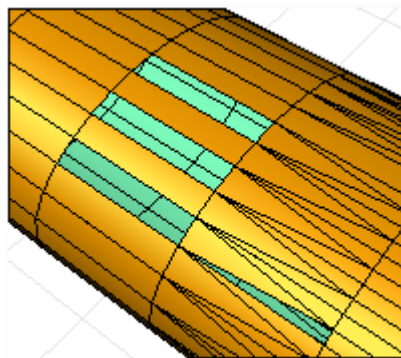
Bonus menu: Mesh > Fill Hole

Fills a hole in the mesh selected by picking the hole edge. The command searches around the naked edge you select and attempts to create a closed boundary to fill.

Options

JoinMesh

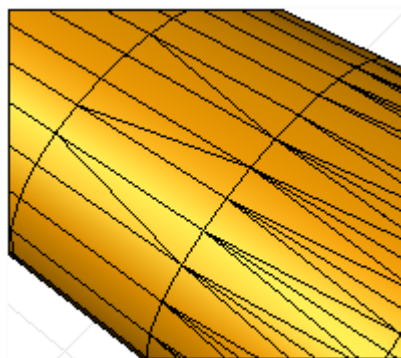
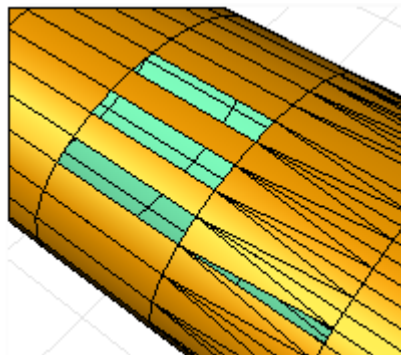
If **Yes**, the new faces are joined to the original mesh.



FillHoles

Bonus menu: Mesh > Fill Holes

Attempts to fill every hole in the mesh.





PatchSingleFace

Bonus menu: Mesh > Patch Single Face

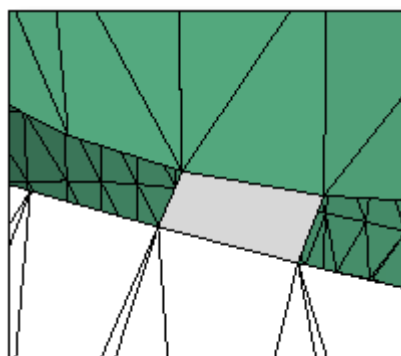
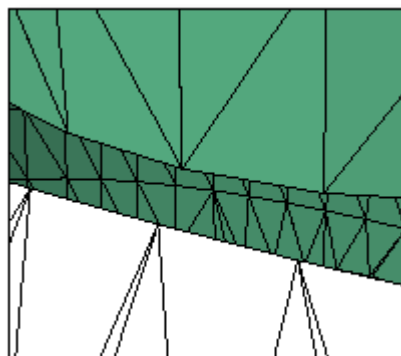
Lets you select edges and vertices of a mesh to create a new face that connects those edges.

Use the PatchSingleFace command to bridge gaps and then use the FillHole command to fill in the resulting hole.

Options

JoinMesh

If **Yes**, the new face is joined to the original mesh.



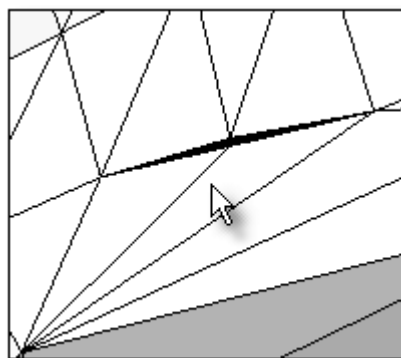
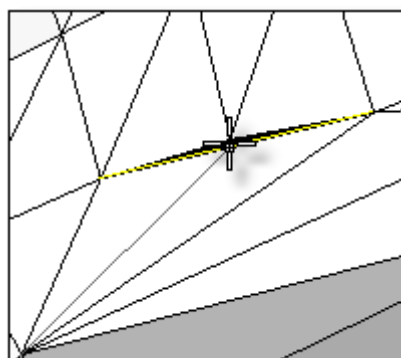
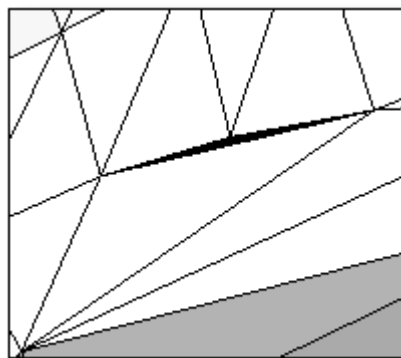


SplitMeshEdge

Bonus menu: Mesh > Utilities > Split Edge

Splits a mesh edge to create two triangles.

Use the SplitMeshEdge command to specify how you want to split faces, and then match an adjacent mesh using the MatchMeshEdge command.





AlignMeshVertices

Bonus menu: Mesh > Align Mesh Vertices

Moves vertices that are within a tolerance to the same point.

This is good for areas that have many vertices that should be in the same spot, but for some reason are not.

Options

SelectVertices

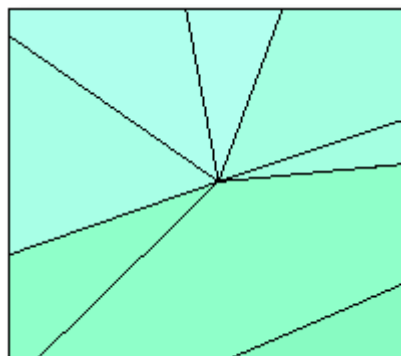
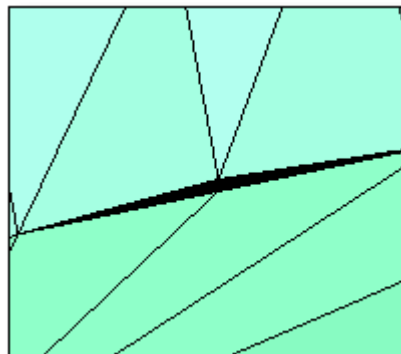
Select vertices to align.

SelectNakedEdges

Select naked edges to align all vertices on the edge.

DistanceToAdjust

Set the tolerance distance.





Collapse faces and edges

Like the extract commands, the collapse commands find triangles in a mesh that fit specified criteria. Unlike the extract commands, the collapse commands move vertices without opening additional holes in the mesh. This is a good way to remove small or long and thin triangles.

CollapseByArea

Bonus menu: Mesh > Collapse > by Surface Area

Collapses mesh faces that have surface areas that are greater and/or less than a specified number.

Options

SelectFacesGreaterThan

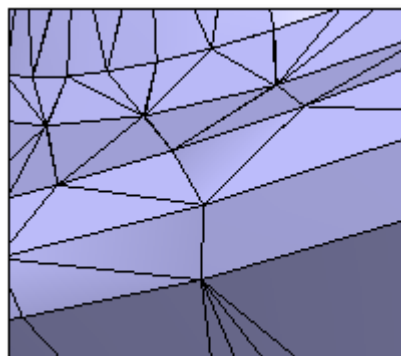
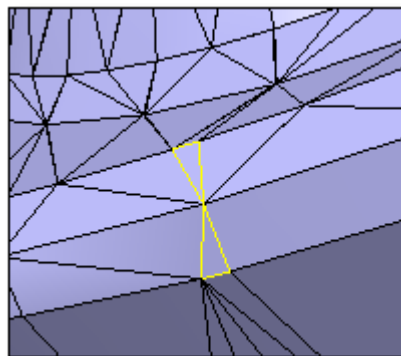
Selects faces with an area greater than the specified setting.

SelectFacesLessThan

Selects faces with an area less than the specified setting.

PickRangeFromFace

Sets the area by picking an example face. A range of ± 0.1 of the area of the selected face is used.





CollapseByAspectRatio

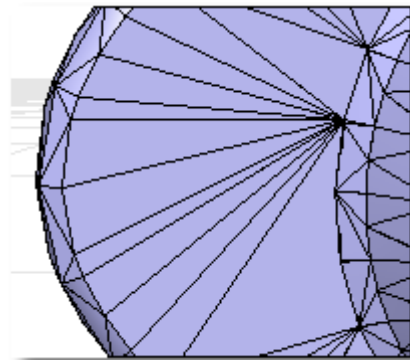
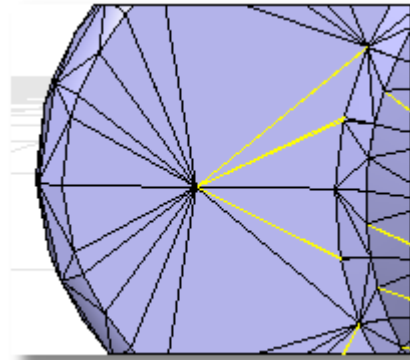
Bonus menu: Mesh > Collapse > by Aspect Ratio

Collapses mesh faces based on a specified ratio of length to width. A ratio of 25:1 or above is considered long.

Option

AspectRatio

Set the target aspect ratio.



CollapseByEdgeLength

Bonus menu: Mesh > Collapse > by Edge Length

Collapses all faces that have an edge greater or less than a specified length.

This command is good for removing small triangles or large triangles that do not belong in the mesh.

Options

SelectFaces

If **LessThan**, selects faces with an edge length less than the EdgeLength setting.

If **GreaterThan**, selects faces with an edge length greater than the EdgeLength setting.

EdgeLength

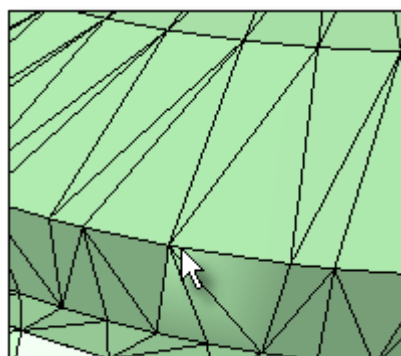
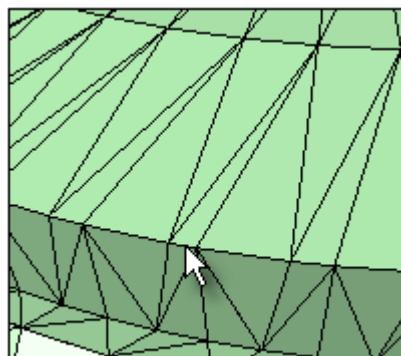
Set the edge length to compare.



CollapseMeshEdge

Bonus menu: Mesh > Collapse > Edge

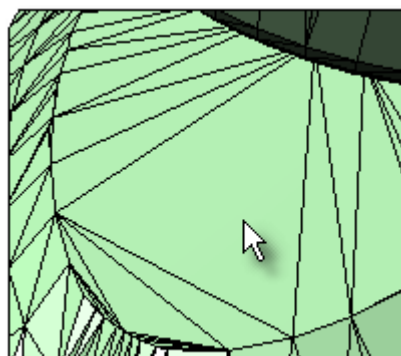
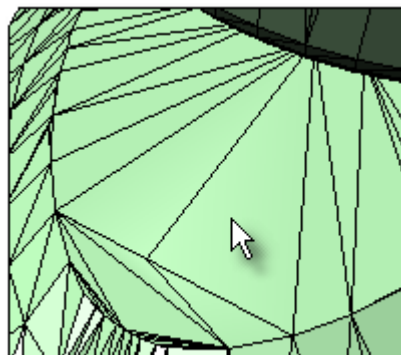
Collapses selected edges. The edge will be collapsed to one vertex.



CollapseMeshFace

Bonus menu: Mesh > Collapse > Face

Collapses selected faces. The face will collapse to one vertex.

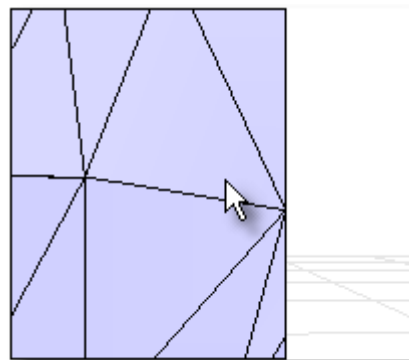
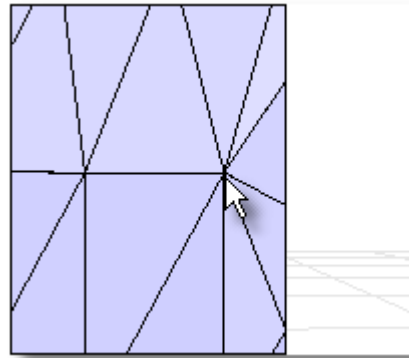




CollapseMeshVertex

Bonus menu: Mesh > Collapse > Point

Collapses all the faces connected to a selected vertex. The adjacent faces adjust to fill the hole.





Thicken/Offset Mesh Objects

Mesh offset lets you offset the mesh to create a solid shell.

OffsetMesh

Bonus menu: Mesh > Offset Mesh

Offsets the mesh a specified distance with the option to fill the space between the two surfaces to create a solid.

Options

OffsetDistance

Sets the distance or thickness.

DeleteInput

Deletes the original surface.

CapMeshes

Caps the space between the original and new mesh to create a solid.

