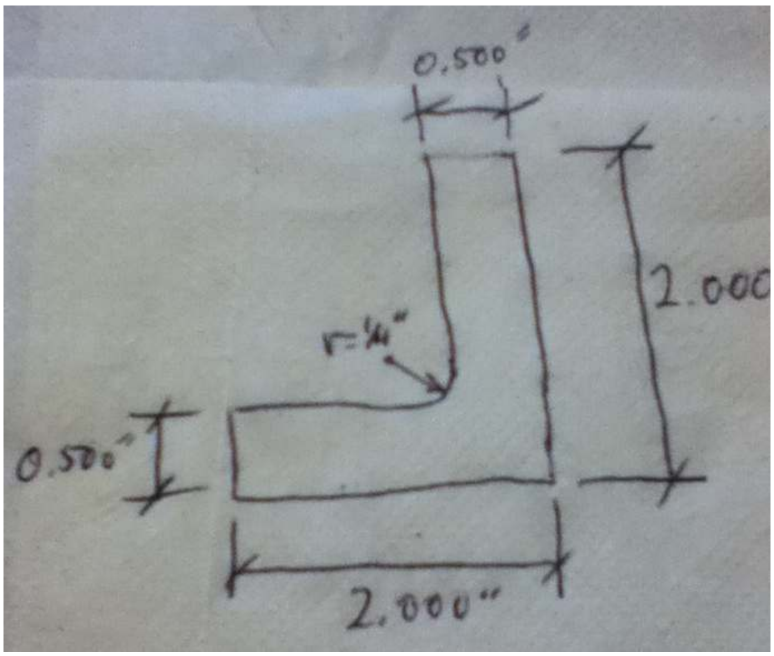
Milling An Angle Bracket, Version 2

By R. G. Sparber

You have decided to mill a bracket. It will be a good test of both your new machine and a means of learning how to run it. But where do you start?



This article attempts to help someone new to machining through the steps of making a sample bracket.

You will see that most of the time spent on this project is in planning. The actual time running the mill is rather short. The alternative is to spend a lot of time on the machine making, and then remaking the desired part. You may run out of patience before you run out of material.

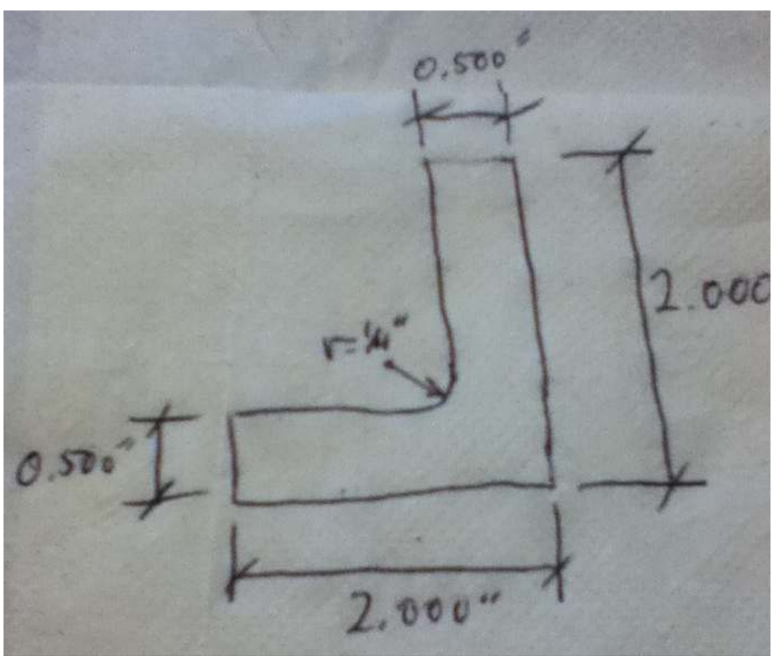
So let's start with the basics. The first step is to sketch out what you want to make. My sketches were done on Mc Donald©'s napkins.

Next is a difficult step: What do you want this bracket to do? Answers can range from "I just want to make something" to "I want a precision square". The answer dictates how best to make the part.

Machinist commonly talk about "fit and finish". "Fit" relates to how well the part fits the application. "Finish" relates to its overall look and feel. You can take a piece of rusty steel bar, bend it over in a vise with a hammer, and have a shelf support that is fine for the shed in your backyard. But try to use it in the living room at your own peril. The Fit may be OK but the finish will never be accepted. On the other hand, making a shelf support that matches the plans within +/- 0.001" is rarely necessary. Yet you might choose to do this in order to sharpen your skills. Such is the beauty of working within a hobby.

Another basic concept is the idea of rough cuts and finish cuts. In most cases we cut metal at an aggressive rate until we get "close" to our final value. Cutting this way causes some stress on the machine which causes minute bending of both the machine and the cutter. This should not harm the machine but your accuracy and finish will not be as good as possible. Often it is good enough. Good enough? That takes us back to fit and finish.

Once we are done with the rough cuts, we are ready for the finish cut. Ideally you make one finish cut and you are done. But often I make multiple finish cuts in order to see exactly how much a cut takes off. I develop a correction factor that compensates for feed error. Then my final finish cut is more accurate. Accurate, how accurate? We have again circled back to fit and finish. With care, I can make a part to within +/- 0.001" on my RF-30 mill/drill.



It is time to move from theory to practice. My goal is to make an aluminum 2" by 2" bracket with a 1/2" square cross section and a 1/4" radius in the inside corner. This rough figure satisfies my need for a clear picture. Although I do show 3 place accuracy to the right of the decimal, I really have not decided what I want yet.

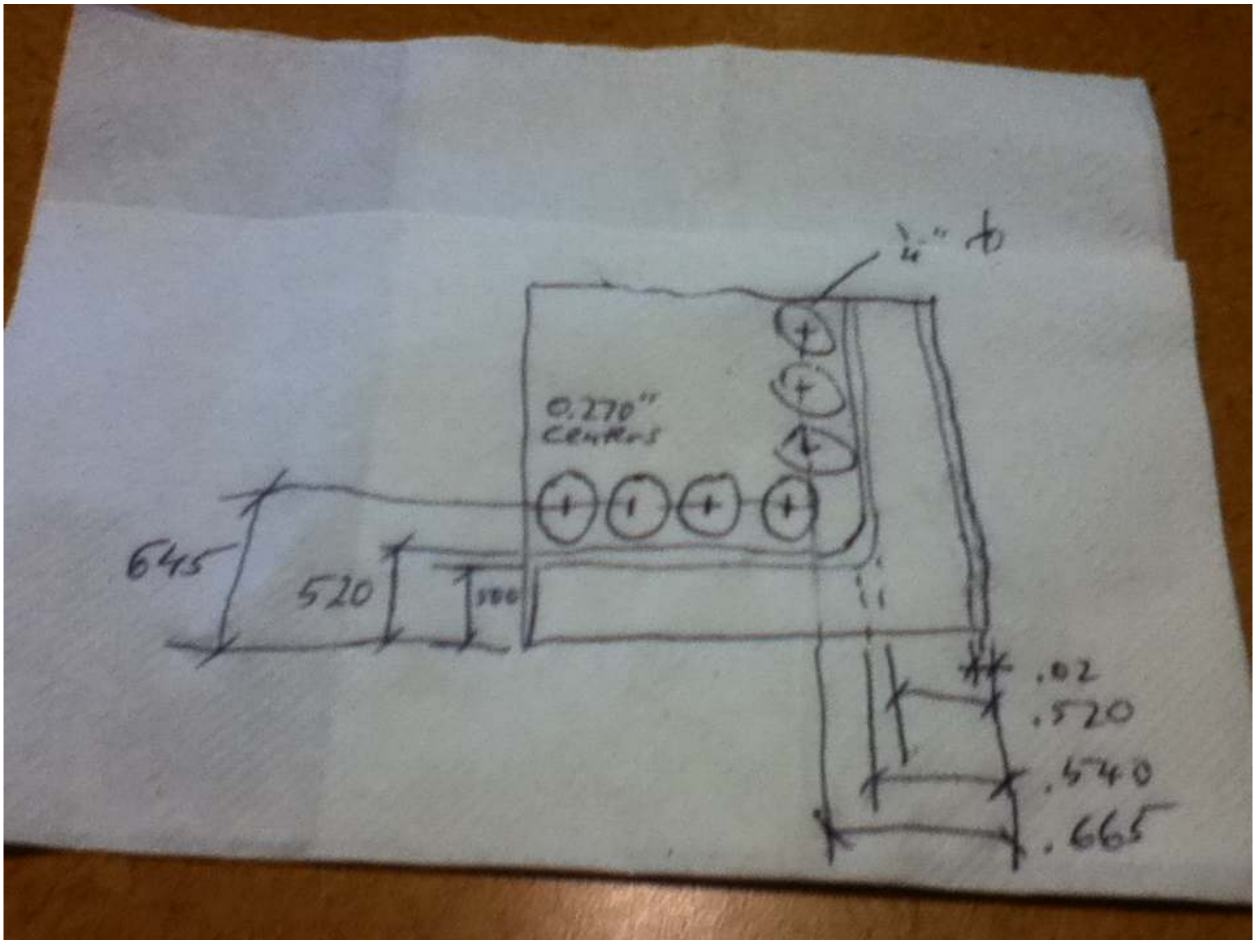
My goal is to illustrate technique so I chose a piece of 1/2" thick by 2" wide aluminum plate. My desired thickness has been achieved assuming the raw accuracy of the plate satisfies my fit and finish requirement.

The plate width gives me no margin for my rough cut. I can expect that the leg cut along the 2" width will be less than 2". The closer I can align the plate's edge to the mill's axes, the smaller the error in that leg.

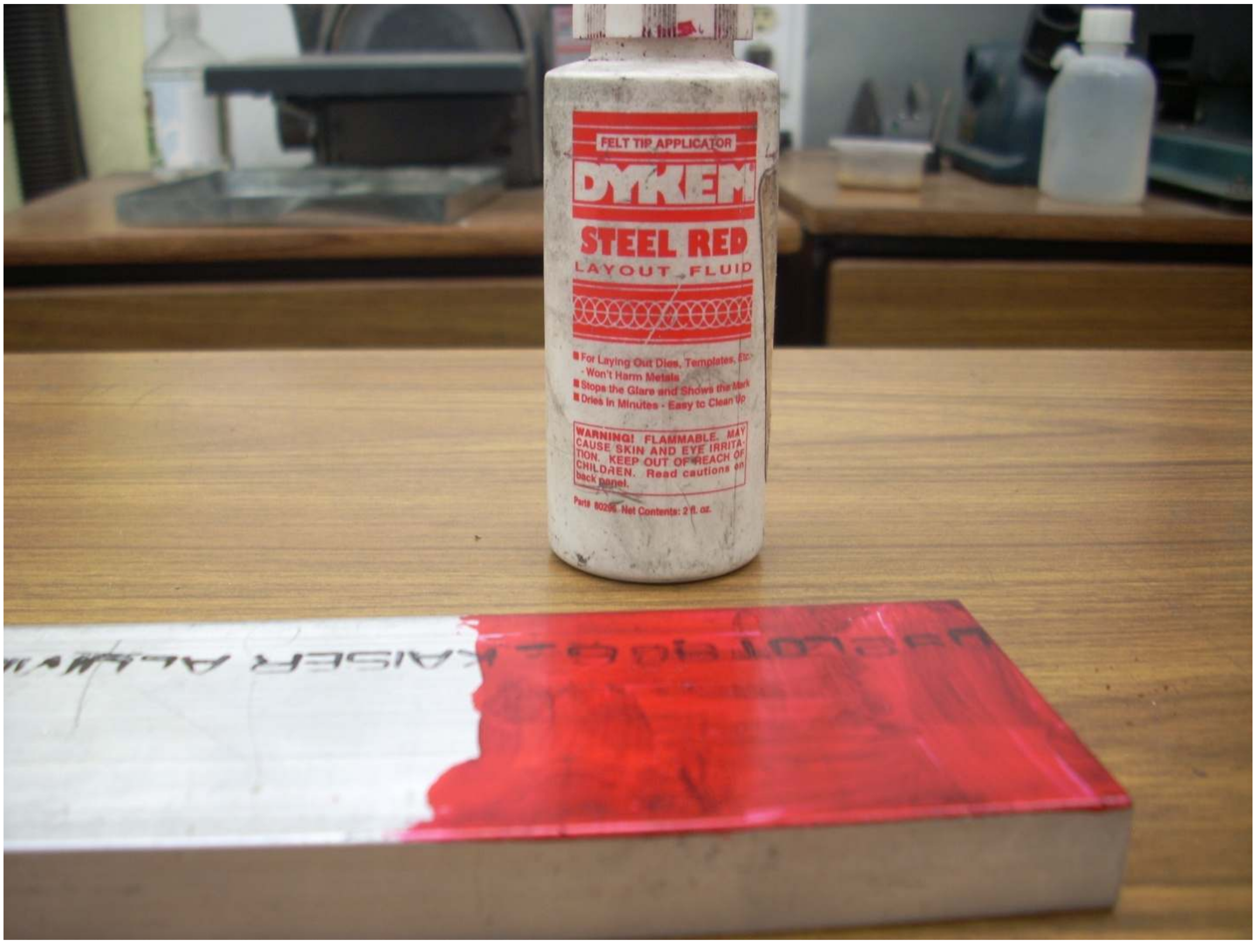
If I started with a thicker plate, I would have to reduce its thickness first. This is done by removing half of the excess material from each face. Taking it all from one side can cause the plate to warp from uneven stress.

Note in my rough sketch that all dimensions are relative to two "reference surfaces". These surfaces are the outside edges marked as 2.000”. The accuracy of the part depends on how well I align these reference surfaces to my mill's axes. If not critical, I can eye-ball it. For better accuracy, I use a machinist square. For maximum accuracy, I clamp the plate down and cut the reference surfaces and all features *without removing the plate*. So in fact, I achieve my highest degree of accuracy with the least amount of alignment effort. This is the approach I will use.

The shape of this part is not all that complex yet it still is good practice to scribe the raw plate with all desired features. I often find myself focusing on the nearest 0.001" and missing the fact that my cut is off by 0.100". The scribe lines reduce the chances of these kinds of bone head errors. Sadly, you will see that I am still capable of dumb mistakes.



Note in the figure that my finish lines are 0.02"away from all finish lines except along the bottom which is the smooth edge of the plate.



I could take a sharp knife and scribe lines directly on the raw metal. The problem is that the contrast is poor unless these lines are cut deep. Instead, I use a layout fluid which is painted on the surface and left to dry for a few minutes.

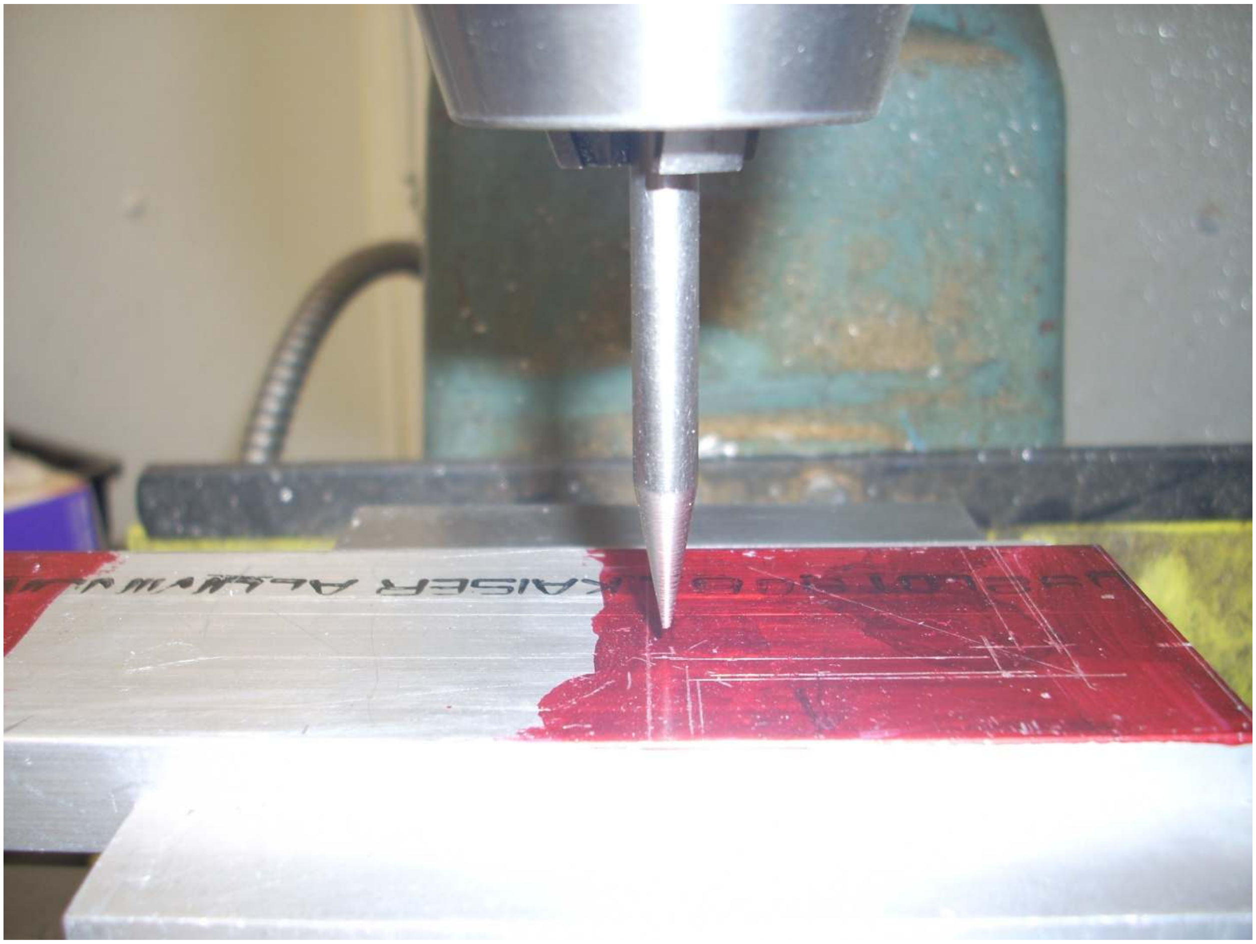
The bottom edge is reasonably straight and smooth so I will use my machinist square against it. Lines are scribed with a knife and very little pressure. The goal is to cut through the dye and not into the metal. I also used a 6" steel ruler that reads in decimal inches.

Before we start the rough cut, I must decide the best approach. If I only had a hacksaw, then the work can be sped up by "chain drilling" as shown in the sketch. Scribing the line that defines the center of these holes is a good idea. The holes should be located no closer than about 0.02" from the finish line.

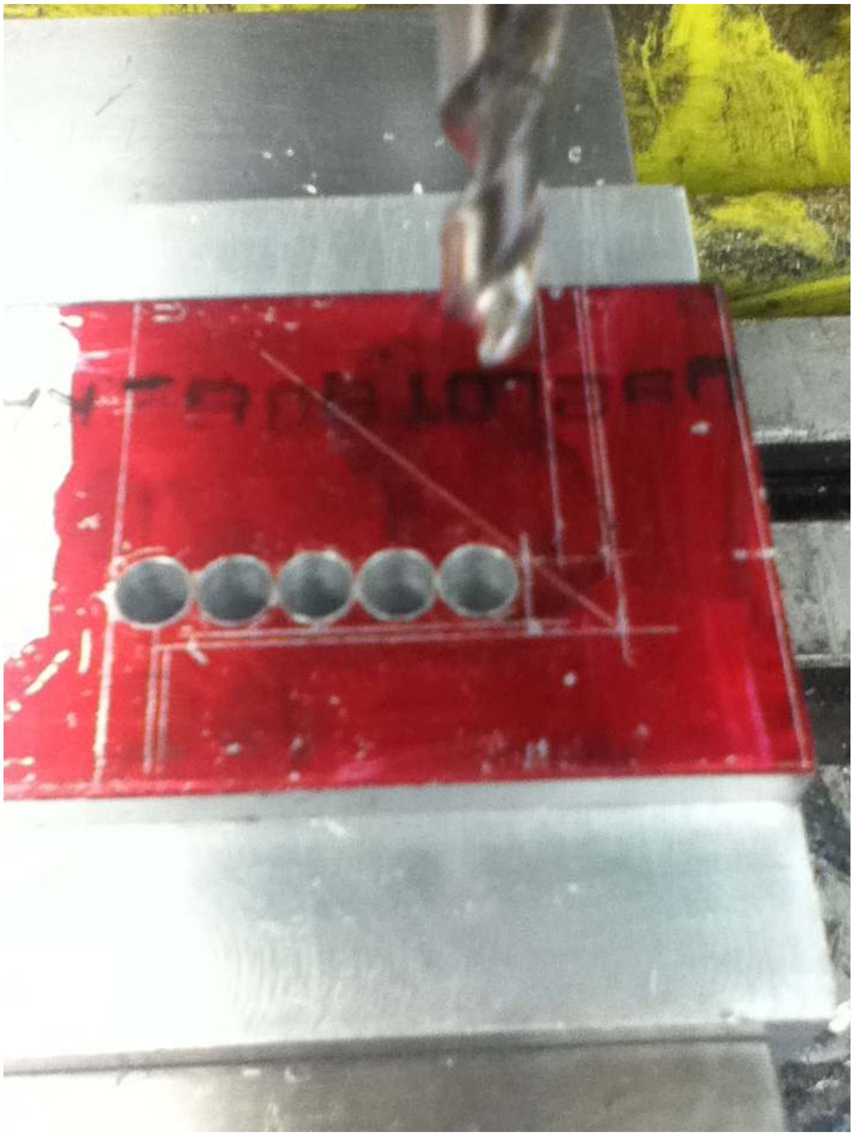
I do own a bandsaw so can skip the chain drilling. However, I will demonstrate both.

The bottom of the horizontal foot will ideally be the original edge of the plate. But if the plate is not perfectly aligned to my mill's axes, some cutting will be necessary to square up the part.

The next line up from this bottom edge is my finish line. 0.02" above this finish line is my rough cut line. Then 1/8" above the rough cut line is the center line for my chain drilling. I set the distance at 1/8" because I plan to use a ¼" drill. These holes will be on ¼" + 0.02" or 0.270" centers. This will leave me with a 0.02" thick web between holes. A thinner web may enable the drill to blow through into the last hole and bend the drill. A thicker web means more work with the hacksaw.



I have placed the plate into my vise and am using a “spud” to locate the drill chuck’s center of rotation on the chain drill scribed line.



The ¼” drill was freshly sharpened on my Drill Doctor® so easily cuts through the plate. Note that the edges of the holes touch the rough cut line. I have scribed the hole center for the other leg but will use my bandsaw on the rough cut line instead.

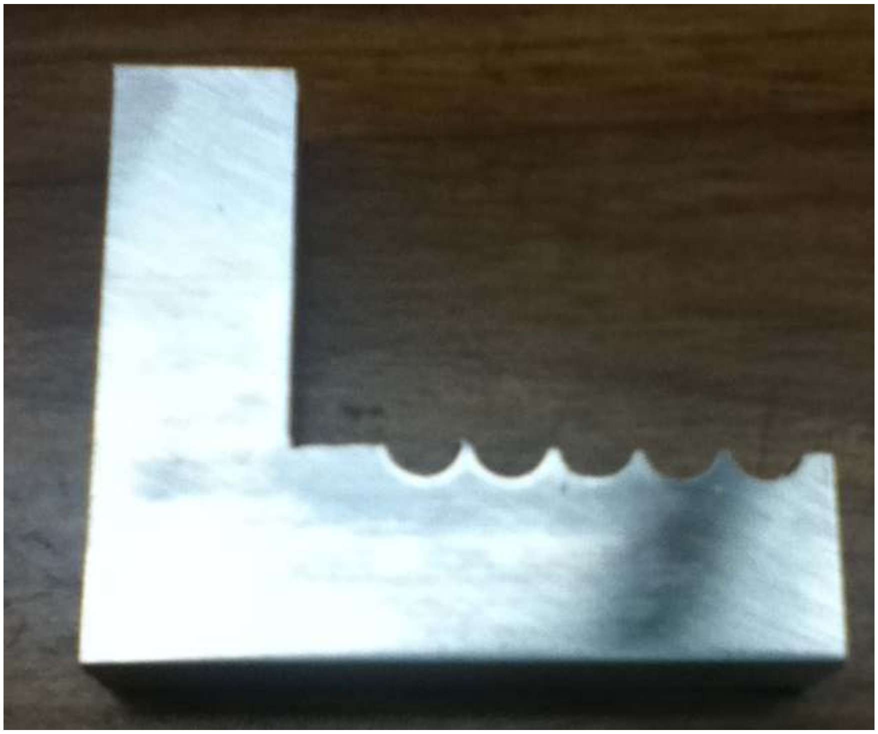
I'm using a 24 teeth per inch hacksaw blade to cut the web. It only takes one or two passes to clear each web.

The total work is reduced by using my bandsaw because I don't need to chain drill first.

If you look closely, you will see my bone headed mistake here. My rough cut line is here but I am cutting about ¼" away from it. I didn't discover this error until the very end of the project.

So to repeat, scribe lines can help protect you from big errors during machining. But if the scribe lines are wrong or misinterpreted, there isn't much hope other than to recheck the work before cutting.

With the roughed out part free from the plate, I am ready to start milling. The left end rough and finish cut lines are clearly visible. I just didn't see them!



All of that drilling and sawing has raised burrs on the back side of the roughed out part. I used my belt sander to smooth the surface.

I end up with my part roughly cut out and ready to mill. I'll use my square on one of the reference scribe lines to roughly align the part on the mill table.

My mill must cut the full edge of the part. If I just clamp the plate down to the table, the bottom of my cutter will hit the table. Instead, I will clamp the plate to something that can be sacrificed. I could use some scrap aluminum plate but prefer to use a bit of Medium Density Fiberboard (MDF). This stuff is remarkably accurate with the front and back faces parallel to within a few thousandths of an inch. It also costs much less than metal.

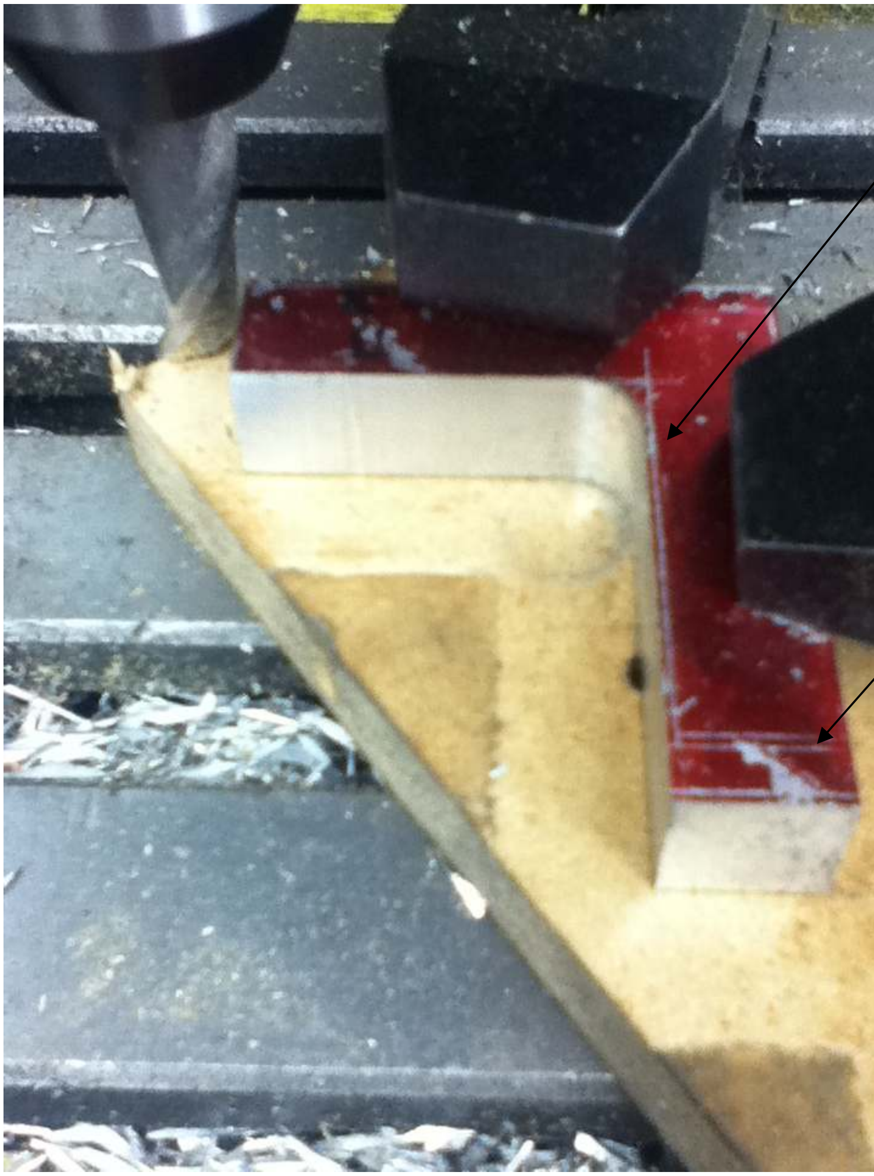
We are finally ready to run the mill. Since the inside corner is to have a 1/4" radius, I will use my 1/2" diameter end mill. It is mounted in an end mill holder which makes it convenient to install into my spindle.

I will employ a maximum of 3 hold down clamps to prevent the plate from flying across the room during milling. As necessary I will move these clamps so they don't get in the way of cutting. At no time will I run with fewer than 2 clamps. Doing so can enable the part to turn from the cutter's force.

I start by cutting the outside edges which are also my reference surfaces.

The clamps are then moved to the other side one at a time. I don’t want the part to be completely unclamped and possibly shift.

Now I have free access to the ends and inside edges.



I have now finished the rough cut. Notice the finish line is still visible.

You can also see my confusion here. The rough cut line on the end was not touched.

This is after the finish cut. You can clearly see that I almost got it right. The instant I fed in the cutter at what really was the right point (2”), I saw that I had taken a very big cut. I quickly backed out and then saw the wrong finish line so cut to it. This would have been fine if I had just realized which was the true finish line.

I removed the part from the mill in preparation for final deburring.

Except for the one screw up, the part seems to be fine. But does it really meet the Fit and Finish requirement? In my case – yes since my goal is just to demonstrate technique. But how close to the plan did I get? The last phase of the work will answer that question. It is time to do an evaluation of the part.

I used a Digital Read-Out (DRO)[2] to guide the movement of the mill's table. No other measurements were taken. This approach is fine for "moderate" accuracy but if I was going for maximum accuracy, I would use my micrometer after the rough cut to gage the exact final cut values. I might even take two finish cuts as mentioned previously.

My first test is for the thickness of the longer leg. My micrometer is good to +/- 0.00005" and has been zeroed before use. I read 0.50245" so am 0.00245" too thick at this point. The test was repeated at two other spots along this leg and a maximum variation of 0.00015" was seen. I then repeated the test on the short leg and saw 0.050340" at the end with a maximum variation of 0.00015". The absolute thickness error of 0.002" or 0.003" could easily be improved. The variation is good

[2] A DRO tells you the relative location of the mill's table with respect to an arbitrary point in space.

enough to probably encourage more experienced machinists to be suspicious. No, I didn't have the hold button pushed on the mic…

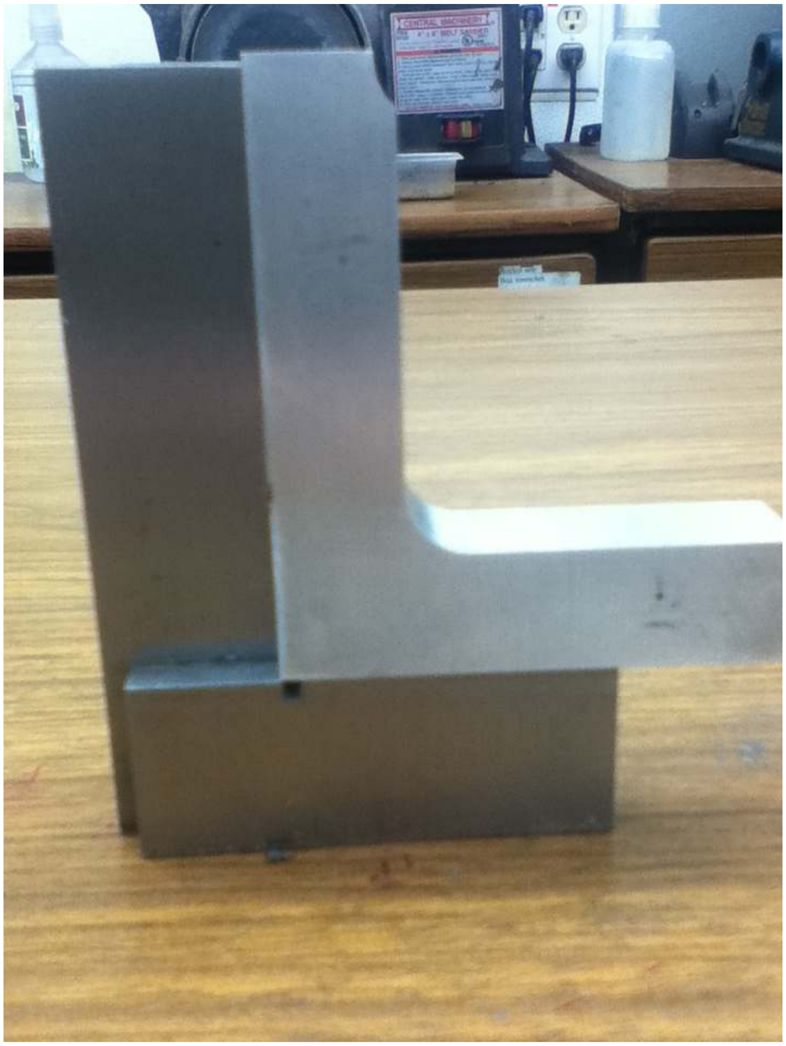
My mic reads up to 1" so another method is needed to measure the length of the legs.

I own a set of what are called Spacer Blocks. These cylinders have a length accurate to +/- 0.0002". I have removed two 1.000" blocks.

I also own a cheap Harbor Freight digital caliper. I zeroed the caliper on the two spacer blocks. In this way the readout will show me differences from 2.000". The caliper has its own error but experience has shown me that this error is small when movement is small. I am only expecting an answer to the nearest 0.001".

When I placed the caliper on the short leg, I read 1.9965" so am short by about 0.004". The long leg read 2.2510" so clearly I blew that dimension. Yet even here it is not all bad news. I was off by 0.251" which is only 0.001" from what I thought was the right dimension.

If I had wanted maximum accuracy, I would have used the caliper only to transfer the dimension and spacer blocks to tell me the value. In this way only the resolution and repeatability of the caliper effect my accuracy. I have been able to achieve an accuracy of +/- 0.001" in the past with this method.



The last parameter to assess is the angle between the legs of the bracket. A quick and simple test is to place a known accurate square next to the part and look for light pass thing through gaps in the edges. I saw no light so this is a decent fit. A better assessment would involve a surface plate and a Dial Test Indicator. Let's leave that for another day.

Afterthought

Although this is just a test part, it annoyed me to see that error in the longer leg. So I went back and fixed the mistake. First I clamped it into my vise and took a reference cut. I then set my DRO to zero.

I then brought out my spacer blocks and zeroed my caliper at 2.000".

I could see that I had 0.247” to go. Two passes of 0.100” each got me down to about 0.05”. Then I made a 0.030” pass before checking with the caliper again. The caliper showed I had 0.014” to go. I then took my first, calibrating, finish cut of 0.007”. The caliper said I now had 0.007” to go. This told me that there was no need for a correction factor. I then dialed in my final 0.007” cut.

After deburring, I did a final check with the caliper. Now, that’s a lot closer than being 0.251” off!

Acknowledgement

Thanks to Kris Johnson for suggesting this topic.

I welcome your questions and comments. It is the only way I know to improve this article. All of us are smarter than any one of us.

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