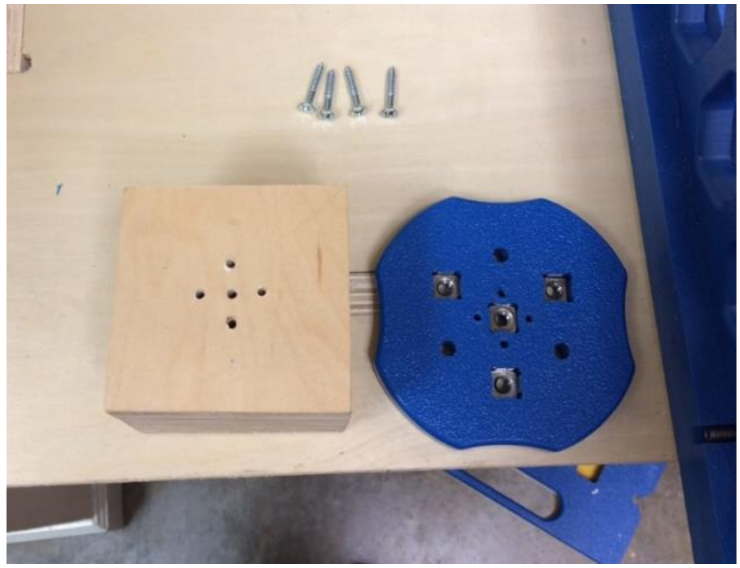
Manual + 2 Axis Accessory

Aspire (5 Axis) Case Study: Teacup

Stock

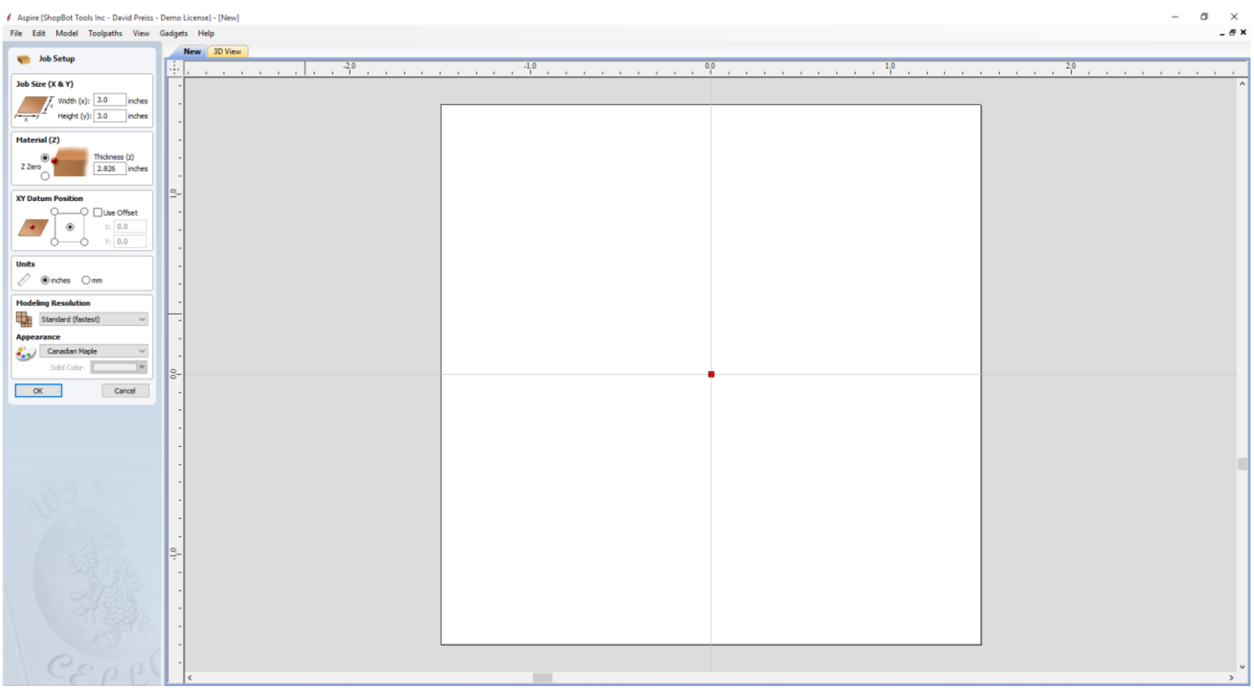
A 0.7065 inch thick sheet of Baltic Birch plywood was machined into 3" x 3" squares using the Handibot. 3 of these squares were glued up to form a cube of dimensions 3" x 3" x 2.826"



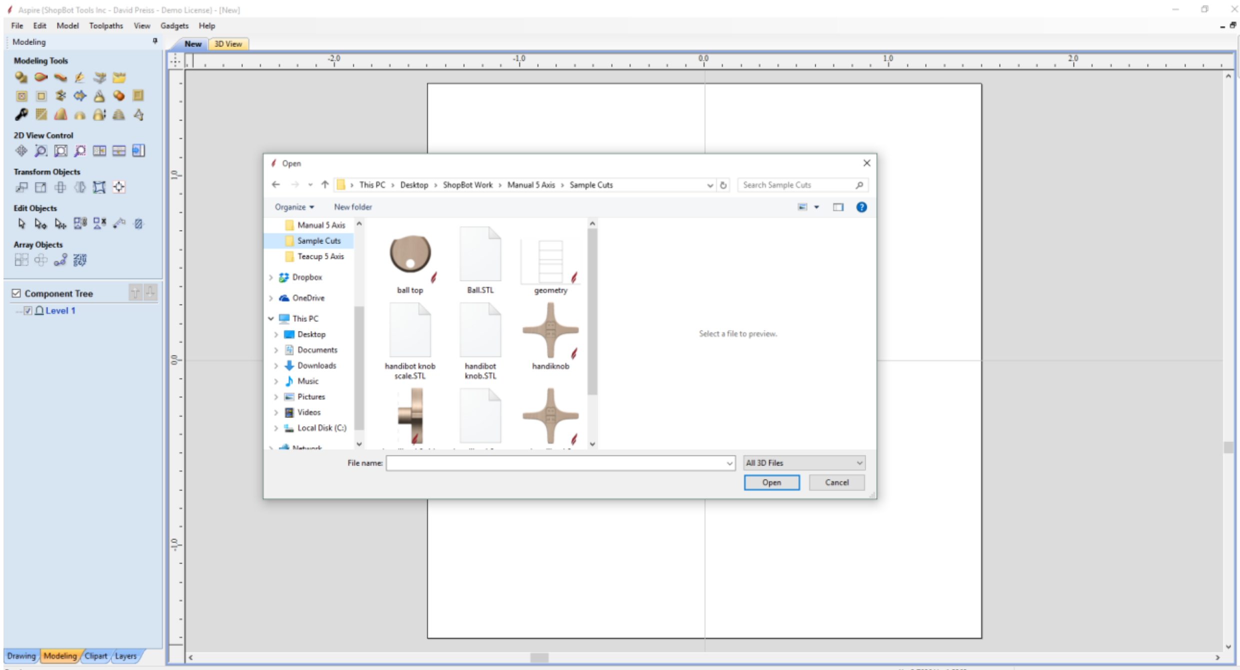
4 Screws, 1" in length were used to attach the stock to the mounting plate. An approximate center point was marked on the bottom of the stock using 2 intersecting lines from corner to corner. A shallow 1/8" pilot hole was then drilled, the mounting plate was attached through its center and 4 more surrounding pilot holes were drilled, and screwed, and finally the center screw was removed.

Setting up an Aspire File:

Start a new file in Aspire and set your stock dimensions in the default position into aspire.



In the modeling tab, select the "Import a Component or 3D model" tool and import the desired 3D model in STL format.


Aspire [ShopBot Tools Inc - David Preiss - Demo License] - [New]
File Edit Model Toolpaths View Gadgets Help
Modeling
Modeling Tools
2D View Control
Transform Objects
Edit Objects
Array Objects
Component Tree
Level 1
New
3D View
Open
This PC › Desktop › ShopBot Work › Manual 5 Axis › Sample Cuts
Search Sample Cuts
Organize
New folder
Manual 5 Axis
Sample Cuts
Teacup 5 Axis
Dropbox
OneDrive
This PC
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Documents
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ball top
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Select a file to preview.
File name:
All 3D Files
Open
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Drawing
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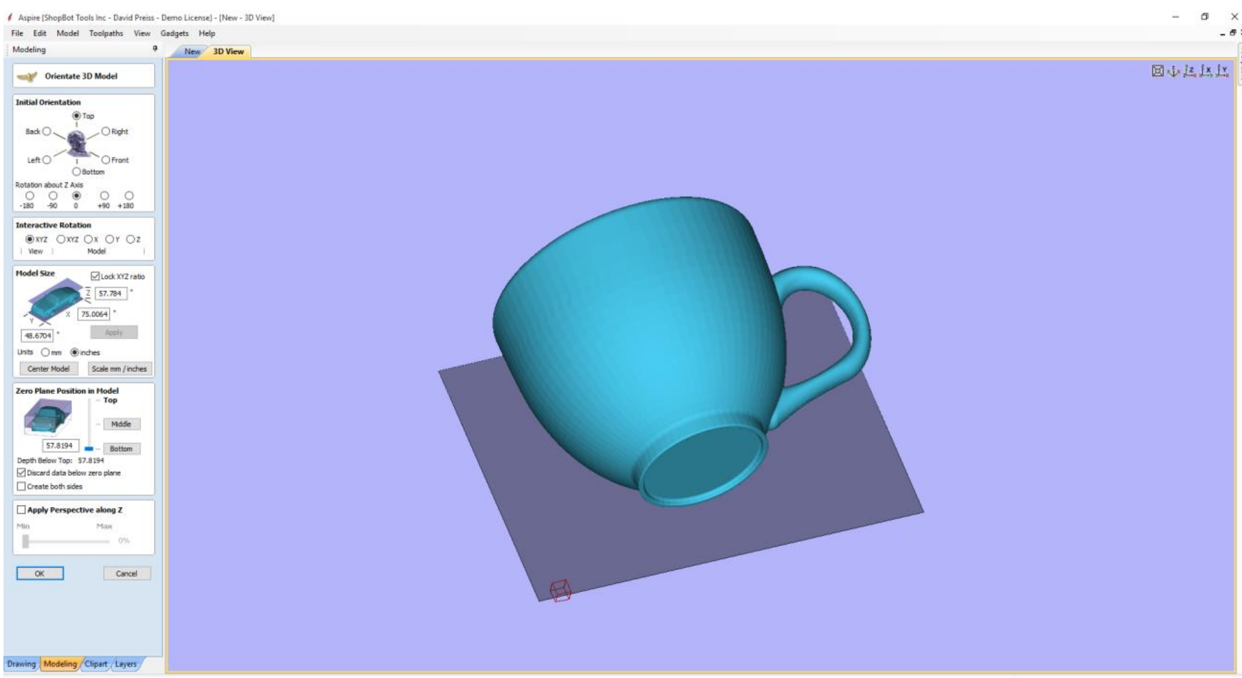
Aspire [ShopBot Tools Inc - David Preiss - Demo License] - [New - 3D View]
File Edit Model Toolpaths View Gadgets Help
Modeling
New
3D View
Orientate 3D Model
Initial Orientation
Top
Back
Right
Left
Front
Bottom
Rotation about Z Axis
-180
-90
0
+90
+180
Interactive Rotation
XYZ
XYZ
X
Y
Z
View
Model
Model Size
Lock XYZ ratio
57.784
75.0064
48.6704
Apply
Units
mm
inches
Center Model
Scale mm / inches
Zero Plane Position in Model
Top
Middle
Bottom
57.8194
Depth Below Top: 57.8194
Discard data below zero plane
Create both sides
Apply Perspective along Z
Min
Max
0%
OK
Cancel
Drawing
Modeling
Clipart
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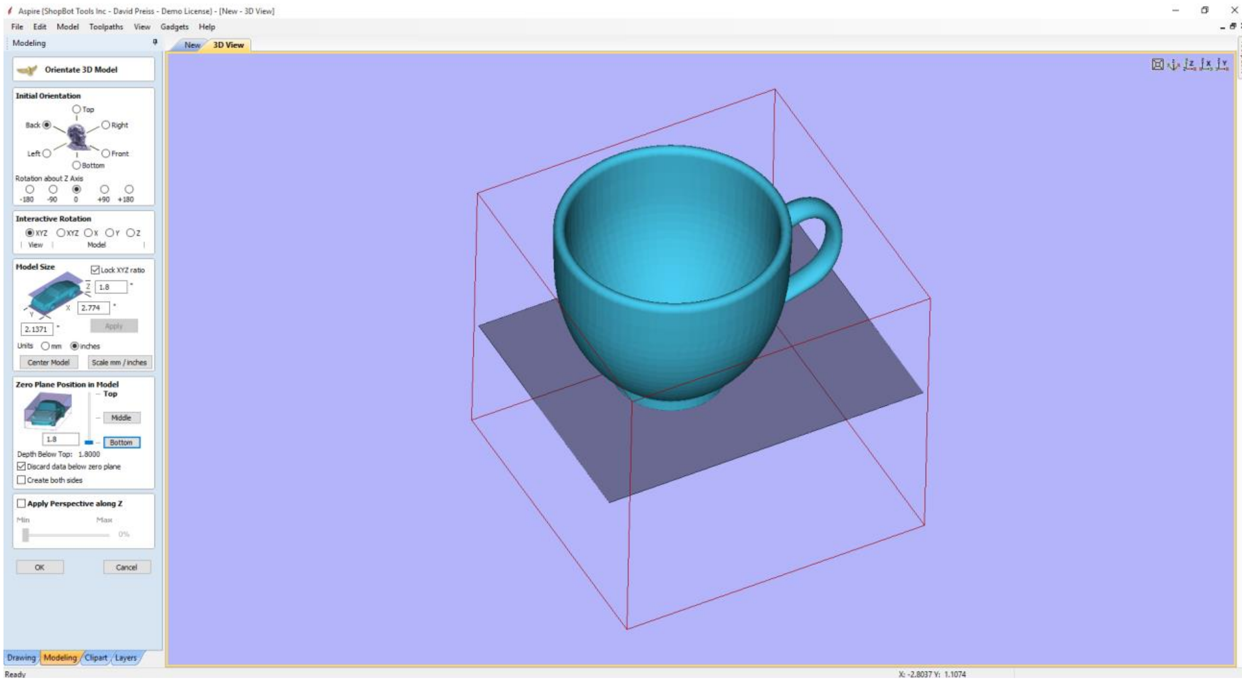


Position your model in the desired orientation using the “Initial Orientation” options.

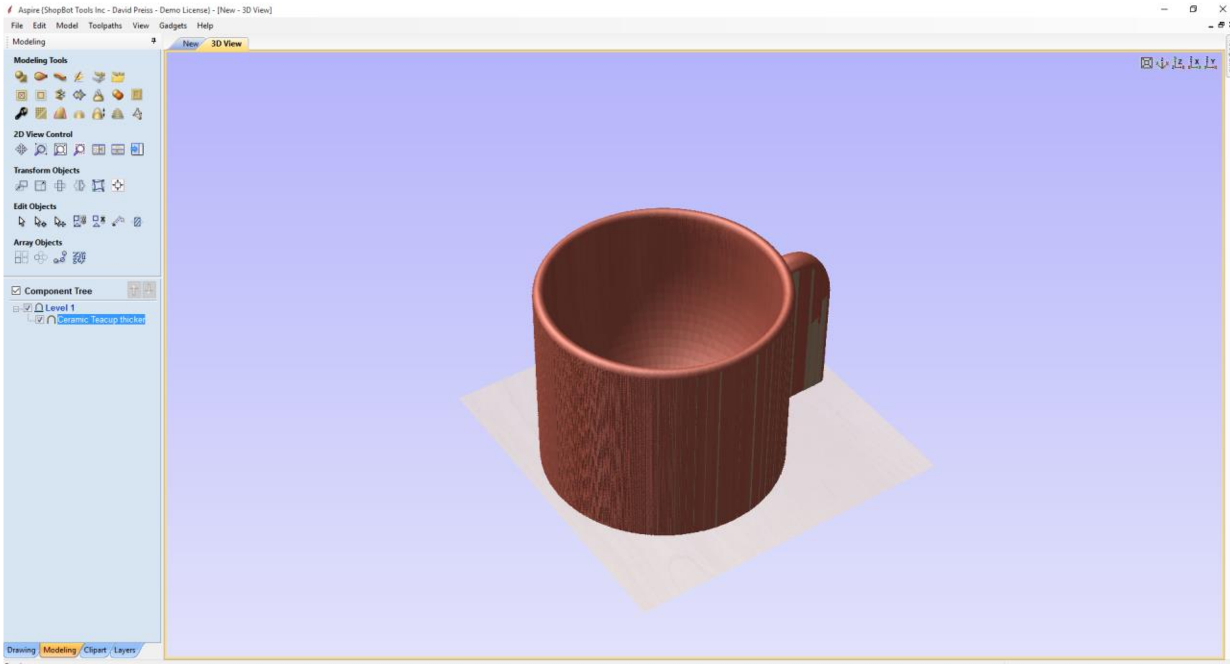
In the “Model Size” tab, set an XYZ dimension of your model (making sure that the “Lock XYZ ratio” box is checked) keeping in mind that these will be the final machined dimensions of your model, regardless of the file you imported. Press Apply.

In this case we have chosen to cut to a depth of 1.8” largely due to the fact that it is the maximum length of exposed 0.25” end mill we can use for roughing given the limitations of the teacup geometry. Our X dimension has also scaled to 2.774” which is around the limitations of our 3” x 3” stock volume. When choosing a Z dimension to scale to, it is critical to account for the material that must be left at the bottom of the stock where the mounting screws are positioned. As discussed in the stock section, this was estimated at 0.5” of depth, therefore 1.8” + 0.5” = 2.3” which is safely within our 2.826” stock Z dimension.

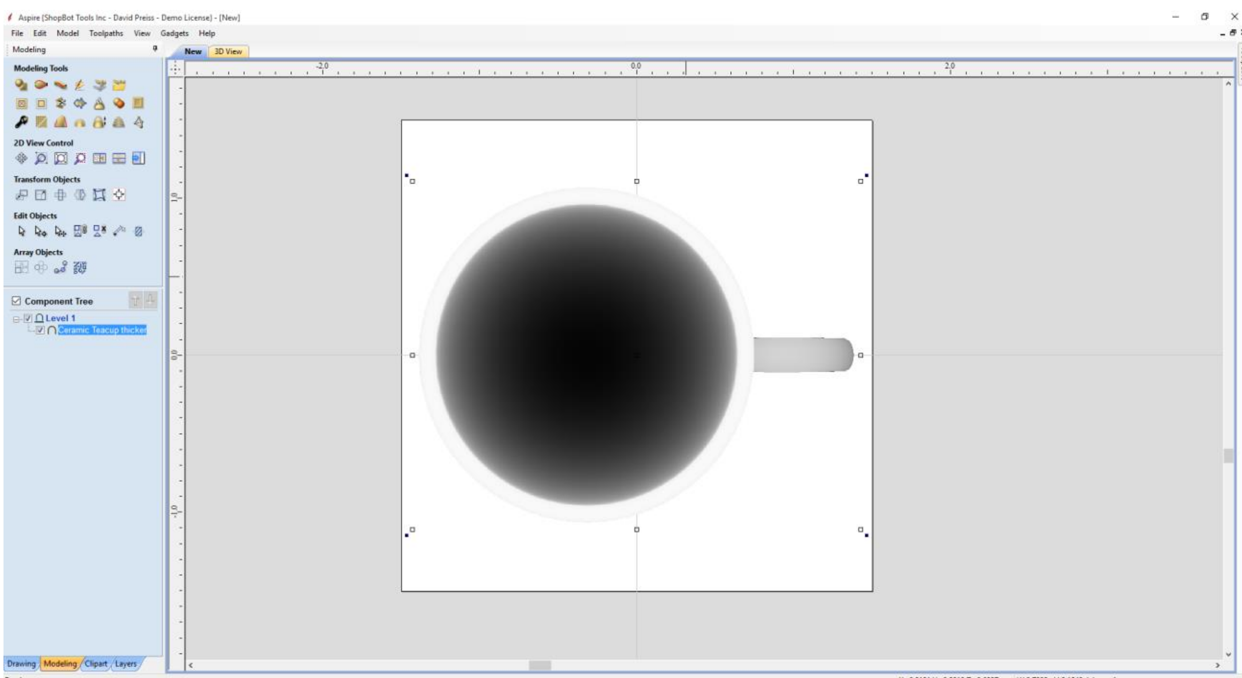
Select “Center Model” button.

Set the “Zero Plane Position in Model” to limit the depth of material you wish to machine for this pass. Keep in mind that this depth is limited to the length of cutter used, along with the geometry of the part being machined. Machining to a depth below the length of your cutter may result in the collet crashing into unmachined stock, which cannot be accounted for in the software. Keep in mind that the “Zero Plane Position in Model” tab will dictate the cutoff point for where the toolpathing will end, and if using a ball-nose bit, parameter should be a minimum of the bit diameter below the desired cutoff point. This value will not affect where you zero the bit in the Z.

Select OK.



Only accessible geometry will be kept, and the resulting 3D model will appear checked in the component tree beneath the modeling tree. By switching between the 2D and 3D viewing tabs, it is possible to get a comprehensive view of how the software has imported and interpreted your model.

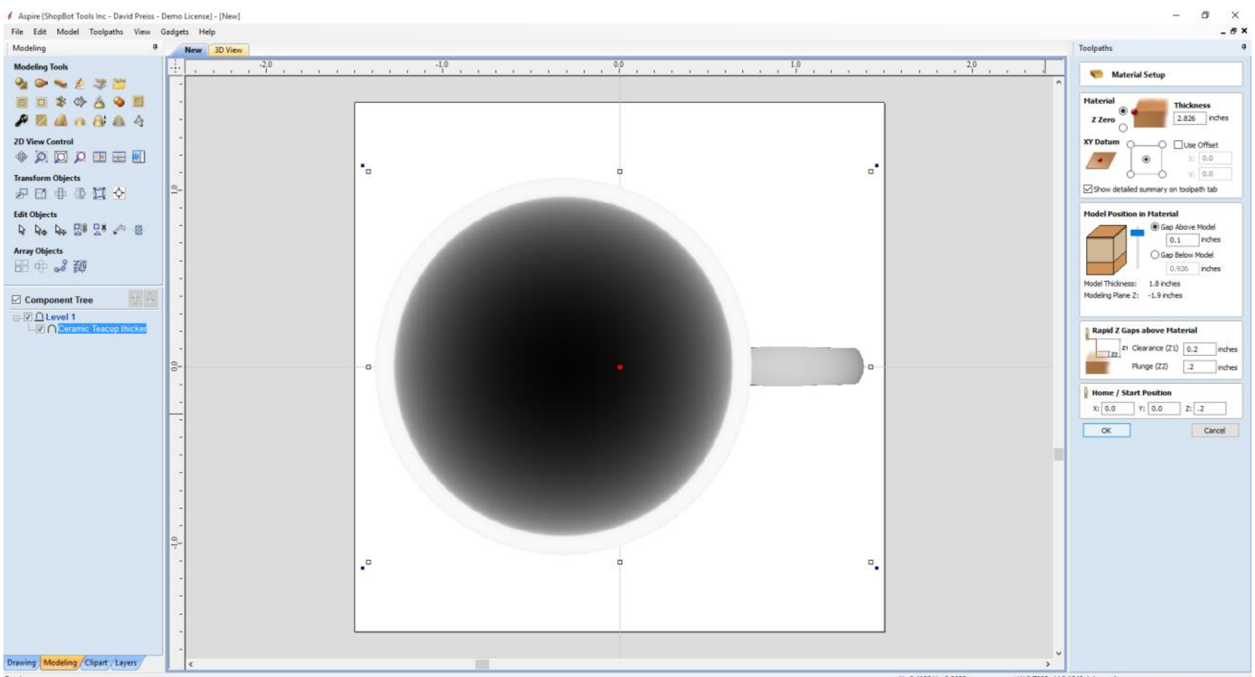


Open and pin the toolpaths tab to the right of the screen, and select "Material Setup." Here it is necessary to select where the material's Z Zero point will be located (under most circumstances it will be best to zero to the top of the material).

Under the “Model Position in Material” menu, it will be necessary to select a model position that leaves enough clearance at the top of the stock to get a good finish and account for any misalignment of the stock, as well as making sure that it does not position the material to be cut below the mounting plate, or within the depth of mounting screws. Generally it is best to choose a small depth defined by selecting “Gap Above Model” to minimize the amount of material to be removed in the roughing toolpath and not risk collet collision. The “Gap Below Model” field is linked and will be populated using the material thickness value defined previously.

It is also necessary to select a Home / Start Position that will not cause the tool to crash mid machining. If using a centered XY Datum position, it is usually best to choose an X and Y home of Zero, and a Z home position that can safely clear the stock and sides of the manual 5 Axis Jig, without maxing out the tools Z-travel. To be safe, it is practical to set the Clearance and Plunge values to a similarly safe Z height. These values will account for material thickness whether your Z Zero plane is at the top or bottom of the material.

Select OK.



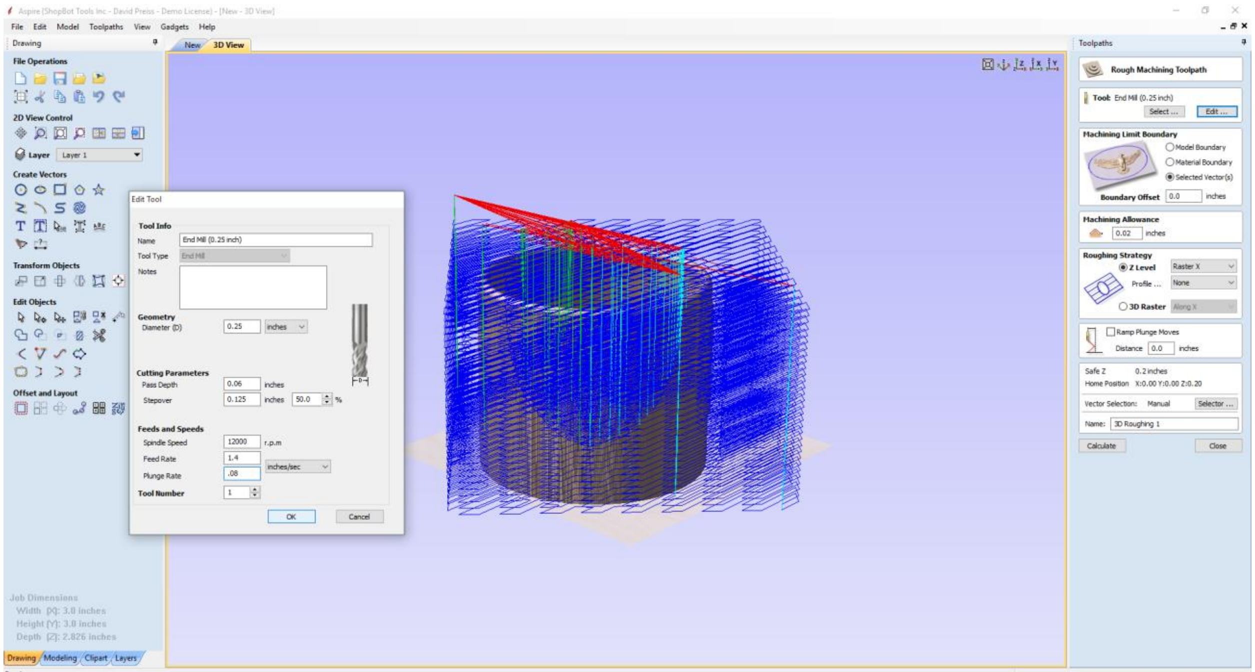
Toolpathing Side 1:

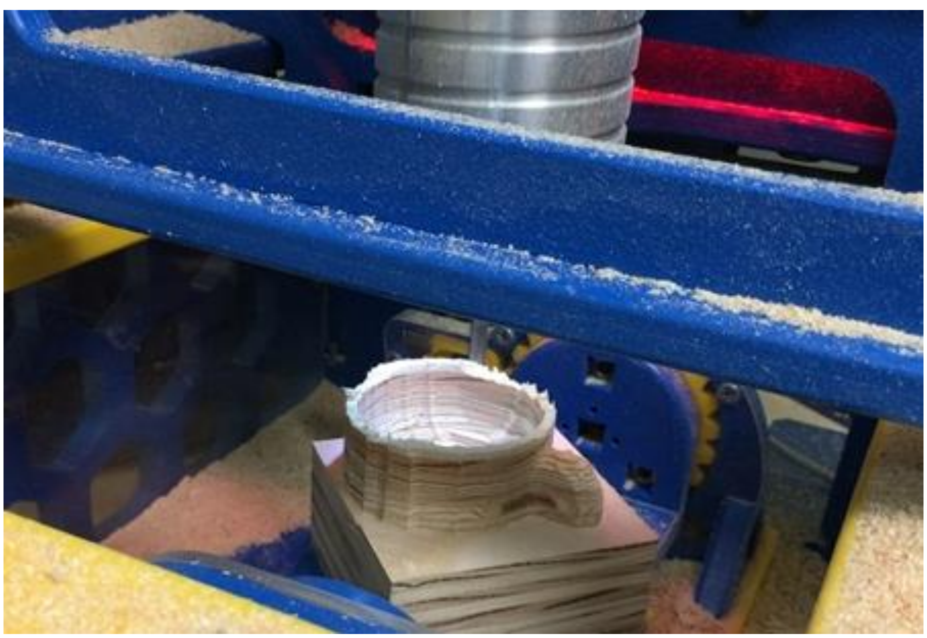
For this particular model and machining angle, we will opt to start with a roughing toolpath using a 0.25” flat end mill to quickly remove the bulk of material, and then use a finishing toolpath with an 1/8” tapered ball nose bit to achieve the desired finish.

Select the “Rough Machining Toolpath” icon from the toolpaths tab.

Tool selection was made as an existing 0.25” end mill, and feeds and speeds were altered to allow in the edit menu native to this file. Many of the variables associated with feeds and speeds will be changed to accommodate for decrease in rigidity caused by the trunnion.

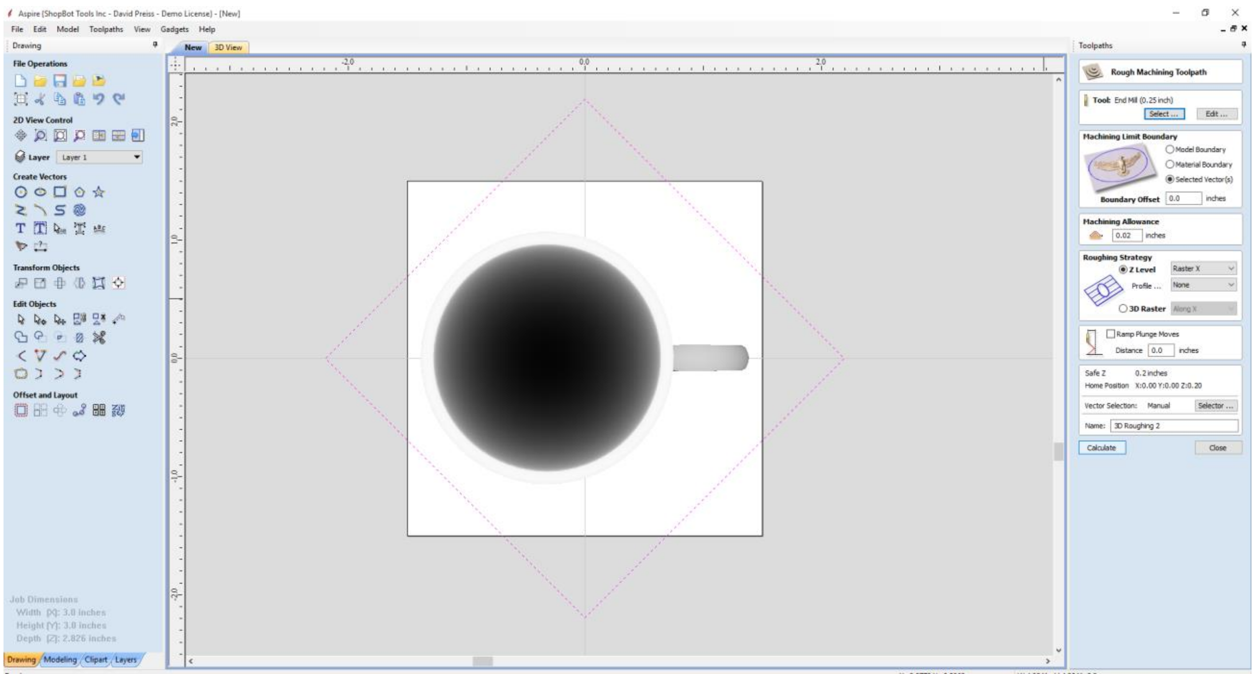
For Baltic Birch, and the 0.25” cutter, a pass depth of 0.06,” a 50% stepover, and a feed and plunge rate of 1.4 and 0.08 inch/sec were selected as shown in the figure below. These values are slightly more conservative than what could be achieved on a spoil board mounted sheet of plywood, but yielded a reasonable 45 minutes of estimated machining time.





Machining Limit Boundary

Under most circumstances, drawing a specific vector and using it to limit cutting area can improve efficiency and decrease cutting time. We will use this roughing cut to remove material that would be limiting in future rotations. In this case a 3.1” x 3.1” square was drawn around the material boundary, and then rotated 45 degrees to account for the angle at which the stock is oriented. Despite the fact that the boundary vector extends beyond the limits of our stock, the toolpath will be generated here as well.



A machining allowance of 0.02” will be sufficient to allow for a good finish without leaving too much material that might risk breaking the more delicate finishing bit.

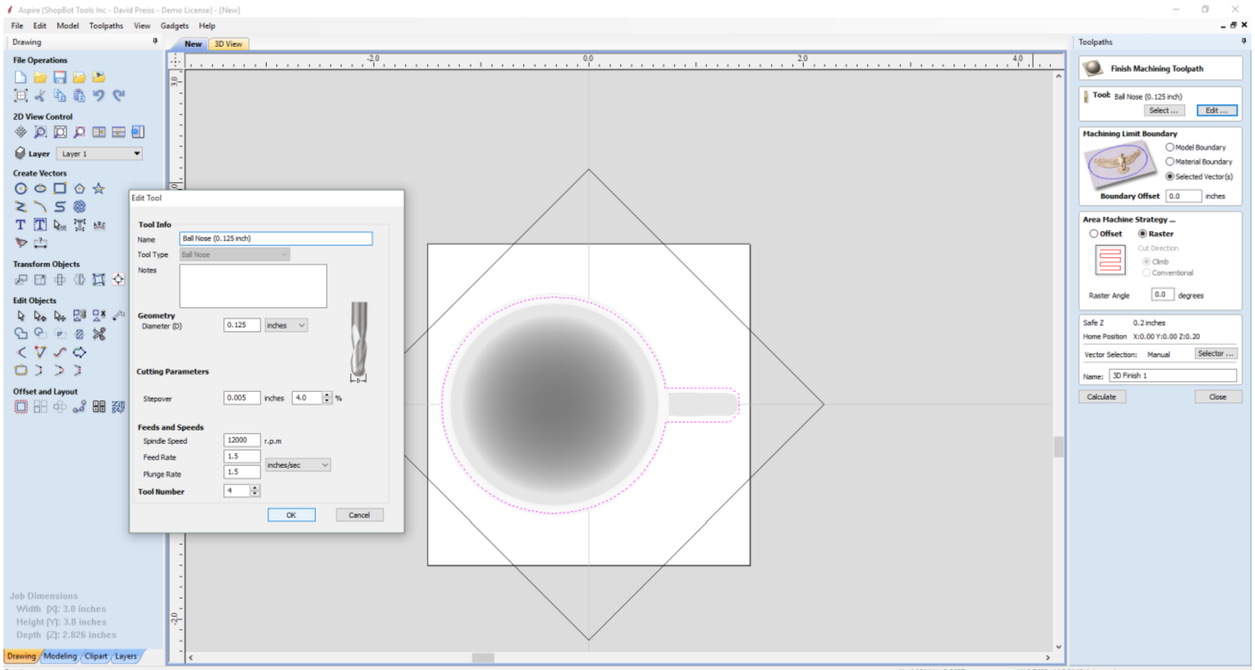
Choosing an appropriate roughing strategy may be important in minimizing cutting time and preventing tool vibration. Z Level machining was used here due to the thin walled sides of the cup, frequent and dramatic changes in the Z, and nature of the laminated plywood. It is recommended to try several strategies and both watch the previews and check estimated machining times of each.

Finish Toolpathing Side 1

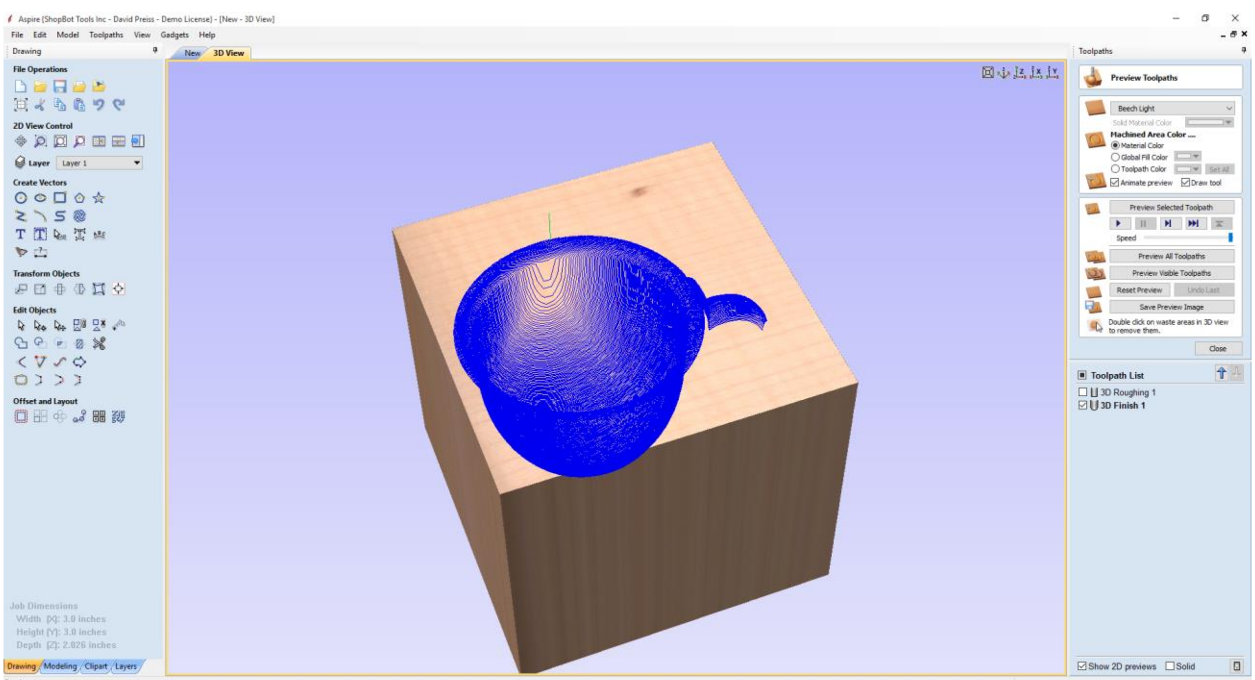
Select the 3D Finishing Toolpath icon in the toolpaths tab.

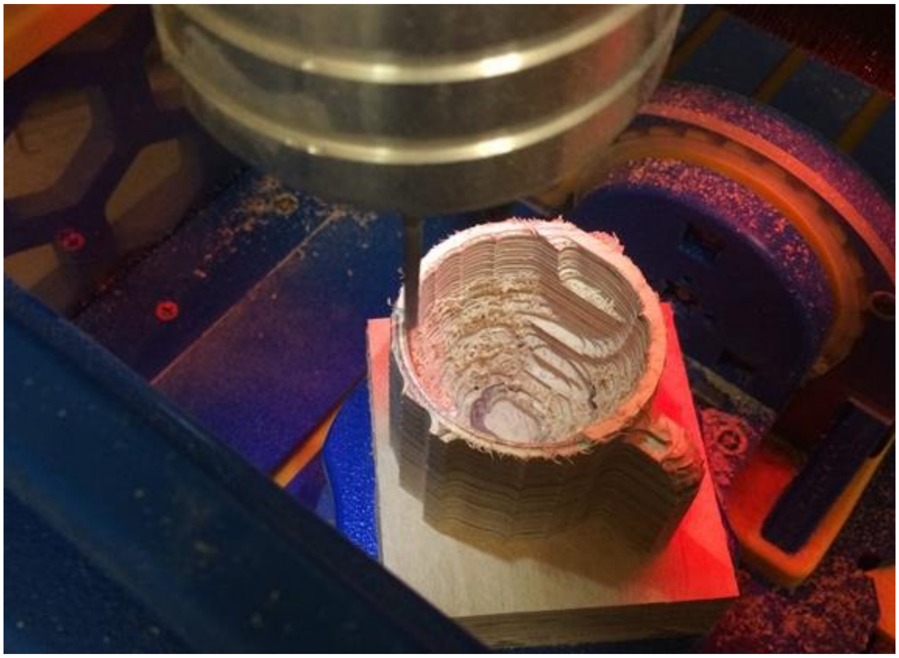
Under these circumstances, it was chosen to finish only the inside of the cup and the top of the handle by drawing a bounding vector around those areas in the 2D drawing tab. This was done to optimize machining time, as the concave regions of the cup past the lip will not be accessible until the part has been rotated. Assessing the optimal strategies for machining individual parts is a necessary part of machining in 5 axis. Unfortunately there is no exact formula to follow, but by understanding the geometry of your part and limitations of your machine, it will become easier to optimize the machining process.

For machining Baltic Birch with the 1/8” tapered ballnose, a 4% stepover was used, along with a 1.5 inch/second feed and plunge rate.



A rastered machining strategy is typically used for finishing and will produce excellent surface finish with sufficiently small stepover at good speeds. The finished toolpath is represented in the figure below. When machining wood it is possible to sand away any texture left by stepover, but each part and material might have an optimal machining strategy unique to its given case.



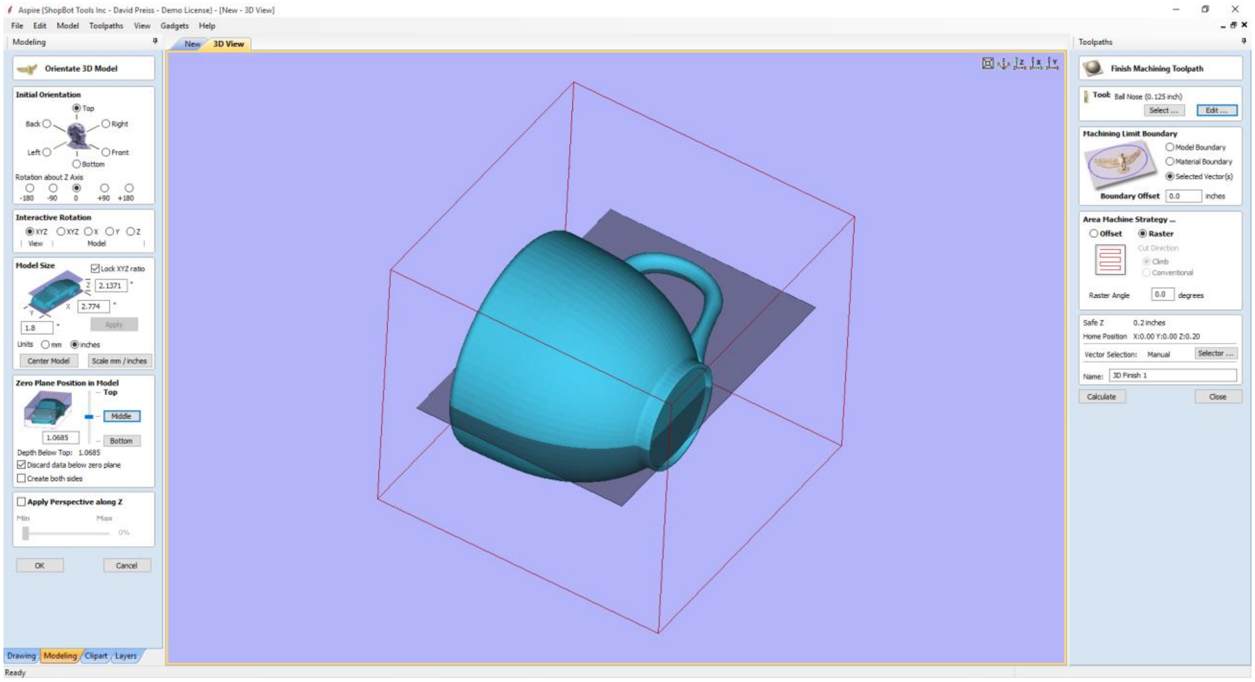


Toolpathing Side 2

First it will be necessary to choose any additional sides we would like to machine. In this case, we will machine only 2 additional sides, each mirrors of the same plane as the handle of the teacup, to ensure that we fully machine the inside of the handle. Therefore the 4th axis will be rotated 90 degrees, and in this case the 5^{th} axis will also be rotated 90 degrees. It is critical to reflect these changes in our Aspire file, and doing this can be challenging, depending on how your part is oriented.

The technique we will use to re-orient the tool will be to import the teacup again at a 90 degree orientation, position it relative to the parameters we defined when setting up for side 1, and then re-zeroing the tool such that it zeroed to the center of the rotated part (the part's zero point will only move in the X and Z, not in the Y).

First we will re-import the teacup at 90 degrees to our original, making sure to take note that the Y dimension is now 1.8" as shown and verified in the figures below. The Zero plane will be directly through the center of the teacup which will make the zeroing process easier (although it would be beneficial to machine slightly further when using a ball nose bit).



Your part will be imported on top of the old geometry which can be usefull for verifying that it has been imported properly.

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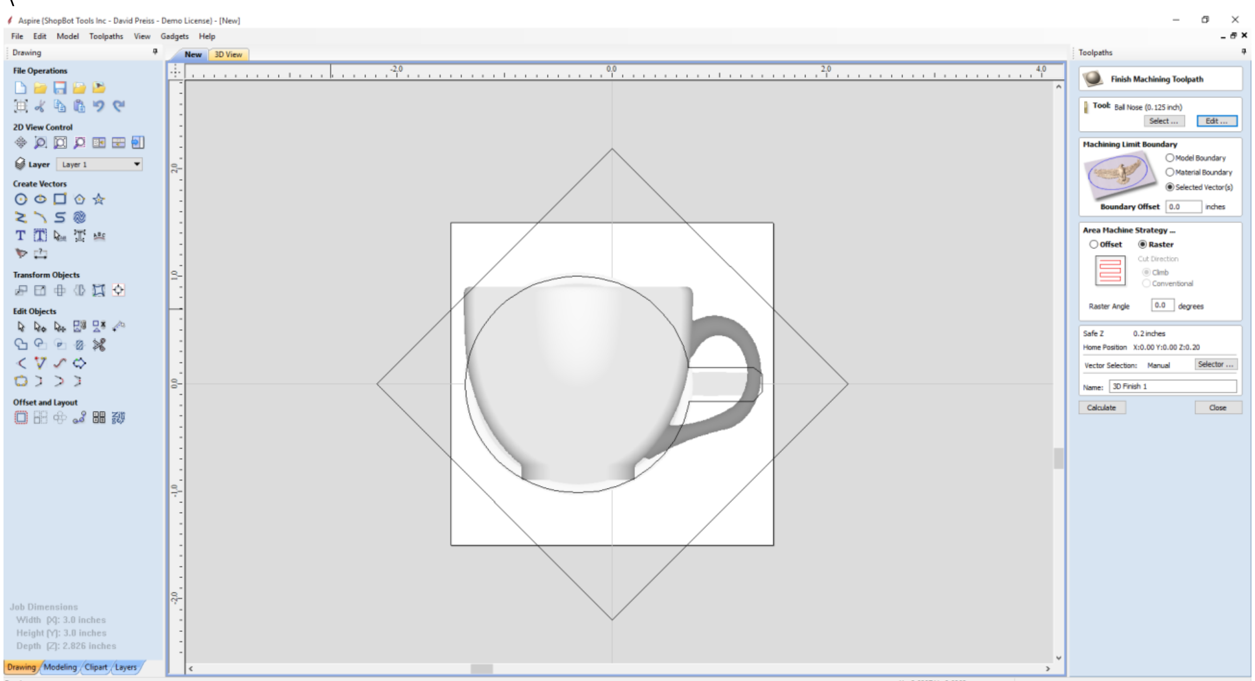
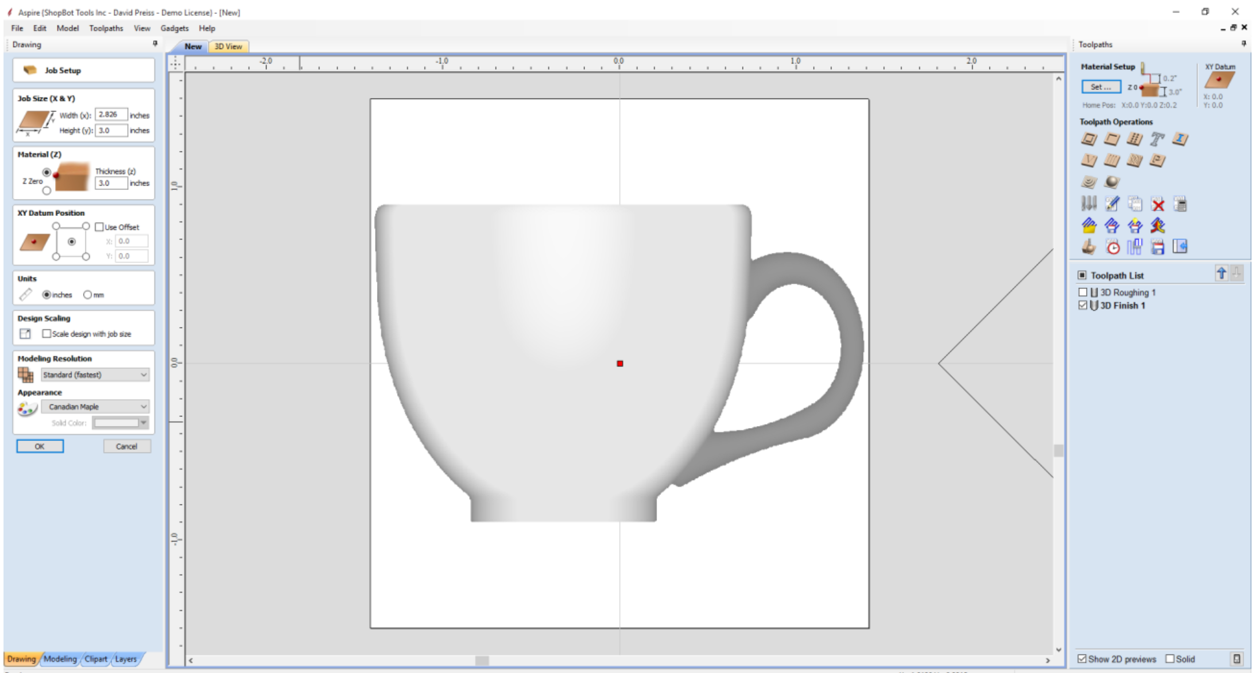
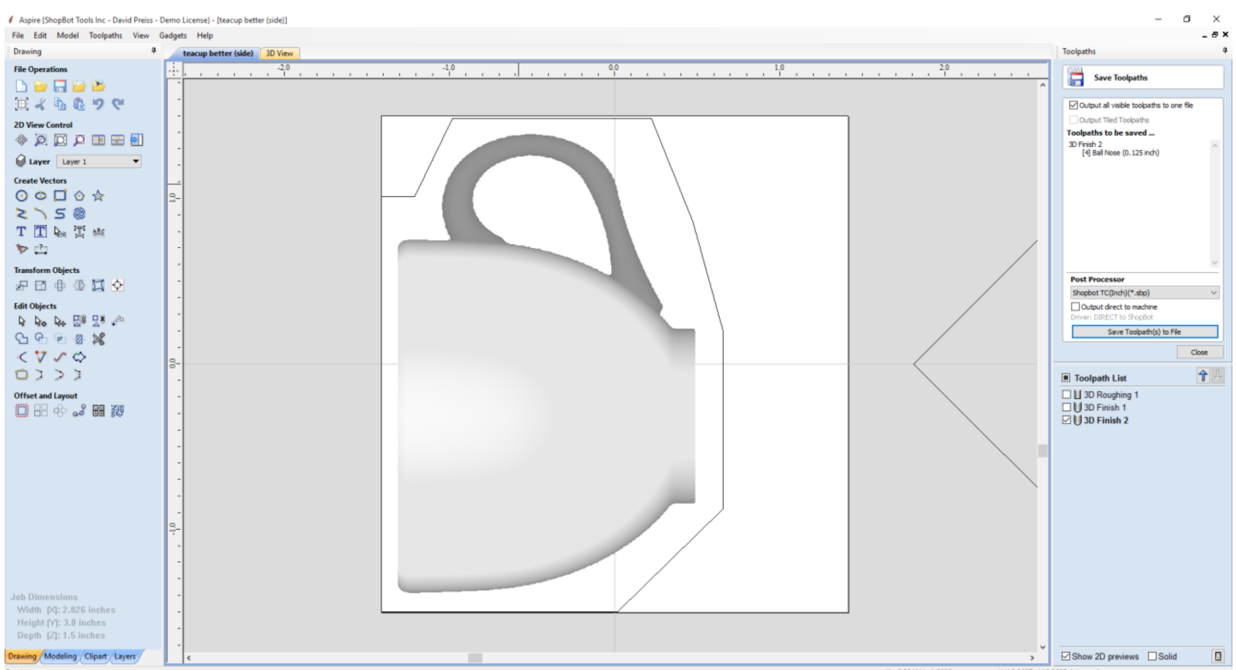
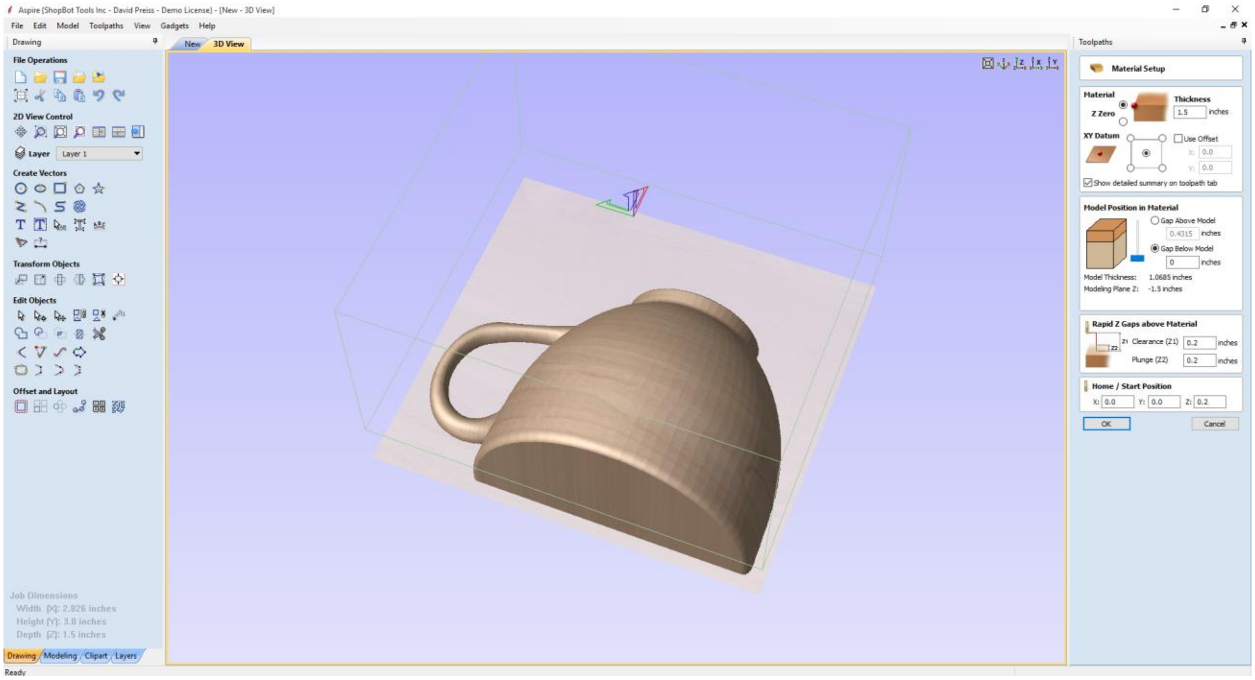


At this point pay careful attention to how the part is oriented in your machine with respect to the X and Y axis of your specific tool, and be sure to align the part and material in Aspire to match it. In this case the handle is oriented to face in the positive Y direction, and the top of the cup is facing in the negative X. First the part was rotated 90 degrees counterclockwise, keeping the center of rotation at the center of the stock. The cup was then moved in the X axis, such that the rim was exactly 0.1” from the negative X side of the stock. This represents the “Thickness Above Material” parameter defined when setting up for side 1. The value and direction should be assessed on a case by case basis.





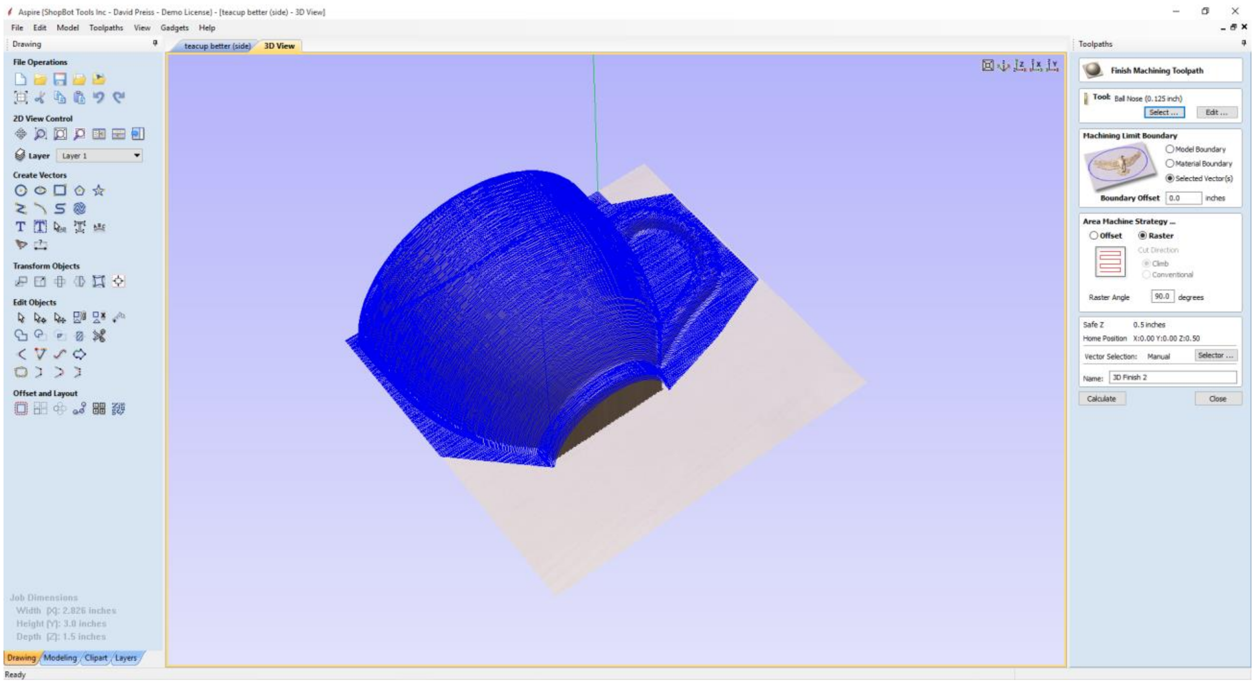
In the Material Setup tab, be sure that the “Model Position in Material” is representative of how you plan on zeroing the part. In this case we will zero to the top of the stock, and the intersecting plane of the teacup is positioned 1.5” below, so we will have a “Gap Below Model” of 0.”



Because we have removed the bulk of material from our stock with the roughing toolpath in side 1, it won't be necessary to set up additional roughing toolpaths.

> *Under many circumstances, it may be possible to skip a roughing toolpath and move directly to finishing. This is done by rastering the finishing toolpath in either the X or Y direction, and using a very small stepover, in the range of 4%. This results in for every stepped-over pass after the first, only a very small amount of material will be removed, which is manageable for more delicate finishing bits, like the 1/8" tapered ball nose used in this project. What remains is the problem that for the first pass, the tool will be forced to cut directly into the material at full depth. There are two work-arounds to this problem, one is to start the rastering outside of the stock using a bounding vector, so that it never has to cut into the material at full depth. The other work-around is to generate a toolpath with very slow feed and plunge rates, allow it to make its first pass, and then start again with a new file at full feeds and speeds, so that any subsequent passes will only be removing an amount of material defined by the stepover.*
>
> *Moving directly to a finishing toolpath is a good time saving measure, but can only be done if there are no dramatic changes in Z during the toolpathing. For example, the top side of the teacup would not have been a good candidate for this technique, as the deep sides of the cup would present too much material to safely remove in the Z without breaking the bit.*

Again a rastered machining strategy will be used with the technique discussed above. Notice that the toolpath does not machine away the base of the teacup, which is important to keep the part rigid enough to complete the machining process. This particular file will start at the base of the teacup and raster along the Y axis. Feeds and speeds were identical to the finishing toolpath used for side 1.


Aspire [ShopBot Tools Inc - David Preiss - Demo License] - [teacup better (side) - 3D View]
File Edit Model Toolpaths View Gadgets Help
Drawing
teacup better (side)
3D View
File Operations
2D View Control
Layer
Layer 1
Create Vectors
Transform Objects
Edit Objects
Offset and Layout
Job Dimensions
Width (X): 2.826 inches
Height (Y): 3.0 inches
Depth (Z): 1.5 inches
Drawing
Modeling
Clipart
Layers
Ready
Toolpaths
Finish Machining Toolpath
Tool: Ball Nose (0.125 inch)
Select ...
Edit ...
Machining Limit Boundary
Model Boundary
Material Boundary
Selected Vector(s)
Boundary Offset
0.0
inches
Area Machine Strategy ...
Offset
Raster
Cut Direction
Climb
Conventional
Raster Angle
90.0
degrees
Safe Z 0.5 inches
Home Position X:0.00 Y:0.00 Z:0.50
Vector Selection: Manual
Selector ...
Name: 3D Finish 2
Calculate
Close

Toolpathing Side 3

Side 3 can be machined by simply mirroring the part and boundary geometry from side 2, and recalculating the toolpath. The more radial symmetry in your part there is, the higher the likelihood that you will be able to reuse toolpaths in this way. Finally the teacup was cut from the stock material using a band saw, and the finished results can be seen below.