A Gentle Introduction to Abrasive (Waterjet) Machining

Brought to you by the MIT FabLab Staff.

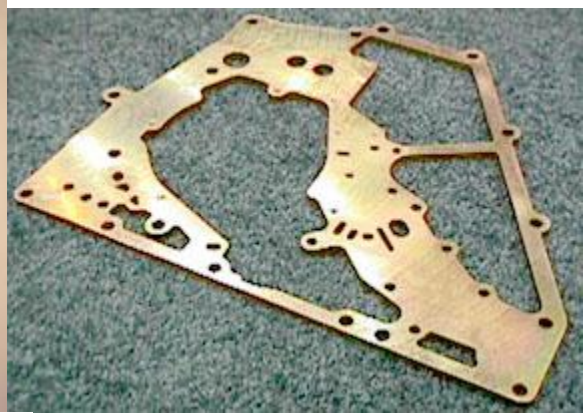
In this brief two part tutorial we will give you a jump start toward making your first project parts utilizing the Department of Architecture's new OMAX waterjet machine. In Part I we assume that you have access to a computer running the *OMAX Layout* software required to define new geometry or import your previously defined part geometry and then create tool paths based on this geometry. In Part II we assume that you have access to the actual waterjet machine itself, the *OMAX Make* software which controls the physical machine, as well as knowledgeable lab monitor or staff member who'll be able to help with any questions or safety issues that might arise.

First, a little background information about abrasive machining:

The *OMAX 2652* is a relatively new type of machine tool which uses a very high pressure (> 50k psi) stream of water and garnet abrasive to cut virtually any kind of material by eroding the material along an arbitrarily complex tool path that you define, leaving a thin (~0.025"), *kerf*. Both thin and thick materials such as aluminum, steel and stainless steel, plastics such Plexiglas and Lexan, rubber, brick and glass, and even wood may be cut on a waterjet. Material thickness can range from 1/16" through 4", even when cutting very hard materials. Some special precautions and procedures are required for cutting brittle or very thin materials.

The procedures and techniques required to use the OMAX waterjet are pretty straightforward and quick to learn. And please be assured that the OMAX waterjet is quite safe to use when simple best practices are followed. This tutorial should take you less than an hour to complete, assuming you already have a part geometry file created in Rhino or AutoCAD

Here are some sample parts that can be made using a waterjet:



Now, let's make a part…

The short and skinny:

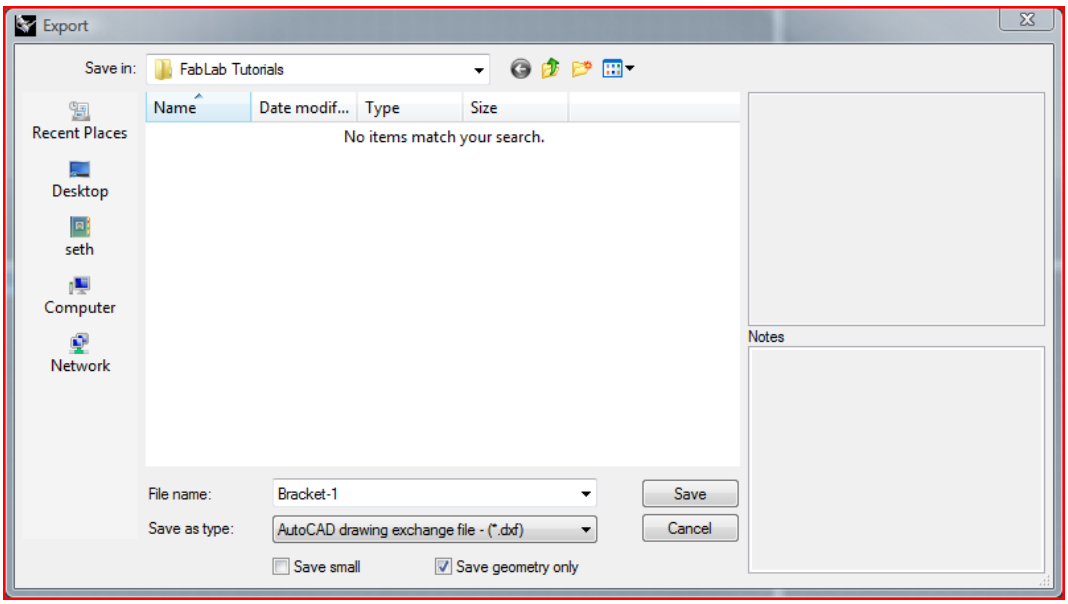
The three basic steps required to make a part on the OMAX waterjet are as follows (Steps 2 and 3 will be described in detail in the following pages):

- Your part geometry must be either imported into the *OMAX Layout* software from some kind of CAD program like Rhino, AutoCAD, or SolidWorks, or you will have to create the part geometry you'd like using the *OMAX Layout* program itself (which is not discussed in the tutorial.)
- Once your part geometry has been imported (or created within *OMAX Layout*), you must then create a *toolpath*, which is simply a set of instructions for the OMAX to follow in order to manufacture your part out of some kind of *raw stock*, usually some type of relatively thin sheet material but which can vary quite a bit in practice. Part I of this tutorial will show you how to do this in three basic steps.
- Finally, the *toolpath* (now contained in an .ORD file), must be loaded into the *OMAX Make* program which actually runs the machine itself and which will control all motion, high pressure pump operations, water and abrasive flow, and more or less anything else the OMAX must do to cut your part(s). Part II of this tutorial will cover the machine operations required to actually cut a part.

Part I – Creating your Geometry and a Toolpath

Step 1: Creating your part geometry

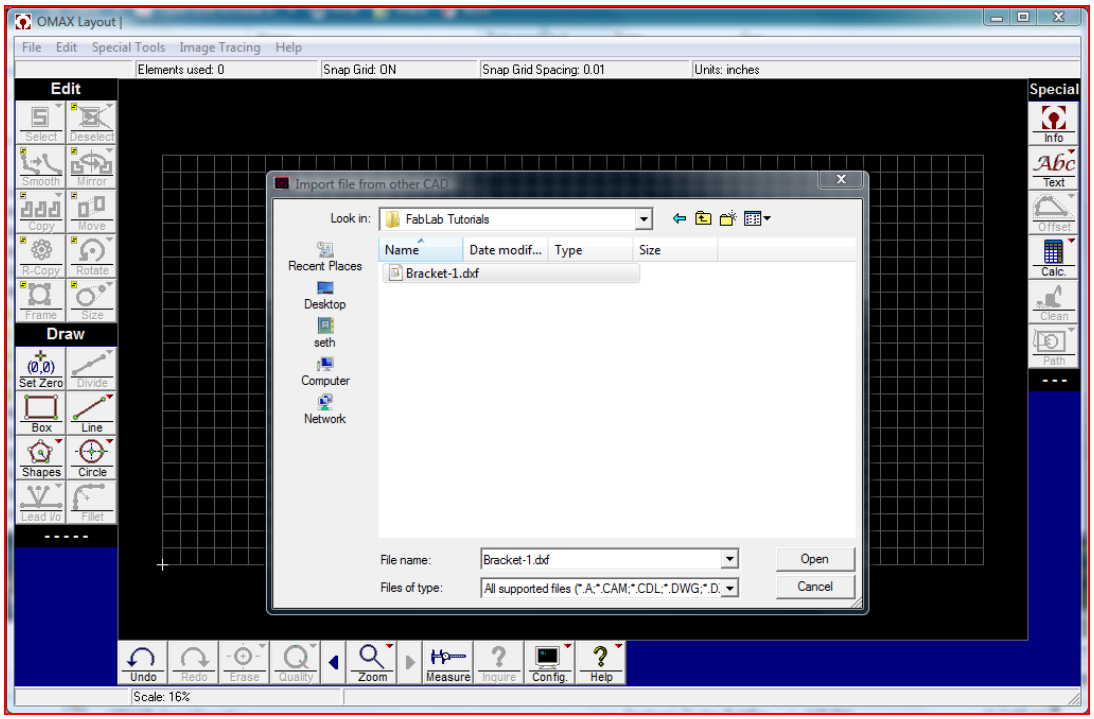
You will usually prepare your part geometry in Rhino, AutoCAD, or some other familiar-to-you CAD program. Simply save your model or part in AutoCAD .DXF file format. If given the option, try to use the AutoCAD 2004 version, as this will make importing your geometry into *OMAX Layout* substantially easier. Here is an example of how to do this in Rhino v4:



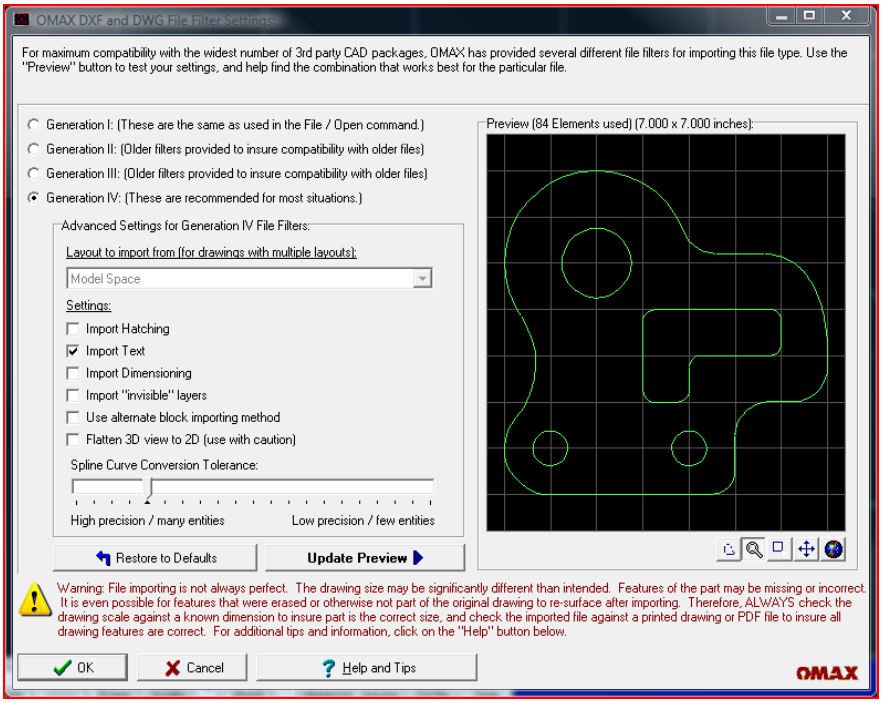
The result will be a new file named *Bracket-1.dxf*, and this is the file you will *import* into the *OMAX Layout* software.

Step 2, Importing your part geometry

Now start up the *OMAX Layout* program, either using the icon on your Desktop or by going to the Start menu, and looking under *OMAX Layout and Make*. In *OMAX Layout*, go to the *File->Import from other CAD*.... and enter the name and location of your DXF geometry file, as shown below:

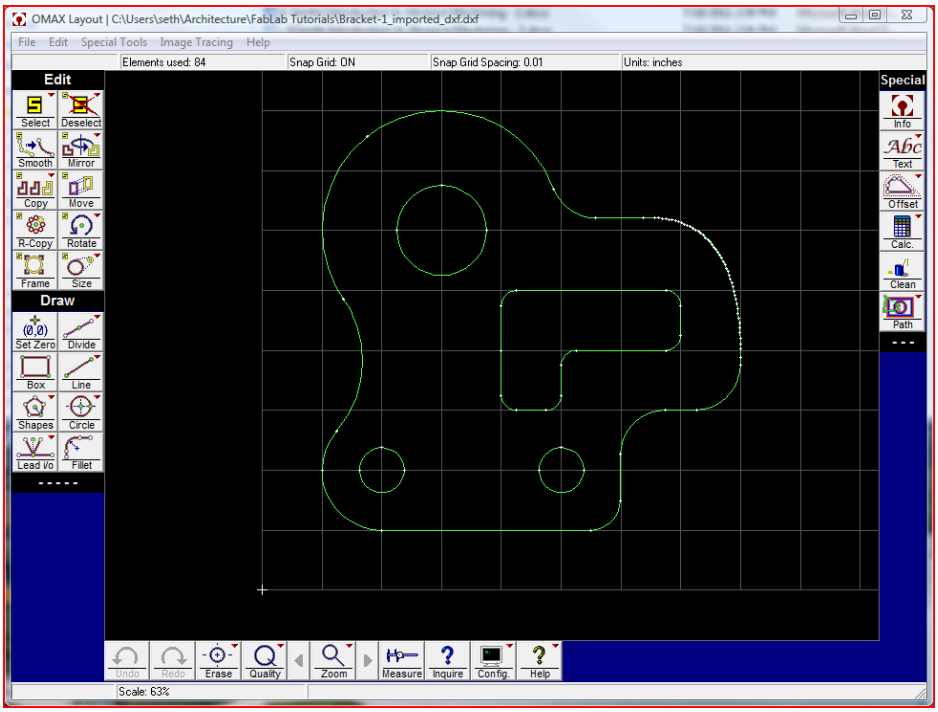


You will then be presented with a page that looks like that below; selecting the defaults is usually a safe bet, but you may try selecting some of the options and they hit *Update Preview* if you suspect something might be missing.



Step 2, continued…

After hitting the *OK* button, your geometry should appear in the main *OMAX Layout* drawing area:



Hint: If you can't see your part in the *Layout* window, you may have some spurious points or geometry that is way outside of what you think of as your part. Press the *Home* key (usually just above the cursor keys on your keyboard), and *Layout* will zoom out so that all of your geometry (including errors!), will fit into the main window; this will help you figure out what you did wrong.

Assuming everything looks good, complete the importing of your geometry by checking your new part for duplicate points and lines, gaps and unclosed paths, etc. You do this by selecting the *Clean* function on the right hand side of the *Layout* screen. A brief report of what was done will be issued.

Note 1: Immediately save your new part file under a new name, something different from your recently imported geometry file, maybe something like *Bracket-1_OMAX.dxf,* using *File->Save As...*

Note 2: You now have created a 2-D representation of your part geometry; there is no 3-D information in the new *OMAX Layout* .DXF file you create in this step.

Step 3: Creating the toolpath

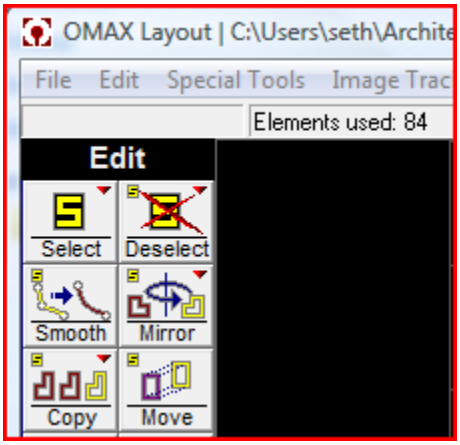
In order to make any cuts (e.g., generate *toolpaths*), you must first identify *exactly* what lines, arcs, etc., you want included in your *toolpath*. You must also tell *OMAX Layout* a few other things, including the *quality* of the cut you'd like to make, and both where to begin and in what order you want the features of your part cut. All of this is relatively simple to do, as you'll soon see.

Step 3, continued…

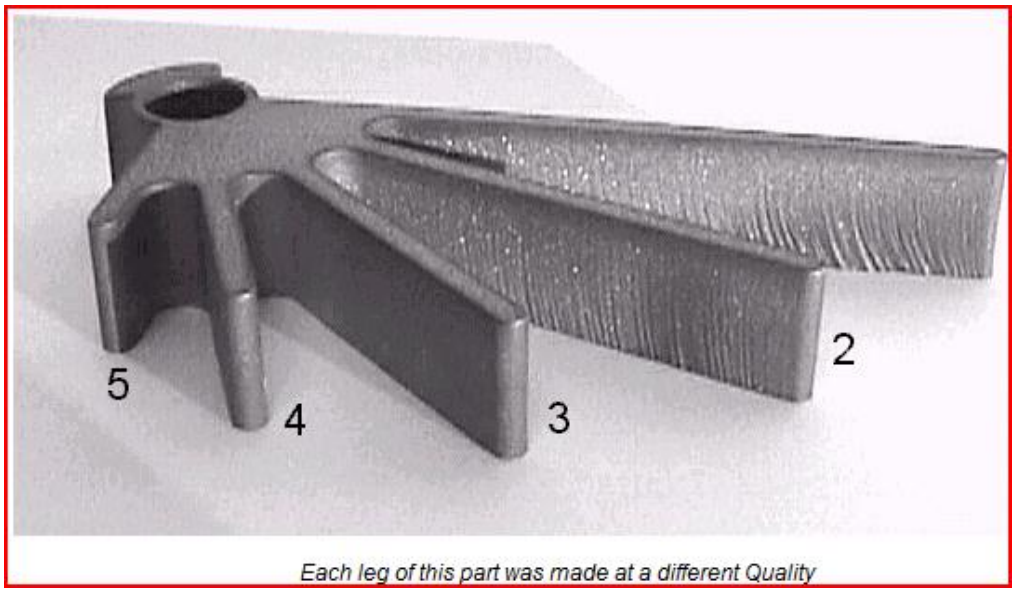
The first thing we need to do is to identify for *Layout* exactly what it is you'd like to cut. We can do this by *selecting* any or all of the geometry we just imported, using the 

button in the upper left hand corner of the *Layout* graphics screen.

A brief digression: Notice that the *Select* button as well as many others in *OMAX Layout*, have little red triangles in the upper right hand corners; this is *Layout's* way of telling you that you have additional options associated with this function button. If you *right click* on a button marked with a triangle, a list will pop up from which you may choose any of several options related to the main function. Try it by right clicking on the *Select* button and you'll see that you can select *All* of your geometry immediately, or use a rubber band *Window* to select a subset of possible objects. Either way, whatever is selected will immediately turn bright yellow, visually confirming for you what is currently selected.



After identifying exactly what geometry we wish to cut, we then need to tell *OMAX Layout* what *quality* of cut we'd like. *Cut quality* translates roughly into surface finish of the cut edges of your part. It also has implications for part accuracy. Usually, the higher the *quality* we choose, the better the finish and accuracy. Here is a visual reference that makes clear what cut quality looks like in a finished part:

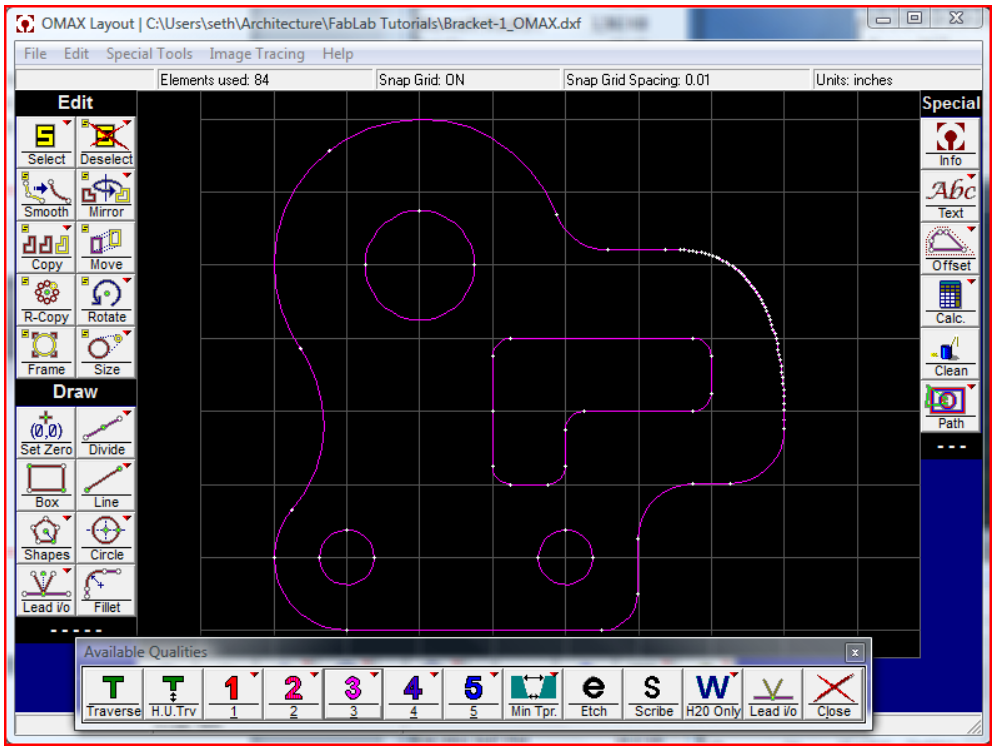


Each leg of this part was made at a different Quality

Step 3, continued…

Generally we'll use a *quality* of 3 for most of our work. When we need a really good surface finish, or when we need to get the best possible dimensional accuracy, or we're cutting something really hard and thick (like a piece of 3" tool steel), we might choose a *quality level* of 5. The trade-off is the time it takes to cut our part(s), and the amount of garnet abrasive consumed.

In the image below you can see that we have *selected all* of our geometry and assigned it a quality of 3 by first hitting the *Quality* button and then selecting the  button. Our quality assignment is confirmed visually by changing all of the selected geometry to the color purple. Notice that each quality number is associated with a different color, and that new geometry created in *Layout* is always of *Traverse* quality by default, which is represented in the color green.



Hint: When you are creating your part geometry in *Rhino* or *AutoCAD*, by assigning certain parts of your geometry to different *layers* (see table below), you can automatically associate *cut quality* with these objects when you import your geometry into *OMAX Layout*. This not only saves you time having to do this manually in *Layout*, it also makes it much less likely that you'll unintentionally "miss" some lines, curves, or points when you try to use the *Select* function within *Layout*. Here is a list of the quality assignments associated certain layers:

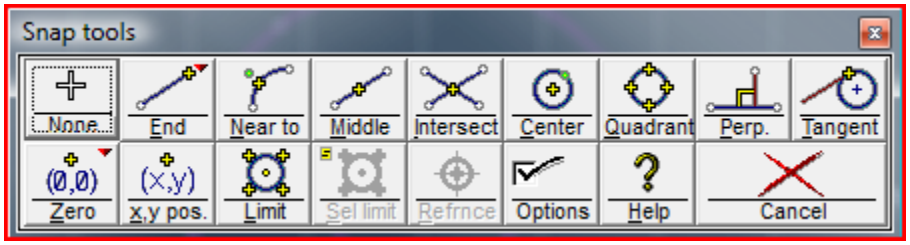
CAD Layer	OMAX Quality	CAD Layer	OMAX Quality
0	Traverse	10	Heads-up traverse
1	1	11	Minimum Taper
2	2	21	Quality of 1 slit
3	3	22	Quality of 2 slit
4	4	23	Quality of 3 slit
5	5	24	Quality of 4 slit
6	Etch	25	Quality of 5 slit
7	Scribe	28	Quality of Water Only s
8	Water only	31	Quality of Minimum Ta
9	Lead I /O	Other	Traverse

Step 3, continued…

Now that we have defined what we want to cut, and what quality our cuts will be, we're ready to tell *OMAX Layout* the order in which we want our cuts to be made. It should be obvious that we need to cut out interior holes and other shapes *before* we cut the exterior profile of the part: if we didn't, the part could move while we were cutting these interior features, since now our exterior profile has been separated from the sheet of raw stock and nothing prevents it from moving. (Using *tabs* is another way of controlling this problem.)

We will need to start our cuts slightly away from the finished surfaces so that we don't leave dwell marks and other defects when the high pressure pump turns on and off. We use *Lead-Ins* and *Lead-Outs* to accomplish this. We'll add them to our part in order to control how the water jet approaches and departs the finish geometry while cutting. You do this by selecting the 

button on the left side of the main *Layout* window. The *Snap Tools* bar will pop up, allowing you to use numerous kinds of *snaps* to attach the *Lead i/o* to the part. Notice that once you have attached a *Lead i/o* to your part, before letting go of the left mouse button, rotate and orient the *Lead i/o* so that the abrasive jet will smoothly ramp onto and off of your part. This will greatly reduce dwell marks on the finished surface.



The Snap Tools toolbar

Once you have all of your *Lead i/o*s added to your part you must connect them together with *Rapid Traverse* lines in the order you want the *OMAX* to cut out your features. Remember, cut interior holes and features first, followed by the exterior profile. Keep in mind to that the water jet normally cuts *slightly to the left of your path*, so that the edge of the jet is actually coincident with the desired part geometry. ***Note:*** there is a way to force the cut to be on the right hand side, or even the centerline of the part geometry.)

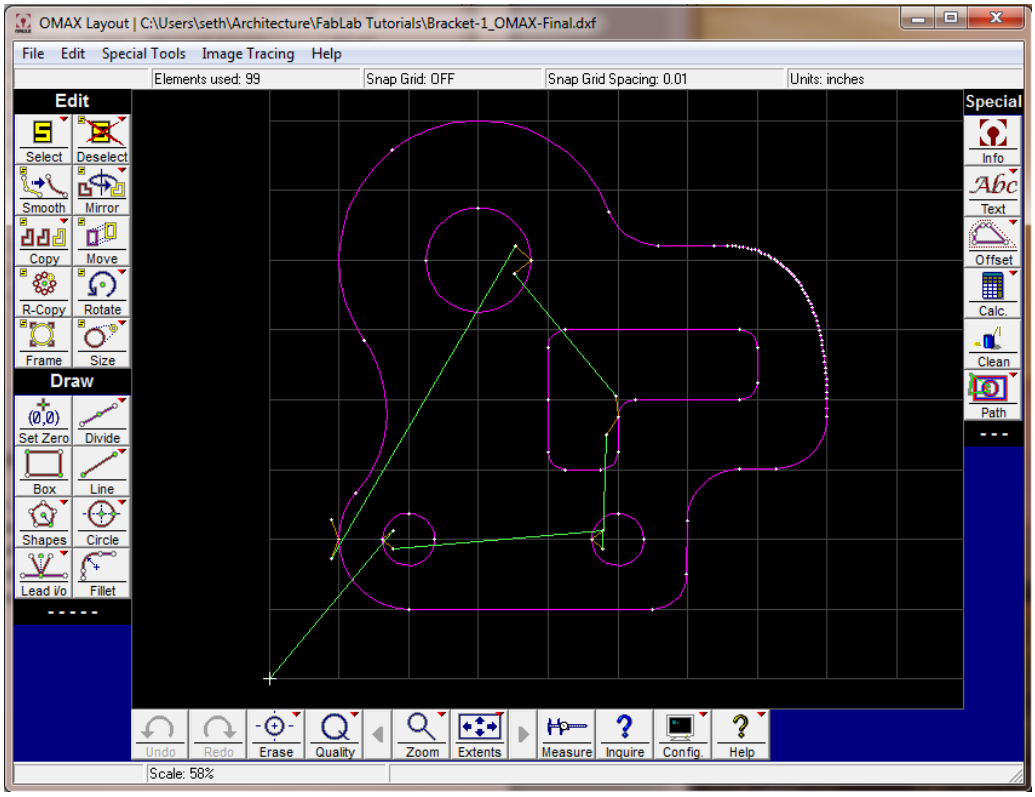
To add *Rapid Traverse* lines, click the 

button, select an *End* snap, and then click near the *Lead i/o* line which will keep the cut on the correct side of the line for the feature you are cutting. Notice that interior feature's *Lead i/os* will need to be connected in the opposite way than exterior *Lead i/o* lines, in order to keep the water jet kerf on the correct side of the line. Don't worry though: you will be able to visually confirm the correct location of the kerf after you create the tool path and before you actually try to cut the part.

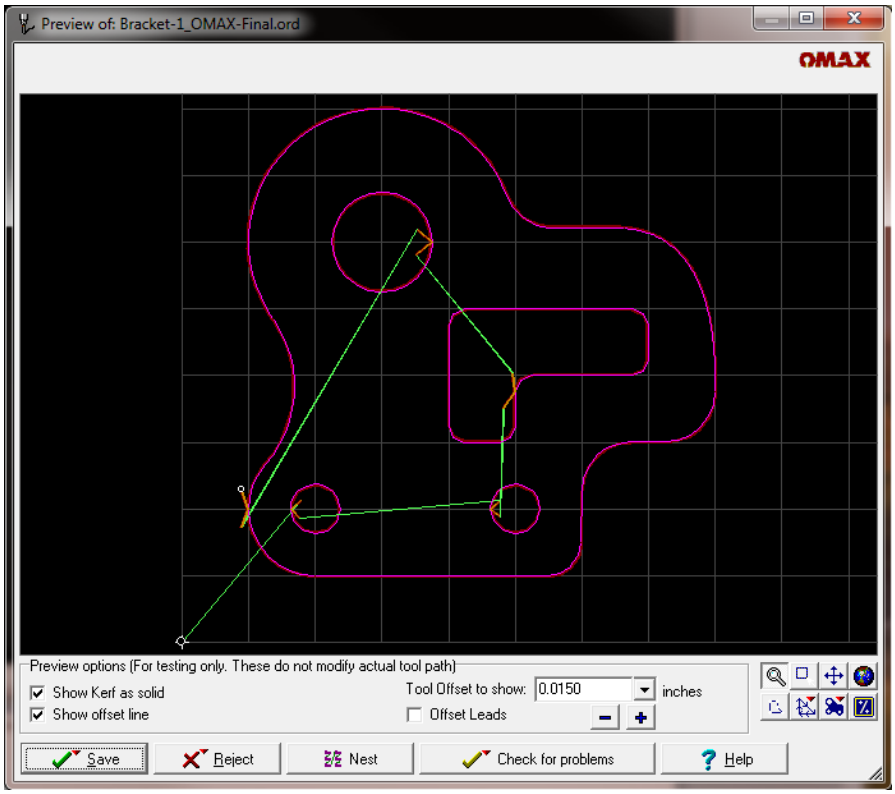
Note: It is good operating practice to always start you path at both the *0,0* point in your part geometry, and have this point coincide with what's called the *User Home* location on the OMAX. This permits you to make multiple parts quite easily, using the X and Y axis registration bars to accurately place your part in the cutting tank. Doing this also allows you to relatively easily "register" a part that needs to be modified, recut, repaired, etc., as long as you remember to make the *Path Start* coincident with what's called *User Home* on the machine before you start to make your part. This will be discussed in a little more detail in Part II of this tutorial, which covers actually running the machine.

Step 3, continued…

Here is what your part should look like when you are ready to create a *toolpath*:

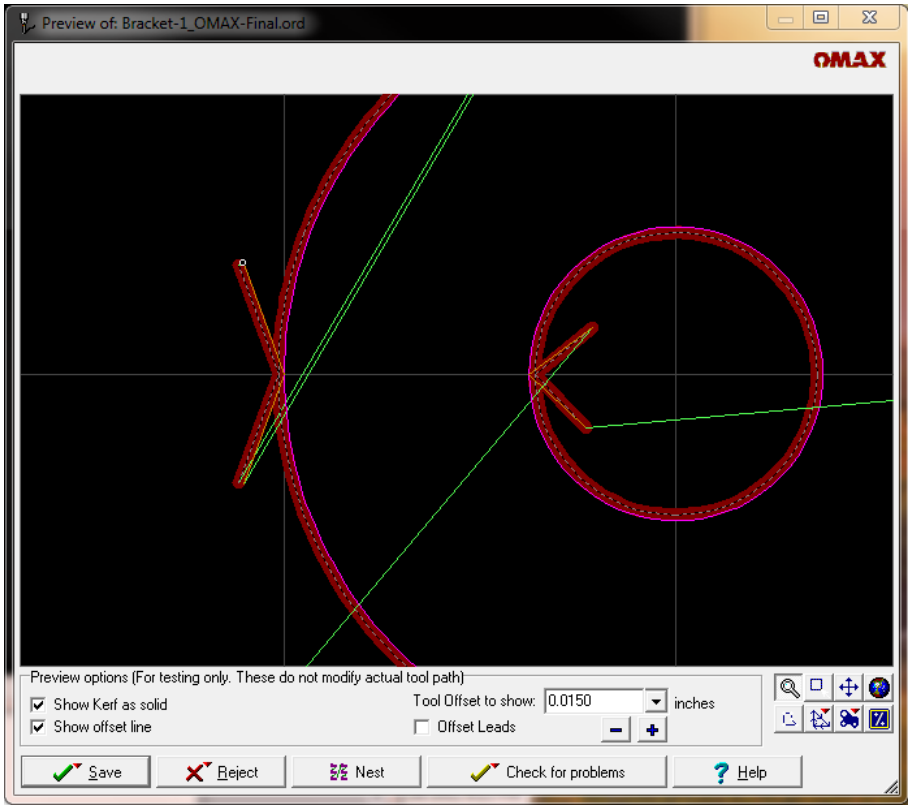


To create a *toolpath*, first *Clean* your part one last time to be sure there are no spurious lines, points, or other geometry that could confuse the automatic cutter path generation logic. Then click the *Path* button and in the new window that pops up, select the point where you'd like machining to start, usually the 0,0 origin point. The path will be automatically generated and will look more or less like this:



Step 3, continued…

Here's an enlarged section of your new path (use the mouse scroll to zoom in and out at any time)::



Notice that the kerf is shown as a dashed line in the middle of a red band of color, and must be on the correct side of your part geometry. The solid magenta line is the actual edge of your part geometry. If something is wrong with your *toolpath*, click the *Reject* button to discard this *toolpath* and return to *Layout* to fix whatever problem you may have with your path settings or the geometry itself. Sometimes problems with the geometry are pretty hard to see or identify; this is when you will probably want to seek the advice of the FabLab staff, the Lab monitor, or perhaps your TA.

If all is well and you don't see any errors in the new *toolpath*, simply click the *Save* button which will save your *toolpath* in a file of the same name as your part file, but with an .ORD file type. This is the file that you'll take to the *OMAX* to actually make your part. You'll want to copy this file to a USB mem stick or some other safe backup device. A USB mem stick is also a convenient way to move your part to the OMAX.

Congrats! Your done. You will now have to schedule a time slot on the *OMAX Waterjet* when there is an experience monitor or staff member available, to guide you through the steps required to set up and cut your part. Please review Part II of this tutorial before you schedule machine time.